TECHNICAL SUPPORT DOCUMENT: ENERGY EFFICIENCY PROGRAM FOR CONSUMER PRODUCTS AND COMMERCIAL AND INDUSTRIAL EQUIPMENT:

GAS-FIRED INSTANTANEOUS WATER HEATERS

DECEMBER 2024

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CHAPTER 1. INTRODUCTION

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CHAPTER 1. INTRODUCTION

1.1 PURPOSE OF THE DOCUMENT

This technical support document (TSD) is a stand-alone report that provides the technical analyses and results supporting the final rule for gas-fired instantaneous water heaters.

1.2 SUMMARY OF NATIONAL BENEFITS

DOE has performed an analysis of the national impacts that could occur with more stringent energy conservation standards for a subset of gas-fired instantaneous water heaters, specifically, those products with storage volumes less than 2 gallons and with input rates greater than 50,000 British thermal units (Btu) per hour. DOE's analyses indicate that the amended energy conservation standards being adopted for gas-fired instantaneous water heaters will save a significant amount of energy. Relative to the case without amended standards, the lifetime energy savings for gas-fired instantaneous water heaters purchased in the 30-year period that begins in the anticipated year of compliance with the amended standards (2030–2059) amount to 0.58 quadrillion Btu, or quads.[a] This represents a savings of 1.9 percent relative to the energy use of these products in the case without amended standards (referred to as the "no-new-standards case").

The cumulative net present value (NPV) of total consumer benefits of the adopted standards for gas-fired instantaneous water heaters are $0.87 billion at a 7-percent discount rate and $3.07 billion at a 3-percent discount rate. This NPV expresses the estimated total value of future operating-cost savings minus the estimated increased product and installation costs for gas-fired instantaneous water heaters purchased in 2030–2059.

In addition, the adopted standards for gas-fired instantaneous water heaters are projected to yield significant environmental benefits. DOE estimates that the adopted standards would result in cumulative emission reductions (over the same period as for energy savings, 2030–2059) of 32 million metric tons (Mt)[b] of carbon dioxide (CO_2), 0.12 thousand tons of sulfur dioxide (SO_2), 86 thousand tons of nitrogen oxides (NO_X), 398 thousand tons of methane (CH_4), 0.06 thousand tons of nitrous oxide (N_2O), and an increase of 0.0004 tons of mercury (Hg).[c]

DOE estimates the value of climate benefits from a reduction in greenhouse gases (GHG) using different estimates of the social cost of CO_2 (SC-CO_2), the social cost of methane (SC-

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[a] The quantity refers to full-fuel-cycle (FFC) energy savings. FFC energy savings includes the energy consumed in extracting, processing, and transporting primary fuels (i.e., coal, natural gas, petroleum fuels), and, thus, presents a more complete picture of the impacts of energy efficiency standards. For more information on the FFC metric, see chapter 10 of this document.

[b] A metric ton is equivalent to 1.1 short tons. Results for emissions other than CO_2 are presented in short tons.

[c] DOE calculated emissions reductions relative to the no-new-standards case, which reflects key assumptions in the *Annual Energy Outlook 2023* (*AEO2023*). *AEO2023* represents current federal and state legislation and final implementation of regulations as of the time of its preparation. See chapter 13 of this document for further discussion of *AEO2023* assumptions that effect air pollutant emissions. The *AEO 2023* reflects the impact of the Inflation Reduction Act.

CH_4), and the social cost of nitrous oxide (SC-N_2O).[d] Together these represent the social cost of GHG (SC-GHG). DOE used an updated set of SC-GHG estimates published in 2023 by the Environmental Protection Agency (EPA) (2023 SC-GHG), as well as the interim SC-GHG values (in terms of benefit per ton of GHG avoided) developed by an Interagency Working Group on the Social Cost of Greenhouse Gases (IWG) in 2021 (2021 Interim SC-GHG), which DOE used in the notice of proposed rulemaking for this rule before the updated values were available.[e] The derivation of these values is discussed in chapter 14 of this document. The climate benefits associated with the average SC-GHG at a 2-percent near-term Ramsey discount rate using the 2023 SC-GHG estimates are estimated to be $7.1 billion, and the climate benefits associated with the average 2021 Interim SC-GHG estimates at a 3-percent discount rate are estimated to be $1.7 billion. DOE notes, however, that the adopted standards would be economically justified even without inclusion of the estimated monetized benefits of reduced GHG emissions.

DOE estimated the monetary health benefits of SO_2 and NO_X emissions reductions using benefit per ton estimates from the Environmental Protection Agency's Benefits Mapping and Analysis Program[f], as discussed in chapter 14 of this document. DOE did not monetize the change in mercury emissions because the quantity is very small. DOE estimated the present value of the health benefits would be $0.9 billion using a 7-percent discount rate, and $2.7 billion using a 3-percent discount rate.[g] DOE is currently only monetizing health benefits from changes in ambient fine particulate matter ($PM_{2.5}$) concentrations from two precursors (SO_2 and NO_X), and from changes in ambient ozone from one precursor (NO_X), but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions.

Table 1.2.1 summarizes the economic benefits and costs expected to result from the amended standards being adopted for gas-fired instantaneous water heaters. There are other important unquantified effects, including certain unquantified climate benefits, unquantified public health benefits from the reduction of toxic air pollutants and other emissions, unquantified energy security benefits, and distributional effects, among others.

[d] Estimated climate-related benefits are provided in compliance with Executive Order 12866.
[e] *Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990* published in February 2021 by the IWG. ("February 2021 SC-GHG TSD"). http://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf. https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-final-rule-20231130.pdf; https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf (last accessed July 3, 2024)
[f] U.S. EPA. Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors. Available at: www.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-21-sectors.
[g] DOE estimates the economic value of these emissions reductions resulting from the considered TSLs for the purpose of complying with the requirements of Executive Order 12866.

Table 1.2.1 Summary of Monetized Benefits and Costs of the Adopted Energy Conservation Standards for Gas-fired Instantaneous Water Heaters at TSL 2 Shipped During the Period 2030-2059 (Volume < 2 gal, Rated Input > 50,000 Btu/h)

	Billion 2023$
3% Discount Rate	
Consumer Operating Cost Savings	4.5
Climate Benefits* (2023 SC-GHG estimates)	7.1
Climate Benefits* (2021 interim SC-GHG estimates)	1.7
Health Benefits**	2.7
Total Benefits† (2023 SC-GHG estimates)	14.3
Total Benefits† (2021 interim SC-GHG estimates)	8.9
Consumer Incremental Product Costs‡	1.5
Net Benefits† (2023 SC-GHG estimates)	12.8
Net Benefits† (2021 interim SC-GHG estimates)	7.4
Change in Producer Cashflow (INPV)‡‡	(0.03) – 0.04
7% Discount Rate	
Consumer Operating Cost Savings	1.7
Climate Benefits* (2023 SC-GHG estimates)	7.1
Climate Benefits* (2021 interim SC-GHG estimates)	1.7
Health Benefits**	0.9
Total Benefits† (2023 SC-GHG estimates)	9.6
Total Benefits† (2021 interim SC-GHG estimates)	4.2
Consumer Incremental Product Costs‡	0.8
Net Benefits† (2023 SC-GHG estimates)	8.9
Net Benefits† (2021 interim SC-GHG estimates)	3.4
Change in Producer Cashflow (INPV)‡‡	(0.03) – 0.04

Note: This table presents the costs and benefits associated with gas-fired instantaneous water heaters shipped in 2030−2059. These results include benefits to consumers which accrue after 2059 from the products shipped in 2030−2059.

* Climate benefits are calculated using different estimates of the social cost of carbon ($SC\text{-}CO_2$), methane ($SC\text{-}CH_4$), and nitrous oxide ($SC\text{-}N_2O$). Climate benefits are estimated using two separate sets of estimates of the social cost for

each greenhouse gas, an updated set published in 2023 by the Environmental Protection Agency (EPA) (2023 SC-GHG) and the interim set of estimates used in the NOPR which were published in 2021 by the Interagency Working Group on the SC-GHG (IWG) (2021 Interim SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 2 percent near-term Ramsey discount rate are shown for the 2023 SC-GHG estimates, and the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown for the 2021 interim SC-GHG estimates.
** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. Table 5 of the EPA's *Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 21 Sectors* TSD provides a summary of the health impact endpoints quantified in the analysis. See chapter 14 of this document for more details.
† Total and net benefits include those consumer, climate, and health benefits that can be quantified and monetized. For presentation purposes, total and net benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 2-percent near-term Ramsey discount rate for the 2023 estimate and the average SC-GHG with 3-percent discount rate for the 2021 interim SC-GHG estimate.
‡ Costs include incremental equipment costs as well as installation costs.
†† Operating Cost Savings are calculated based on the life-cycle costs analysis and national impact analysis as discussed in detail below. *See* chapter 8 and chapter 10 of this TSD. DOE's national impacts analysis includes all impacts (both costs and benefits) along the distribution chain beginning with the increased costs to the manufacturer to manufacture the product and ending with the increase in price experienced by the consumer. DOE also separately conducts a detailed analysis on the impacts on manufacturers (i.e., manufacturer impact analysis, or MIA). *See* chapter 12 of this TSD. In the detailed MIA, DOE models manufacturers' pricing decisions based on assumptions regarding investments, conversion costs, cashflow, and margins. The MIA produces a range of impacts, which is the rule's expected impact on the INPV. The change in INPV is the present value of all changes in industry cash flow, including changes in production costs, capital expenditures, and manufacturer profit margins. Change in INPV is calculated using the industry weighted average cost of capital value of 9.6 percent that is estimated in the MIA (*see* chapter 12 of this TSD for a complete description of the industry weighted average cost of capital). For gas-fired instantaneous water heaters, the change in INPV ranges from -$34 million to $41 million. DOE accounts for that range of likely impacts in analyzing whether a TSL is economically justified. *See* section V.C of the final rule notice. DOE is presenting the range of impacts to the INPV under two manufacturer markup scenarios: the Preservation of Gross Margin scenario, which is the manufacturer markup scenario used in the calculation of Consumer Operating Cost Savings in this table; and the Preservation of Operating Profit scenario, where DOE assumed manufacturers would not be able to increase per-unit operating profit in proportion to increases in manufacturer production costs. DOE includes the range of estimated INPV in the above table, drawing on the MIA explained further in chapter 12 of this TSD to provide additional context for assessing the estimated impacts of this final rule to society, including potential changes in production and consumption, which is consistent with OMB's Circular A-4 and E.O. 12866. If DOE were to include the INPV into the net benefit calculation (2023 SC-GHG estimates) for this final rule, the net benefits would be $12.8 billion at 3-percent discount rate and $8.9 billion at 7-percent discount rate. Parentheses indicate negative () values.

The benefits and costs of the adopted standards can also be expressed in terms of annualized values. The monetary values for the total annualized net benefits are (1) the reduced consumer operating costs, minus (2) the increase in product purchase prices and installation costs, plus (3) the monetized value of climate and health benefits of emission reductions, all annualized.[h]

The national operating cost savings are domestic private U.S. consumer monetary savings that occur as a result of purchasing the covered products and are measured for the lifetime of

[h] To convert the time-series of costs and benefits into annualized values, DOE calculated a present value in 2024, the year used for discounting the NPV of total consumer costs and savings. For the benefits, DOE calculated a present value associated with each year's shipments in the year in which the shipments occur (e.g., 2020 or 2030), and then discounted the present value from each year to 2024. Using the present value, DOE then calculated the fixed annual payment over a 30-year period, starting in the compliance year, that yields the same present value.

gas-fired instantaneous water heaters shipped in 2030–2059. The benefits associated with reduced emissions achieved as a result of the adopted standards are also calculated based on the lifetime of gas-fired instantaneous water heaters shipped in 2030–2059. Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with a 2 percent near-term Ramsey discount rate for the 2023 SC-GHG estimates and the average SC-GHG with 3-percent discount rate for the 2021 interim SC-GHG estimates.[i]

Table 1.2.2 presents the total estimated monetized benefits and costs associated with the adopted standards, expressed in terms of annualized values. The results under the primary estimate are as follows.

Using a 7-percent discount rate for consumer benefits and costs and health benefits from reduced NO_x and SO_2 emissions, and the 2-percent near-term Ramsey discount rate case or the 3-percent discount rate case for climate benefits from reduced GHG emissions, the estimated cost of the standards adopted in this rule is $88 million per year in increased equipment costs, while the estimated annual benefits are $187 million in reduced equipment operating costs, $349 million in climate benefits (using the 2023 SC-GHG estimates) or $98 million in climate benefits (using the 2021 interim SC-GHG estimates), and $101 million in health benefits. In this case, the net benefit would amount to $549 million per year (using the 2023 SC-GHG estimates) or $297 million per year (using the 2021 interim SC-GHG estimates).

Using a 3-percent discount rate for consumer benefits and costs and health benefits from reduced NO_X and SO_2 emissions, and the 2-percent near-term Ramsey discount rate case or the 3-percent discount rate case for climate benefits from reduced GHG emissions, the estimated cost of the adopted standards is $87 million per year in increased equipment costs, while the estimated annual benefits are $268 million in reduced operating costs, $349 million in climate benefits (using the 2023 SC-GHG estimates) or $98 million in climate benefits (using the 2021 interim SC-GHG estimates), and $158 million in health benefits. In this case, the net benefit would amount to $689 million per year (using the 2023 SC-GHG estimates) or $437 million per year (using the 2021 interim SC-GHG estimates).

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[i] DOE notes that using consumption-based discount rates (e.g., 2 percent) is appropriate when discounting the value of climate impacts. Combining climate effects discounted at an appropriate consumption-based discount rate with other costs and benefits discounted at a capital-based rate (i.e., 7 percent) is reasonable because of the different nature of the types of benefits being measured.

Table 1.2.2 Annualized Benefits and Costs of the Adopted Energy Conservation Standards for Gas-fired Instantaneous Water Heaters at TSL 2 Shipped During the Period 2030–2059 (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)

	Million 2023$/year		
	Primary Estimate	**Low-Net-Benefits Estimate**	**High-Net-Benefits Estimate**
3% Discount Rate			
Consumer Operating Cost Savings	268	249	288
Climate Benefits* (2023 SC-GHG estimates)	349	344	355
Climate Benefits* (2021 interim SC-GHG estimates)	98	96	100
Health Benefits**	158	156	161
Total Benefits† (2023 SC-GHG estimates)	776	749	804
Total Benefits† (2021 interim SC-GHG estimates)	525	502	548
Consumer Incremental Product Costs‡	87	86	89
Net Benefits† (2023 SC-GHG estimates)	689	663	715
Net Benefits† (2021 interim SC-GHG estimates)	437	416	459
Change in Producer Cashflow (INPV)‡‡	(3) – 4	(3) – 4	(3) – 4
7% Discount Rate			
Consumer Operating Cost Savings	187	174	200
Climate Benefits* (2023 SC-GHG estimates)	349	344	355
Climate Benefits* (2021 interim SC-GHG estimates)	98	96	100
Health Benefits**	101	99	102
Total Benefits† (2023 SC-GHG estimates)	637	616	658
Total Benefits† (2021 interim SC-GHG estimates)	386	369	402
Consumer Incremental Product Costs‡	88	87	90
Net Benefits† (2023 SC-GHG estimates)	549	530	568
Net Benefits† (2021 interim SC-GHG estimates)	297	283	312
Change in Producer Cashflow (INPV)‡‡	(3) – 4	(3) – 4	(3) – 4

Note: This table presents the costs and benefits associated with gas-fired instantaneous water heaters shipped in 2030–2059. These results include benefits to consumers which accrue after 2059 from the products shipped in 2030–2059. The Primary, Low Net Benefits, and High Net Benefits Estimates utilize projections of energy prices from the AEO2023 Reference case, Low Economic Growth case, and High Economic Growth case, respectively. In addition, incremental equipment costs reflect a medium decline rate in the Primary Estimate, a low decline rate in the Low Net Benefits Estimate, and a high decline rate in the High Net Benefits Estimate. The methods used to derive projected price trends are explained in chapter 8 of this document. Note that the Benefits and Costs may not sum to the Net Benefits due to rounding.

* Climate benefits are calculated using different estimates of the global SC-GHG (see chapter 14 of this document). Climate benefits are estimated using two separate sets of estimates of the social cost for each greenhouse gas, an updated set published in 2023 by the Environmental Protection Agency (EPA) (2023 SC-GHG) and the interim set of estimates used in the NOPR which were published in 2021 by the Interagency Working Group on the SC-GHG (IWG) (2021 Interim SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 2 percent near-term Ramsey discount rate are shown for the 2023 SC-GHG estimates, and the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown for the 2021 interim SC-GHG estimates.

** Health benefits are calculated using benefit-per-ton values for NO_X and SO_2. DOE is currently only monetizing (for SO_2 and NO_X) $PM_{2.5}$ precursor health benefits and (for NO_X) ozone precursor health benefits, but will continue to assess the ability to monetize other effects such as health benefits from reductions in direct $PM_{2.5}$ emissions. Table 5 of the EPA's *Estimating the Benefit per Ton of Reducing PM2.5 Precursors from 21 Sectors* TSD provides a summary of the health impact endpoints quantified in the analysis. See section chapter 14 of this document for more details.

† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 2-percent near term Ramsey discount rate for the 2023 estimate and the average SC-GHG with 3-percent discount rate for the 2021 interim SC-GHG estimate.

‡ Costs include incremental equipment costs as well as installation costs.

†† Operating Cost Savings are calculated based on the life-cycle costs analysis and national impact analysis as discussed in detail below. *See* chapter 8 and chapter 10 of this TSD. DOE's national impacts analysis includes all impacts (both costs and benefits) along the distribution chain beginning with the increased costs to the manufacturer to manufacture the product and ending with the increase in price experienced by the consumer. DOE also separately conducts a detailed analysis on the impacts on manufacturers (i.e., MIA). *See* chapter 12 of this TSD. In the detailed MIA, DOE models manufacturers' pricing decisions based on assumptions regarding investments, conversion costs, cashflow, and margins. The MIA produces a range of impacts, which is the rule's expected impact on the INPV. The change in INPV is the resent value of all changes in industry cash flow, including changes in production costs, capital expenditures, and manufacturer profit margins. The annualized change in INPV is calculated using the industry weighted average cost of capital value of 9.6 percent that is estimated in the MIA (see chapter 12 of this TSD for a complete description of the industry weighted average cost of capital). For gas-fired instantaneous water heaters, the annualized change in INPV ranges from -$3 million to $4 million. DOE accounts for that range of likely impacts in analyzing whether a TSL is economically justified. See section V.C of the final rule notice. DOE is presenting the range of impacts to the INPV under two manufacturer markup scenarios: the Preservation of Gross Margin scenario, which is the manufacturer markup scenario used in the calculation of Consumer Operating Cost Savings in this table; and the Preservation of Operating Profit scenario, where DOE assumed manufacturers would not be able to increase per-unit operating profit in proportion to increases in manufacturer production costs. DOE includes the range of estimated annualized change in INPV in the above table, drawing on the MIA explained further in chapter 12 of this TSD to provide additional context for assessing the estimated impacts of this final rule to society, including potential changes in production and consumption, which is consistent with OMB's Circular A-4 and E.O. 12866. If DOE were to include the INPV into the annualized net benefit calculation (2023 SC-GHG estimates) for this final rule, the annualized net benefits would range from $686 million to $693 million at 3-percent discount rate and would range from $546 million to $553 million at 7-percent discount rate. Parentheses "( )" indicate negative values.

1.3 STRUCTURE OF THE DOCUMENT

The TSD consists of 17 chapters and supporting appendices.

Chapter 1 Introduction: Describes the purpose of the TSD, presents the results of the analysis, and outlines the structure of the document.

Chapter 2 Analytical Framework: Describes the general rulemaking process.

Chapter 3 Market and Technology Assessment: Characterizes the market for the considered consumer gas-fired instantaneous water heaters and the technologies available for increasing efficiency.

Chapter 4 Screening Analysis: Identifies all the design options that improve efficiency of consumer gas-fired instantaneous water heaters, and determines which technology options are viable for consideration in the engineering analysis.

Chapter 5 Engineering Analysis: Describes the methods used for developing the relationship between increased efficiency and increased manufacturing cost and presents results of the analysis.

Chapter 6 Markups Analysis: Describes the methods used for establishing markups for converting manufacturing cost to consumer purchase price and presents results of the analysis.

Chapter 7 Energy Use Analysis: Describes the sources and methods used for generating energy-use estimates for the considered consumer gas-fired instantaneous heaters as a function of potential standard levels and presents results of the analysis.

Chapter 8 Life-Cycle Cost and Payback Period Analysis: Describes the methods used for analyzing the economic effects of new or amended efficiency standards on individual consumers and users of the consumer gas-fired instantaneous water heaters with respect to LCC savings and PBP of higher efficiency products and presents results of the analysis.

Chapter 9 Shipments Analysis: Describes the methods used for forecasting shipments with and without new or amended efficiency standards and presents results of the analysis.

Chapter 10 National Impact Analysis: Describes the methods used for estimating the impacts of potential standards on national energy consumption and national economic benefit to consumers and presents results of the analysis.

Chapter 11 Consumer Subgroup Analysis: Describes the methods used for analyzing the effects of potential standards on different subgroups of consumers compared to all consumers and presents results of the analysis.

Chapter 12 Manufacturer Impact Analysis: Describes the methods used for analyzing the effects of potential standards on the finances and profitability of consumer gas-fired instantaneous water heaters manufacturers and presents results of the analysis.

Chapter 13 Emissions Impact Analysis: Describes the methods used for analyzing the impact of potential standards on national emissions of sulfur dioxide, nitrogen oxides, and mercury—as well as on carbon dioxide and other greenhouse gas emissions, and presents results of the analysis.

Chapter 14 Monetization of Emissions Reduction Benefits: Describes the methods used for estimating monetary benefits likely to result from reduced emissions expected to result from potential standards and presents results of the analysis.

Chapter 15 Utility Impact Analysis: Describes the methods used for analyzing key impacts of potential standards on electric utilities and presents results of the analysis.

Chapter 16 Employment Impact Analysis: Describes the methods used for analyzing the impact of potential standards on national employment and presents results of the analysis.

Chapter 17 Regulatory Impact Analysis: Describes the methods used for analyzing the impact of non-regulatory alternatives to energy conservation standards compared to standards and presents results of the analysis.

Appendix 6A Detailed Data for Product Price Markups: Contains the data used to develop markups.

Appendix 6B Incremental Markups: Theory and Evidence: Contains further theory and data about the incremental markup approach as well as a related consultant interview report.

Appendix 7A Household and Building Variables: Contains explanations of the CBECS and RECS building data used in the Energy Use Analysis and LCC Analysis.

Appendix 7B Details about the Energy Use Methodology and Data: Contains further detail of the energy use methodologies, calculations and data in the Energy Use Analysis.

Appendix 7C Mapping of Weather Station Data to RECS and CBECS Buildings: Contains the methodology to map weather station data to CBECS and RECS data.

Appendix 8A User Instructions for the Life-Cycle Cost Analysis Spreadsheet Model: Contains a description of the spreadsheet and instructions that allow the user to examine and reproduce the detailed results of the LCC and PBP analysis.

Appendix 8B	Uncertainty and Variability in the Life-Cycle Cost and Payback Period Analysis: Explains how the LCC model accounts for the uncertainty and variability of the numerical values.
Appendix 8C	Forecast of Product Price Trends for Consumer Gas-Fired Instantaneous Water Heaters: Presents a detailed explanation of the methodology DOE used to determine future equipment price.
Appendix 8D	Installation Cost Determination for Consumer Gas-Fired Instantaneous Water Heaters: Presents a detailed explanation of the methodology DOE used to determine installation costs of consumer gas-fired instantaneous water heaters.
Appendix 8E	Energy Price Calculations for Consumer Gas-Fired Instantaneous Water Heaters: Presents experiential learning analysis in the LCC analysis
Appendix 8F	Maintenance and Repair Cost Determination for Consumer Gas-Fired Instantaneous Water Heaters: Presents a detailed explanation of the methodology DOE used to determine maintenance and repairs costs of the consumer gas-fired instantaneous water heaters.
Appendix 8G	Consumer Gas-Fired Instantaneous Water Heaters Lifetime Determination: Explains how DOE derived lifetime for gas-fired instantaneous water heaters.
Appendix 8H	Distributions Used for Discount Rates: Describes the discount rate distributions used in the LCC analysis.
Appendix 8I	No-New-Standards Case Distribution of Efficiency Levels: Explains how DOE derives no-new-standards case efficiency distribution by efficiency levels.
Appendix 8J	Life-Cycle Cost Analysis Using Alternative Economic Growth Scenarios for Consumer Gas-Fired Instantaneous Water Heaters: Provides sensitivity results supplementary to the reference case analysis.
Appendix 9A	Historical Shipments and Saturations Data: Contains historical shipments of consumer gas-fired instantaneous water heaters and methodology.
Appendix 10A	User Instructions for National Impact Analysis Spreadsheet Model: Contains a description of the National Impact Analysis (NIA) spreadsheet and instructions on how to use it to examine and reproduce the NIA results.
Appendix 10B	Full-Fuel-Cycle Analysis: Contains a summary of the methods used to calculate full-fuel-cycle (FFC) energy savings.
Appendix 10C	National Net Present Value of Consumer Benefits Using Alternative Product Price Forecasts: Provides sensitivity results supplementary to the reference case analysis.

Appendix 10D	National Impact Analysis Using Alternative Economic Growth Scenarios for Consumer Gas-Fired instantaneous Water Heaters: Provides sensitivity results supplementary to the reference case analysis.
Appendix 10E	Rebound Effect Analysis: Discusses the rebound effect where consumers increase their demand for energy as a result of reduction in operating cost, and its impact on potential energy savings.
Appendix 12A	Manufacturer Impact Analysis Interview Guide
Appendix 12B	Government Regulatory Impact Model Overview
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Appendix 14B	Benefit-Per-Ton Values for NO_X and SO_2 Emissions from Electricity Generation
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CHAPTER 2. ANALYTICAL FRAMEWORK

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CHAPTER 2. ANALYTICAL FRAMEWORK

2.1 INTRODUCTION

The Energy Policy and Conservation Act (EPCA),[a] Pub. L. 94-163 (42 U.S.C. 6291 *et seq*.), requires the U.S. Department of Energy (DOE) to establish energy conservation standards that achieve the maximum improvement in energy efficiency of covered consumer products that is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) This chapter describes the general analytical framework that DOE uses in developing such standards, and, in particular, its application in the context of the energy conservation standards for gas-fired instantaneous water heaters. The analytical framework is a description of the methodology, the analytical tools, and the relationships among the various analyses that are part of this rulemaking. The methodology that addresses the statutory requirement for economic justification, for example, includes analyses of life-cycle cost; economic impact on manufacturers and users; national benefits; effects, if any, on utility companies; and impacts from any lessening in competition among manufacturers.

Figure 2.1.1 summarizes the analytical components of DOE's standards-setting process. The focus of this figure is the center column, identified as "Analyses." The column labeled "Key Inputs" lists the types of data and information required for each analysis. Some key inputs come from public databases; DOE collects other inputs from interested parties or other knowledgeable experts within the field. The column labeled "Key Outputs" shows analytical results that feed directly into the standards-setting process. The figure shows how the analyses fit into the rulemaking process and how they relate to one another. Arrows connecting analyses show the types of information that feed from one analysis to another.

[a] All references to EPCA in this document refer to the statute as amended through the Energy Act of 2020, Pub. L. 116-260 (Dec. 27, 2020).

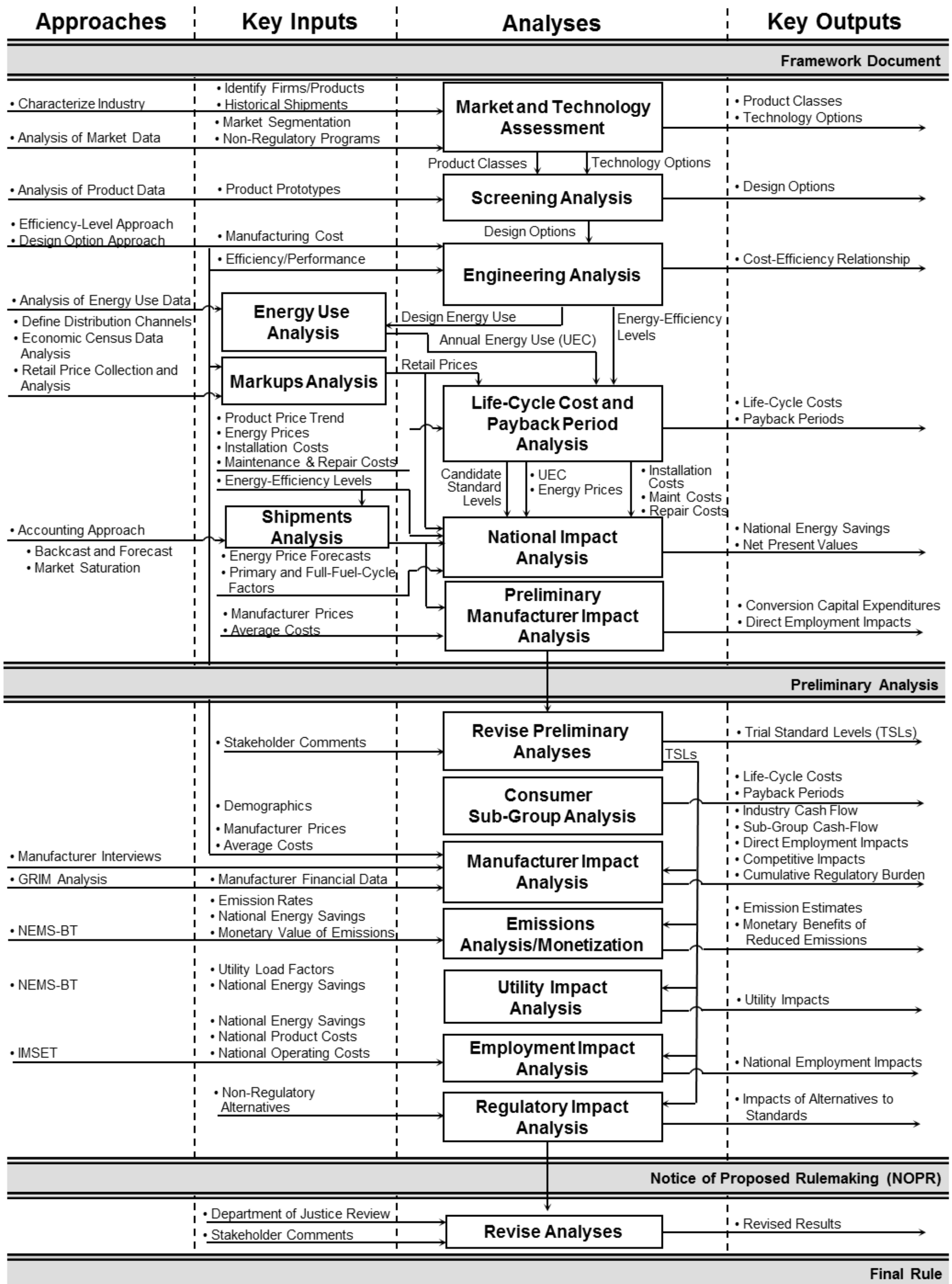

Figure 2.1.1 Flow Diagram of Analyses for the DOE Rulemaking Process[b]

[b] A framework document, as depicted in this diagram, can be replaced by a Request for Information (RFI).

This chapter provides a description of the analytical framework that DOE used to evaluate amended energy conversation standards for gas-fired instantaneous water heaters for the final rule. This chapter sets forth the methodology, analytical tools, and relationships among the various analyses that are part of this rulemaking.

- A market and technology assessment to characterize the relevant product markets and existing technology options, including prototype designs.
- A screening analysis to review each technology option and determine if it is technologically feasible; is practical to manufacture, install, and service; would adversely affect product utility or product availability; would have adverse impacts on health and safety, or represents a unique pathway to meeting a given standard level.
- An engineering analysis to develop cost-efficiency relationships that show the manufacturer's cost of achieving increased efficiency.
- An analysis of mark-ups for determining product price; mark-ups throughout the distribution channel relate the manufacturer selling price (MSP) to the retail cost paid by the consumer.
- An energy use analysis to determine the annual energy use of the considered product for a representative set of users.
- A life-cycle cost (LCC) and payback period (PBP) analysis to calculate the anticipated savings in operating costs the consumer will realize throughout the life of the covered product compared to any increase in installed product cost likely to result directly from a standard.
- A shipments analysis to forecast product shipments, which then are used to calculate the national impacts of potential standards on energy consumption, net present value (NPV), and future manufacturer cash flows. NPV accounts for the time value of money.
- A national impact analysis (NIA) to assess the aggregate impacts, at the national level, of potential energy conservation standards for the considered product, as measured by the NPV of total consumer economic impacts and the national energy savings (NES).
- A consumer subgroup analysis to evaluate variations in consumer characteristics that may cause standards to affect particular consumer sub-populations differently than the overall population.
- A manufacturer impact analysis (MIA) to estimate the financial impacts of potential energy conservation standards on manufacturers and to calculate impacts on competition, direct employment, and manufacturing capacity.
- An emissions impacts analysis to provide estimates of the effects of potential standards on emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2), nitrogen oxides (NO_x), and mercury (Hg).
- An emissions monetization that estimates the economic value of reductions in greenhouse gas emissions as well as SO_2 and NO_X emissions from the considered standards.
- A utility impact analysis to estimate the effects of adopted standards on electric and gas utilities.

- An employment impact analysis to assess the aggregate impacts of amended energy conservation standards on national employment.
- A regulatory impact analysis to assess alternatives to amended energy conservation standards that could achieve substantially the same regulatory goal at a lower cost.

The following sections provide a brief overview of the different analytical approaches used for analyzing amended standards for gas-fired instantaneous water heaters. DOE used the most reliable data available at the time of each analysis in this rulemaking.

2.2 ENERGY USE METRIC

Currently, manufacturers are required to demonstrate compliance with the energy conservation standards for gas-fired instantaneous water heaters found at 10 CFR section 430.32(d)(1) of Title 10 of the Code of Federal Regulations (CFR), which are in terms of uniform energy factor (UEF). The UEF metric, which replaced the energy factor (EF) metric, is the statutorily required metric for gas-fired instantaneous water heaters. Certain gas-fired instantaneous water heaters do not yet have UEF-based standards and instead fall under the scope of EF-based standards at the initial statutory levels established by EPCA, as amended. (42 U.S.C. 6295(e)(1)) The amended standards are all in terms of the UEF metric. The current DOE test procedure for gas-fired instantaneous water heaters appears at 10 CFR part 430 subpart B, appendix E ("appendix E") and produces the UEF metric.

2.3 MARKET AND TECHNOLOGY ASSESSMENT

The market and technology assessment characterize the relevant product markets and existing technology options, including working prototype designs, for the considered products.

2.3.1 Market Assessment

When analyzing potential energy conservation standards, DOE initially develops information that provides an overall picture of the market for the products analyzed, including the nature of the products, the industry structure, and market characteristics for the products. This activity consists of both quantitative and qualitative efforts based primarily on publicly available information. In the context of the present final rule analysis, the subjects addressed in the market assessment for gas-fired instantaneous water heaters include manufacturers, trade associations, and the quantities and types of products sold and offered for sale. DOE examined both large and small and foreign and domestic manufacturers. Finally, DOE reviewed other energy efficiency programs from utilities, individual States, and other organizations.

DOE reviewed relevant literature to develop an overall picture of the gas-fired instantaneous water heater industry in the United States. Industry publications, government agencies, and trade organizations provided the bulk of the information, including manufacturers and industry trends. The analysis developed as part of the market and technology assessment is described in chapter 3 of this TSD.

2.3.2 Product Classes

When evaluating and establishing energy conservation standards, DOE generally divides covered products into product classes by the type of energy used, capacity, or other performance-related features that affect efficiency. Different energy conservation standards may apply to different product classes. (42 U.S.C. 6295(q)) For gas-fired instantaneous water heaters, the product classes are based on storage volume, input rate, and delivery capacity (i.e., very small, low, medium, or high draw patterns).[c]

2.3.3 Technology Assessment

DOE typically uses information relating to existing and past technology options and working prototype designs as inputs to determine what technologies manufacturers might use to attain higher performance levels for the subject covered products. In consultation with interested parties, DOE develops a list of technologies for consideration. Initially, these technologies encompass all those that are technologically feasible. In this case, DOE developed its list of technologically feasible design options for gas-fired instantaneous water heaters through review of previous rulemakings for consumer water heaters, product literature, technical papers, market assessment, and product teardowns in addition to feedback from stakeholders on the preliminary analysis. Chapter 3 of this TSD includes a detailed list of all technology options DOE identified for this rulemaking.

2.4 SCREENING ANALYSIS

The purpose of the screening analysis is to evaluate technologies identified in the technology assessment to determine which options to consider further in the analysis and which options to screen out.

The screening analysis examines various technologies to determine whether they: (1) are technologically feasible; (2) are practicable to manufacture, install, and service; (3) have an adverse impact on product utility or availability; (4) have adverse impacts on health and safety; and/or (5) utilize proprietary technology that represents a unique pathway to achieving a given efficiency level. 10 CFR part 430, subpart C, appendix A, 6(a)(3)(iii)(A)–(E) and 7(b)(1)–(5). DOE developed an initial list of efficiency-enhancement technology options from those identified in the technology assessment. Then, DOE reviewed the list to assess each technology against the screening criteria listed above. Those technologies that were not screened out in the screening analysis were considered further in the engineering analysis. Chapter 4 of this TSD contains details on the screening analysis for gas-fired instantaneous water heaters.

[c] The draw pattern dictates the frequency and duration of hot water draws during the 24-hour simulated use test, and is an indicator of delivery capacity of the water heater. Draw patterns are assigned based on the first hour rating (FHR), for non-flow-activated water heaters, or maximum GPM rating (Max GPM), for flow-activated water heaters. For the specific FHR and Max GPM ranges which correspond to each draw pattern, see section 5.4.1 of Appendix E to Subpart B of 10 CFR 430.

2.5 ENGINEERING ANALYSIS

The purpose of the engineering analysis is to establish the relationship between the efficiency and cost of gas-fired instantaneous water heaters. There are two elements to consider in the engineering analysis: (1) the selection of efficiency levels to analyze (i.e., the "efficiency analysis") and (2) the determination of product cost at each efficiency level (i.e., the "cost analysis"). In determining the performance of higher-efficiency products, DOE considers technologies and design option combinations not eliminated by the screening analysis. For each product class, DOE estimates the baseline cost, as well as the incremental cost of improving UEF for products at efficiency levels above the baseline. The output of the engineering analysis is a set of cost-efficiency "curves" that are used in downstream analyses (i.e., the LCC and PBP analyses and the MIA).

Chapter 5 of this TSD discusses the product classes DOE analyzed, the representative baseline units, the incremental efficiency levels, the methodology DOE used to develop manufacturer production costs (MPCs), the cost-efficiency curves, and the impact of efficiency improvements on the considered products.

For gas-fired instantaneous water heaters, DOE also conducted analysis to convert existing EF standards to UEF standards for certain product classes that currently do not have UEF-based standards. The methodology used to arrive at the converted UEF standards for these product classes is also described in chapter 5.

To account for manufacturers' non-production costs and profit margin, DOE applies a multiplier (the manufacturer markup) to the MPC. The resulting MSP is the price at which the manufacturer distributes a unit into commerce. DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K[d] reports filed by publicly traded manufacturers that produce gas-fired instantaneous water heaters, the manufacturer markups from the April 2010 Final Rule, and feedback from confidential manufacturer interviews. 75 FR 20112. Chapter 12 of this TSD contains additional detail on the manufacturer markup.

2.5.1 Baseline Models and Efficiency Levels

In order to analyze design options for energy efficiency improvements, DOE defined a baseline model for each product class. DOE defined baseline models as gas-fired instantaneous water heaters with the most common characteristics that just meet the current energy conservation standards at 10 CFR 430.32(d)(1). Baseline models serve as the reference point against which any changes resulting from energy conservation standards can be measured.

For the final rule analysis, DOE reviewed data in its Compliance Certification Management Database and the Air-Conditioning, Heating and Refrigeration Institute's (AHRI's) Directory of Certified Water Heater Models to evaluate the range of gas-fired instantaneous

[d] U.S. Securities and Exchange Commission. Company Filings. Available at www.sec.gov/edgar/search/ (last accessed September 25, 2024).

water heater efficiencies currently available on the market. DOE used these data to identify clusters of models that correspond with higher efficiency levels, taking into consideration levels already defined by other programs (e.g., ENERGY STAR). Additionally, DOE considered efficiency levels recommended by stakeholders in response to the preliminary analysis. Altogether, this information was used as the basis for defining higher efficiency levels in this final rule analysis. The baseline models and efficiency levels are discussed in detail in chapter 5 of this TSD.

2.5.2 Manufacturing Cost Analysis

The cost analysis portion of the engineering analysis is conducted using one or a combination of costing approaches. The selection of cost approach depends on a suite of factors, including the availability and reliability of public information, characteristics of the regulated product, the availability and timeliness of purchasing the product on the market. The approaches utilized in this final rule analysis are summarized as follows:

- Physical teardowns: under this approach, DOE physically dismantles a commercially-available product, component-by-component, to develop a detailed bill of materials for the product.
- Catalog teardowns: in lieu of physically deconstructing a product, DOE identifies each component using parts diagrams (available from manufacturer websites or appliance repair websites, for example) to develop the bill of materials for the product.

Physical teardowns were supplemented by catalog teardowns as necessary. DOE then used independent costing methods, along with manufacturer and component-supplier data, to estimate the costs of the design changes between baseline models and those at higher efficiency levels based on observed differences in teardown units. The manufacturing cost analysis is discussed in detail in chapter 5 of this TSD.

2.6 MARK-UPS ANALYSIS

DOE analyzed product mark-ups to convert the MSPs, estimated in the engineering analysis, to consumer prices, which then are used in analyzing the LCC and PBP. To develop mark-ups, DOE identified how for gas-fired instantaneous water heaters are distributed from the manufacturer to the consumer. After identifying appropriate distribution channels, DOE relied on economic data from the U.S. Census Bureau and other sources to determine how prices are marked up as products pass from the manufacturer to the consumer. DOE estimated the mark-ups taken by wholesalers, contractors, and retailers and also included sales taxes. DOE calculated mark-ups for baseline products (baseline mark-ups) and for more efficient products (incremental mark-ups). The incremental mark-up relates the change in the manufacturer sales price of higher-efficiency models (the incremental cost increase) to the change in the retailer or distributor sales price.

Chapter 6 of the this TSD provides details on DOE's development of markups for gas-fired instantaneous water heaters.

2.7 ENERGY USE ANALYSIS

To conduct the LCC and PBP analyses described in section 2.8 of this TSD, DOE must determine the operating cost savings to consumers from using more-efficient products. The goal of the energy use analysis is to determine the annual energy consumption of gas-fired instantaneous water heaters for use in the LCC and PBP analyses. Energy use characterization generates a range of energy use values that reflect real-world gas-fired instantaneous water heater use in American homes. By incorporating data on how gas-fired instantaneous water heaters are used by U.S. consumers, DOE can estimate the energy that would be consumed (or potentially saved) by units having various efficiency levels.

To establish a reasonable range of energy consumption in the field for gas-fired instantaneous water heaters, DOE primarily used data from the U.S. Energy Information Administration's (EIA's) 2020 *Residential Energy Consumption Survey* ("*RECS 2020*").[e] *RECS* is a national sample survey of housing units that collects statistical information on the consumption of and expenditures for energy in housing units, along with data on energy-related characteristics of the housing units and occupants. *RECS 2020* is the most recent survey and has a sample size of nearly 18,500 housing units and was constructed by EIA to be a national representation of the household population in the United States. DOE's assumptions for establishing a gas-fired instantaneous water heater sample included the following considerations: (1) the household had a tankless water heater, (2) the household used natural gas or propane for water heating, and (3) the water heating use was greater than zero. DOE also considered the use of gas-fired instantaneous water heaters in commercial applications, based on characteristics from EIA's 2018 *Commercial Building Energy Consumption Survey* ("*CBECS 2018*")[f] for a subset of building types that use for gas-fired instantaneous water heating products covered by a potential standard. DOE utilized average historical shipment data and projected shipments to adjust the building weightings in RECS and CBECS for gas-fired instantaneous water heaters.

In order to calculate the hot water use for each sample, DOE first assigned a draw pattern to the sampled household or building. Then DOE estimated the hot water use per month for each sample and thereafter the energy use associated with providing the hot water. DOE calculated both the fuel and electricity used by the gas-fired instantaneous water heaters at various efficiency levels.

Chapter 7 of this TSD provides more detail about DOE's approach for characterizing energy and hot water use of gas-fired instantaneous water heaters.

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[e] U.S. Department of Energy - Energy Information Administration, *Residential Energy Consumption Survey: 2020 Public Use Data Files* (2020) (Available at: https://www.eia.gov/consumption/residential/data/2020/) (Last accessed September 25, 2024).

[f] U.S. Department of Energy - Energy Information Administration, *Commercial Building Energy Consumption Survey: 2018 Public Use Data Files* (2018) (Available at: https://www.eia.gov/consumption/commercial/data/2018/) (Last accessed September 25, 2024).

2.8 LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

In determining whether an energy conservation standard is economically justified, DOE considers the economic impacts of potential efficiency levels on consumers. Energy conservation standards produce a change in consumer operating costs—usually a decrease—and a change in product purchase price—usually an increase. DOE used the following two metrics to measure potential impacts on consumers.

- LCC is the total consumer cost of an appliance or product, generally over the life of the product. The LCC calculation includes total installed cost (product MSP, mark-ups through the distribution channel, sales tax, and any installation costs), operating costs (energy, repair, and maintenance expenses), product lifetime, and discount rate. Future operating costs are discounted to the time of purchase and summed over the lifetime of the appliance or product.
- PBP measures the amount of time (in years) required for consumers to recover the assumed higher purchase price of a more energy efficient product through reduced operating costs. Inputs to the calculation of PBP include the installed cost to the consumer and first-year operating costs. DOE's analysis produces a simple PBP based on using single-point average values to estimate the purchase price and undiscounted first-year operating cost.

In determining the LCC and PBP, DOE used data regarding engineering performance, markups, energy use, and installation costs. DOE generated LCC and PBP results using a simulation approach in which certain key inputs to the analysis consist of probability distributions rather than single-point values. That analytical technique produces outcomes that also can be expressed as probability distributions. As a result, the analysis produces a range of LCC and PBP results, which enables DOE to identify the fraction of consumers achieving LCC savings or incurring net cost at each considered efficiency level.

Chapter 8 of the TSD describes the LCC and PBP analysis.

2.9 SHIPMENTS ANALYSIS

DOE projected future shipments of gas-fired instantaneous water heaters based on an analysis of key market drivers. Projections of shipments are needed to calculate the potential effects of standards on national energy use, NPV, and future manufacturer cash flows. DOE generated shipments projections for gas-fired instantaneous water heaters. The projections estimate the total number of gas-fired instantaneous water heaters shipped each year during the 30-year analysis period. To create the projections, DOE combined current-year shipments with results of a shipments model that incorporates key market drivers for gas-fired instantaneous water heaters. Chapter 9 of the TSD provides additional details on the shipments analysis.

2.10 NATIONAL IMPACT ANALYSIS

The national impact analysis assesses the aggregate impacts at the national level of potential energy conservation standards for the considered product, as measured by the NPV of total consumer economic impacts and the NES. DOE determined the NPV and NES for the efficiency levels considered for gas-fired instantaneous water heaters. To make the analysis more accessible and transparent to all interested parties, DOE prepared a Microsoft Excel spreadsheet model to forecast national energy consumption and the national consumer economic costs and savings resulting from new standards. The spreadsheet model uses typical values as inputs (as opposed to probability distributions). To assess the effect of input uncertainty on NES and NPV results, DOE may conduct sensitivity analyses by running scenarios on specific input variables.

2.10.1 National Energy Savings

The inputs for determining the NES for each product analyzed are: (1) annual energy consumption per unit, (2) shipments, (3) product stock, (4) national energy consumption, and (5) site-to-power plant energy and full-fuel-cycle conversion factors. DOE calculated the national energy consumption by multiplying the number of units, or stock, of each product (by vintage, or age) by the unit energy consumption (also by vintage). DOE calculated annual NES based on the difference in unit energy consumption between the no-new standards case (without new efficiency standards) and for each higher efficiency standard. DOE estimated energy consumption and savings based on site energy, and converted the electricity consumption and savings to full-fuel cycle energy. Cumulative energy savings are the sum of the NES for each year.

2.10.2 Net Present Value of Consumer Benefit

The inputs for determining NPV of the total costs and benefits experienced by consumers of the considered product are: (1) total annual installed cost, (2) total annual savings in operating costs, (3) a discount factor, (4) present value of costs, and (5) present value of savings. DOE calculated net savings each year as the difference between the no-new-standards case and each standards case in total savings in operating costs and total increases in installed costs. DOE calculated savings over the life of each product. NPV is the difference between the present value of operating cost savings and the present value of total installed costs.

DOE calculated increases in total installed costs as the product of the difference in total installed cost between the no-new standards case and standards case (i.e., once the standards take effect). DOE expressed savings in operating costs as decreases associated with the lower energy consumption of products bought in the standards case compared to the no-new-standards case. Total savings in operating costs are the product of savings per unit and the number of units of each vintage that survive in a given year.

To calculate the NPV, DOE used a discount factor based on real discount rates of 3 percent and 7 percent to discount future costs and savings to present values. Chapter 10 of the TSD provides additional details on the national impact analysis.

2.11 CONSUMER SUBGROUP ANALYSIS

The consumer subgroup analysis evaluates impacts on any identifiable groups of consumers who may be disproportionately affected by a national energy conservation standard. For gas-fired instantaneous water heaters, DOE analyzed the LCCs and PBPs for consumers in the following subgroups: (1) low-income households, (2) senior-only households, and (3) small businesses. Chapter 11 of the TSD provides additional details on the consumer subgroup analysis.

2.12 MANUFACTURER IMPACT ANALYSIS

The purpose of the MIA is to identify and quantify the impacts of any new or amended energy conservation standards on manufacturers. The MIA has both quantitative and qualitative aspects, and includes analyses of projected industry cash flows, the industry net present value (INPV), conversion costs, and direct employment. Additionally, the MIA describes how new or amended energy conservation standards might affect manufacturing capacity and competition, as well as how standards contribute to overall regulatory burden. Finally, the MIA identifies any disproportionate impacts on manufacturer subgroups, including small business manufacturers. The Department analyzes the impact of standards on manufacturers with substantial input from manufacturers and other interested parties.

DOE conducts the MIA in three phases and further tailors its analytical framework based on the comments it receives. In Phase I, DOE created an industry profile to characterize the industry and to identify important issues that require consideration. In Phase II, DOE prepared an industry cash-flow model and determined what information to discuss with manufacturers during manufacturer interviews. In Phase III, DOE interviewed manufacturers and assessed the impacts of potential standards both quantitatively and qualitatively. DOE calculated industry cash flow and INPV using the Government Regulatory Impact Model (GRIM). DOE then assessed impacts on competition, manufacturing capacity, direct employment, and regulatory burden based on manufacturer interview feedback. Chapter 12 of the TSD provides additional details on the MIA.

2.13 EMISSIONS IMPACT ANALYSIS

In the emissions analysis, DOE estimates the reduction in power sector combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), mercury (Hg), methane (CH_4), and nitrous oxide (N_2O) from potential energy conservation standards for the considered products, as well as emissions at the building site. In addition, DOE estimates emissions impacts in production activities (extracting, processing, and transporting fuels) that provide the energy inputs to power plants and for site combustion. Together, these emissions account for the full-fuel-cycle (FFC).

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site (where applicable) combustion emissions of CO_2, NO_X, SO_2, and Hg. The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, CH_4 and N_2O, as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The upstream emissions include emissions from fuel combustion during extraction, processing, and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The analysis of power sector emissions uses marginal emissions factors that are derived from data in *AEO 2023*. The *AEO* incorporates the projected impacts of existing air quality regulations on emissions. *AEO* generally represents current legislation and environmental regulations, including recent government actions, for which implementing regulations were available as of the time of its preparation.

The methodology is described in more detail in chapter 13 of the TSD.

2.14 MONETIZATION OF EMISSIONS REDUCTION BENEFITS

As part of its assessment of energy conservation standards, DOE considered the estimated monetary benefits likely to result from the reduced emissions of CO_2, CH_4, N_2O, SO_2, and NO_X that are expected to result from each of the potential standard levels considered in this phase of the rulemaking.

DOE estimates the benefits of the reductions in emissions of CO_2, CH_4, and N_2O by using a measure of the social cost (SC) of each pollutant (*e.g.,* SC-CO_2). These estimates represent the monetary value of the net harm to society associated with a marginal increase in emissions of these greenhouse gases (GHGs) in a given year, or the benefit of avoiding that increase. DOE estimated the global social benefits of CO_2, CH_4, and N_2O reductions using an updated set of SC-GHG estimates published in 2023 as well as the set of interim SC-GHG values presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order (EO) 13990, published in February 2021 by the Interagency Working Group on the Social Cost of Greenhouse Gases (IWG), which DOE used in the NOPR for this rule before the updated values were available.[g] These values are discussed in chapter 14 of this document.

To estimate the monetary value of reduced NO_X and SO_2 emissions from electricity generation attributable to the standard levels it considers, DOE uses benefit-per-ton estimates derived from analysis conducted by the EPA. For NO_X and SO_2 emissions from combustion at the site of product use, DOE uses another set of benefit-per-ton estimates published by the EPA.

[g] Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990 published in February 2021 by the IWG. ("February 2021 SC-GHG TSD"). www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf. https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-final-rule-20231130.pdf; https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf (last accessed July 3, 2024)

For more detail on the monetization of emissions analysis, see chapter 14 of the TSD.

2.15 UTILITY IMPACT ANALYSIS

In the utility impact analysis, DOE analyzed the changes in electric installed capacity and electricity generation that are projected for each considered trial standard level. For electric utilities, the analysis is based on output of the DOE/EIA's National Energy Modeling System (NEMS). NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *AEO*. The EIA publishes a reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. For gas-fired instantaneous water heaters, DOE used a methodology based on results published for the *AEO 2023* reference case and a set of side cases that implemented a variety of efficiency-related policies. Further detail is provided in chapter 15 of the TSD.

2.16 EMPLOYMENT IMPACT ANALYSIS

Energy conservation standards can affect employment both directly and indirectly. Direct employment impacts are changes in the number of employees at the plants that produce the covered products. DOE evaluated direct employment impacts in the MIA. Indirect employment impacts may result from expenditures shifting between goods (the substitution effect) and changes in income and overall expenditure levels (the income effect) that occur due to standards. DOE defines indirect employment impacts from standards as net jobs eliminated or created in the general economy as a result of increased spending driven by increased product prices and reduced spending on energy.

Indirect employment impacts were investigated in the employment impact analysis using the Pacific Northwest National Laboratory's "Impact of Sector Energy Technologies" (ImSET) model.[h] The ImSET model was developed for DOE's Office of Planning, Budget, and Analysis to estimate the employment and income effects of energy-saving technologies in buildings, industry, and transportation. Compared with simple economic multiplier approaches, ImSET allows for more complete and automated analysis of the economic impacts of energy conservation investments DOE notes that input-output models are appropriate to examine relationships when the economic relationships are stable over time. Because input-output models often rely on statistically estimated relationships over lengthy time periods (e.g., 10 years), the stability of policy and other factors are important aspects of appropriate application of the model. DOE relies on ImSet because the agency believes that the relationships between economic variables are stable enough and the policy changes are not sufficiently large enough to render the model unreliable. In particular, the category at issue is a narrow subset of the entire water heater

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[h] Livingston, O. and et al. *ImSET 4.0: Impact of Sector Energy Technologies Model Description and User's Guide*. 2015. Pacific Northwest National Laboratory. https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-24563.pdf.

market. In future rulemakings, DOE may continue to explore alternative models for estimating national net employment impacts. Further detail is provided in chapter 16 of the TSD.

2.17 REGULATORY IMPACT ANALYSIS

As part of its regulatory impact analysis (RIA), DOE identified major alternatives to standards that represent feasible policy options to reduce the energy consumption of gas-fired instantaneous water heaters. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each alternative to the effectiveness of the adopted standard. DOE recognized that voluntary or other non-regulatory efforts by manufacturers, utilities, and other interested parties can substantially affect energy efficiency or reduce energy consumption. DOE based its assessment on the recorded impacts of any such initiatives to date, but also considered information presented by interested parties regarding the impacts current initiatives may have in the future. Further detail on the analysis is provided in chapter 17 of the TSD.

CHAPTER 3. MARKET AND TECHNOLOGY ASSESSMENT

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3.1 INTRODUCTION

This chapter details the market and technology assessment that the U.S. Department of Energy (DOE) has conducted in support of its energy conservation standards rulemaking for gas-fired instantaneous water heaters, which are a type of consumer water heater.

The goal of the market assessment is to develop a qualitative and quantitative characterization of the gas-fired instantaneous water heater industry and market structure based on publicly available information and data, as well as information that DOE received directly from manufacturers during manufacturer interviews (see chapter 12 of this technical support document (TSD) for details regarding the manufacturer interview process). DOE examined publicly available information from its Compliance Certification Database (CCD)[a] and the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance for Water Heaters to identify the types and characteristics of gas-fired instantaneous water heaters on the market. DOE also reviewed information from the U.S. Census Bureau and the U.S. Energy Information Administration (EIA) to understand trends in the gas-fired instantaneous water heater market. The market and technology assessment addresses definitions and product classes, manufacturer characteristics and market shares, distribution channels, existing regulatory and non-regulatory efficiency improvement initiatives, historical shipments, product lifetimes, and trends in product characteristics. DOE performs the technology assessment to develop a preliminary list of technologies (referred to as technology options) that could be used to improve the efficiency of gas-fired instantaneous water heaters.

3.1.1 Description of Products

Consumer water heaters primarily provide domestic hot water to residences for consumer use, appliances, and other functions. Some consumer water heaters are also capable of providing heated water for space heating systems. Consumer water heaters are classified based on the main energy source (i.e., gas, oil, or electricity) and ratio of input rating to stored water volume to determine whether the water heater is storage-type or instantaneous-type.

All consumer water heaters contain a cold-water inlet, hot water outlet, and an outer case. In gas-fired instantaneous water heaters, one or more heat exchangers is used to heat the water. Consumer instantaneous water heaters, especially “tankless” units with very little storage volume, typically have a flow detector to provide hot water on-demand. Additional main components typically found in gas-fired instantaneous water heaters are a burner and gas valve, burner control thermostat, ignition system, combustion chamber, and heat exchanger and vent.

[a] DOE requires manufacturers of consumer water heaters for sale in the United States to certify compliance of each basic model with the currently applicable energy conservation standards for consumer water heaters in accordance with the requirements in 10 CFR 429.17. The CCD lists all models that have been certified to DOE for the present compliance year. For more information, see www.regulations.doe.gov/ccms.

In the United States, 100 percent of homes (estimated 125 million) have consumer water heaters (as of 2021). Energy consumption attributable to water heater operation represents 3 percent (2.81 quads) of total U.S. primary energy consumption. Within individual homes, water heating represents, on average, 14.9 percent of total annual household site energy consumption and 13.4 percent of total annual household primary energy consumption (as of 2021). Gas-fired instantaneous water heaters are gaining in market share amongst consumer water heaters. DOE estimates that approximately 12 percent of consumer water heaters sold in 2023 were gas-fired instantaneous units. These products account for 0.15 quads of annual primary energy consumption, or 0.8 percent of residential energy use.

3.1.2 Definitions

On March 17, 1987, the National Appliance Energy Conservation Act (NAECA), Public Law 100-12, amended the Energy Policy and Conservation Act (EPCA), Public Law 94-163, and established the definition of a consumer "water heater" as follows:

Water heater means a product that uses oil, gas, or electricity to heat potable water for use outside the heater upon demand, including –

1. Storage-type units which heat and store water at a thermostatically controlled temperature, including gas storage water heaters with an input of 75,000 British thermal units [Btu] per hour [h] or less, oil storage water heaters with an input of 105,000 Btu per hour or less, and electric storage water heaters with an input of 12 kilowatts [kW] or less;
2. Instantaneous-type units which heat water, but contain no more than one gallon of water per 4,000 Btu per hour of input, including gas instantaneous water heaters with an input of 200,000 Btu per hour or less, oil instantaneous water heaters with an input of 210,000 Btu per hour or less, and instantaneous electric water heaters with an input of 12 kilowatts or less; and,
3. Heat pump-type units, with a maximum current rating of 24 amperes at a voltage no greater than 250 volts, which are products designed to transfer thermal energy from one temperature level to a higher temperature level for the purpose of heating water, including all ancillary equipment such as fans, storage tanks, pumps, or controls necessary for the device to perform its function.

(42 United States Code (U.S.C.) 6291(27))

The definition of a consumer water heater is codified at section 430.2 of title 10 of the Code of Federal Regulations (CFR). In addition, DOE has adopted the following definition for gas-fired instantaneous water heaters at 10 CFR 430.2:

> *Gas-fired instantaneous water heater* means a water heater that uses gas as the main energy source, has a nameplate input rating less than 200,000 Btu/h, and contains no more than one gallon of water per 4,000 Btu per hour of input.

The energy conservation standards for gas-fired instantaneous water heaters found at 10 CFR 430.32(d)(1) are represented in terms of the uniform energy factor (UEF). UEF is the ratio of the heat delivered to the energy consumed when tested according to appendix E, "Uniform Test Method for Measuring the Energy Consumption of Water Heaters." UEF accounts for both recovery efficiency and standby losses at prescribed patterns of hot-water draws, and the specific draw pattern is determined by the result of the delivery capacity test described in appendix E, consisting of the first-hour rating (FHR) test and maximum gallons per minute (Max GPM) test for non-flow activated and flow-activated water heaters, respectively. The DOE test procedure at appendix E is discussed further in section 3.1.4.

3.1.3 Product Classes

DOE categorizes consumer water heaters into product classes with a separate energy conservation standard for each class. The criteria for separation into different classes are type of energy used, capacity, and other performance-related features such as those that provide utility to the consumer or others deemed appropriate by the Secretary that would justify the establishment of a separate energy conservation standard. (42 U.S.C. 6295(q)) For consumer water heaters, the product classes are based on energy source (i.e., gas, oil, or electric), ratio of input rating to storage volume (to determine whether it is a storage-type or instantaneous-type water heater) and other performance-related characteristics (e.g., draw pattern).

On February 7, 1989, DOE published an energy conservation standards final rule (February 1989 Final Rule) which codified the consumer water heater definition and energy conservation standards established by NAECA at 10 CFR 430.2 and 10 CFR 430.32(d), respectively, and established the gas water heater, oil water heater, and electric water heater product classes. 54 FR 6062, 6075–6077. On January 17, 2001, DOE published an energy conservation standards final rule (January 2001 Final Rule) which amended the energy conservation standards for consumer water heaters and added the instantaneous gas-fired water heater product class. 66 FR 4474, 4497. On April 16, 2010, DOE published the April 2010 Final Rule, which was DOE’s most recent final rule addressing energy conservation standards for gas-fired instantaneous water heaters. 75 FR 20112. The April 2010 Final Rule maintained a separate product class for gas-fired instantaneous water heaters but did not adopt standards for gas-fired instantaneous water heaters with less than 50,000 Btu/h of input because, at that time, there were no such low-input gas-fired instantaneous water heaters available on the market. *Id*. at 20127.

On July 11, 2014, DOE published a test procedure final rule (July 2014 Final Rule) in which DOE moved the definition of gas-fired instantaneous water heater from appendix E to 10 CFR 430.2. 79 FR 40542, 40547–40548. Finally, the July 2014 Final Rule clarified that the energy conservation standards codified at 10 CFR 430.32(d) were applicable to specific storage volume and input rate ranges that were excluded from the test procedure in effect prior to the effective date of the July 2014 Final Rule. Specifically pertaining to gas-fired instantaneous water heaters, the July 2014 Final Rule determined that the standards codified at that time did not apply to products with more than 2 gallons of storage volume. *Id.*

As a result of these rulemakings, gas-fired instantaneous water heaters with input rates of 50,000 Btu/h or less and gas-fired instantaneous water heaters with 2 or more gallons of storage volume were excluded from the standards that were codified at 10 CFR 430.32(d).

In the December 2016 Conversion Factor Final Rule, DOE declined to develop conversion factors and UEF-based standards for consumer water heaters of certain sizes (by rated storage volume or input rating) and of certain types (i.e., oil-fired instantaneous water heaters) where models did not exist on the market at the time to inform the analysis of the standards conversion. 81 FR 96204, 96210-96211. This included gas-fired instantaneous water heaters with input rates of 50,000 Btu/h or less and gas-fired instantaneous water heaters with 2 or more gallons of storage volume. For consumer water heaters that did not receive converted UEF-based standards, DOE provided its interpretation that the original statutory standards—found at 42 U.S.C. 6295(e)(1) and expressed in terms of the EF metric—still applied; however, DOE would not enforce those statutorily-prescribed standards until such a time conversion factors are developed for these products and they can be converted to UEF. *Id*. Thus, the EF-based standards specified by EPCA apply to any consumer water heaters which do not have UEF-based standards found at 10 CFR 430.32(d)(1). The EF-based standards for gas-fired instantaneous water heaters are set forth at 42 U.S.C. 6295(e)(1) and are repeated in Table 3.1.1.

Table 3.1.1 EF-Based Federal Energy Conservation Standards for Gas-fired Consumer Water Heaters

Product Class	Energy Factor*
Gas water heaters	$0.62 – (0.0019 \times V_r)$

* V_r is the rated storage volume (in gallons), which is currently determined pursuant to 10 CFR 429.17.

Thus, gas-fired instantaneous water heaters are divided into three groups, each with different capacity characteristics and efficiency metrics, as shown in Table 3.1.2.

Table 3.1.2 Current Major Product Class Divisions and Efficiency Metrics for Consumer Gas-fired Instantaneous Water Heaters

Rated Storage Volume and Input Rating (if applicable)	Efficiency Metric
< 2 gal and ≤ 50,000 Btu/h	EF
< 2 gal and > 50,000 Btu/h	UEF
≥ 2 gal	EF

3.1.4 Product Test Procedures

DOE established the initial test procedures for consumer water heaters at appendix E through a final rule published on October 17, 1990. 55 FR 42163 (October 1990 Final Rule). DOE amended appendix E on May 11, 1998, by adding the following provisions: (1) a revision to the method used in determining the first hour rating of storage-type water heaters, (2) an additional rating for electric and instantaneous gas-fired water heaters, and (3) a revision to the definition of a heat pump water heater. 63 FR 25996. On July 20, 1998, DOE published in the *Federal Register* a correction to the May 1998 Final Rule, which added water heater testing schematics. 63 FR 38737. On December 18, 2012, the American Energy Manufacturing Technical Corrections Act (AEMTCA), Public Law 112–210, in relevant part, amended EPCA to require that DOE publish a final rule establishing a uniform efficiency descriptor and accompanying test methods for consumer water heaters and certain commercial water heating equipment. (42 U.S.C. 6295(e)(5)(B))

Appendix E was next updated in the July 2014 Final Rule, which amended appendix E with the following revisions: (1) expanded coverage of test procedure to consumer water heaters of all storage volumes and specific input rate ranges corresponding to residential applications, (2) removed procedures to test add-on heat pump water heaters, (3) requiring a 12-hour soak-in period for consumer water heaters with a rated storage volume greater than 2 gallons, (4) revision to thermostat setting procedure to emphasize an outlet water temperature of 125 degrees Fahrenheit (°F) (51.7 degrees Celsius (°C)), (5) different draw patterns during the 24-hour simulated-use test determined by either the FHR or Max GPM test, and (6) a change from the energy factor (EF) metric to the UEF metric. 79 FR 40542 (July 11, 2014).

Most recently, DOE published the June 2023 TP Final Rule, which adopted several updates to the test procedure. The June 2023 TP Final Rule:

1. Incorporated by reference current versions of industry standards: ANSI/ASHRAE Standard 41.1-2020, "Standard Methods for Temperature Measurement", ANSI/ASHRAE Standard 41.6-2014, "Standard Method for Humidity Measurement", ANSI/ASHRAE 118.2-2022 ,"Method of Testing for Rating Residential Water Heaters and Residential-Duty Commercial Water Heaters", ASTM D2156-09 (Reapproved 2018) "Standard Test Method for Smoke Density in Flue Gases from Burning Distillate Fuels", and ASTM E97-82 (Reapproved) "Standard Test Methods for Directional Reflectance Factor, 45-Deg 0-Deg, of Opaque Specimens by Broad-Band Filter Reflectometry,".
2. Added definitions for "circulating water heater," "tabletop water heater," and "low-temperature water heater."
3. Harmonized various aspects of the DOE test procedure with industry test procedures ASHRAE 118.2-2022 and Northwest Energy Efficiency Alliance (NEEA) Advanced Water Heating Specification v8.0[b].
4. Modified the test condition specifications and tolerances, including electric supply voltage tolerance, ambient conditions (ambient dry-bulb temperature and ambient relative humidity), standard temperature and pressure definition, gas supply pressure, manifold pressure, inlet water temperature, and flow rate tolerances, and adds optional test conditions for heat pump water heaters.
5. Specified and clarified methods for mixing valve installation for affected consumer water heaters, orifice modification, and calculation of volume or mass delivered.
6. Provided instruction for the use of a separate unfired hot water storage tank or separate electric storage water heater for testing consumer water heaters designed to operate with a separately sold tank.
7. Added procedures for estimating internal stored water temperature for consumer water heater designs in which the internal tank temperature cannot be directly measured.
8. Clarified test procedures for consumer water heaters with network connection capabilities.
9. Clarified test procedures for flow-activated water heaters and water heaters that are not flow-activated by aligning terminology.

[b] The NEEA Advanced Water Heating Specification is discussed further in section 3.1.10.5.

10. Included additional testing provisions and calculations for performing high temperature testing (which is not currently applicable to gas-fired instantaneous water heaters).

88 FR 40406.

The June 2023 TP Final Rule also established "effective storage volume," (V_{eff}) a capacity metric designed to account for the increases in delivery capacity resulting from storing water at increased storage tank temperatures as described above.[c] 88 FR 40406. Effective storage volume is determined by multiplying rated storage volume by a dimensionless volumetric scaling factor (k_V) derived from a comparison of the thermal energy stored at the consumer water heater's maximum storage temperature to that of water at 125 °F; consumer water heaters incapable of storage at a temperature above the delivery temperature that the water heater is set at have an effective storage volume equal to their rated storage volume.

3.2 MARKET ASSESSMENT

The following market assessment identifies the manufacturer trade associations, domestic and international manufacturers of consumer gas-fired instantaneous water heaters, and their corresponding market shares. The market assessment also provides information on distribution channels, regulatory and non-regulatory programs, historical shipment data, the cost structure for the consumer water heater industry, product lifetimes, and relevant market performance data.

3.2.1 Trade Associations

DOE recognizes the importance of trade groups in disseminating information and providing growth to the industry they support. To gain insight into the consumer water heater industry, DOE researched various associations available to manufacturers, suppliers, and users of such equipment.

DOE identified AHRI as the trade association that supports the consumer water heater industry.

3.2.1.1 Air-Conditioning, Heating, and Refrigeration Institute

AHRI is a national trade association of manufacturers of residential, commercial, and industrial appliances and equipment, components and related products.[d] AHRI was established in January of 2008, when the Air-Conditioning and Refrigeration Institute (ARI) merged with the Gas Appliance Manufacturers Association (GAMA). AHRI's scope includes gas-fired, oil-fired, and electric products and equipment. According to its website, AHRI describes itself as a "North American association with global interests and services, serving its membership of 300-plus heating, ventilation, air conditioning, and refrigeration (HVACR) and water heating equipment

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[c] For circulating water heaters, which are typically shipped from the manufacturer without any stored volume but require a volume of water to operate in the field, effective storage volume accounts for the volume of water used for testing which is likely to be representative of the volume in the field. Gas-fired water heaters that meet the definition of a "circulating water heater" at 10 CFR 430.2 are classified as gas-fired storage water heaters as opposed to gas-fired instantaneous water heaters. Circulating water heaters are not within the scope of DOE's rulemaking for gas-fired instantaneous water heaters.

[d] For more information, please visit www.ahrinet.org. (Last accessed September 26, 2024)

manufacturers through operations in the United States, Canada, China, Dubai, India, and Mexico. AHRI members manufacture quality, efficient, and innovative HVACR equipment and components for sale around the world. These products account for more than 90 percent of the residential and commercial equipment manufactured and sold in North America." Additionally, AHRI states that it "advocates on behalf of its members at all levels of the United States government and ensures that members' interests are included in final drafts of legislation." AHRI also develops industry-recognized performance standards for industry equipment.[1]

AHRI maintains a Product Performance Certification Program and a database of products and equipment tested under its certification program on its website. Most of the heating products currently manufactured by member manufacturers are included in this database. [2]

3.2.2 Compliance Certification Database

DOE maintains a database of consumer water heaters through the CCD. The CCD houses certification reports and compliance statements submitted by manufacturers for covered products and equipment subject to Federal conservation standards. The public certification database houses only certification records of current basic models that have been submitted within the past year and is updated every two weeks.

3.2.3 Manufacturer Information

The following section provides information about manufacturers of gas-fired instantaneous water heaters and potential small business impacts.

3.2.3.1 Manufacturers and Market Shares

DOE's reviewed its CCD,[3] AHRI's Directory of Certified Product Performance database,[2] Energy Star's Product Finder dataset,[4] California Energy Commission's Modernized Appliance Efficiency Database System,[5] and individual company websites to identify manufacturers that produce gas-fired instantaneous water heaters covered by this rulemaking. DOE identified 23 companies that import, private label, produce, or manufacture the gas-fired instantaneous water heaters. DOE estimates that there are 15 original equipment manufacturers (OEMs) that sell gas-fired instantaneous water heaters covered by this rulemaking within the United States. Some manufacturers offer covered gas-fired instantaneous water heaters under multiple brand names (e.g., A.O. Smith Corporation sells gas-fired instantaneous water heater models under brand names such as A.O. Smith, American, Lochinvar, and Reliance Water Heaters). Based on public data sources, information gathered during manufacturer interviews, and model counts, DOE understands that most of the supply of gas-fired instantaneous water heaters in the United States is provided by four manufacturers: A.O. Smith Corporation, Navien, Inc. (owned by Kyung Dong One Co., Ltd.), Rheem Manufacturing Company (owned by Paloma Co., Ltd.), and Rinnai Corporation. See Table 3.2.1 for the list of gas-fired instantaneous water heater OEMs identified.

Table 3.2.1 Gas-fired Instantaneous Water Heater Original Equipment Manufacturers

Company Name*
A.O. Smith Corporation
Bosch Thermotechnology Corp. (Robert Bosch GmbH)
Bradford White Corporation
Daesung Industrial Co., Ltd.
Kiturami Holdings Co., Ltd.
Furrion Limited (LCI Industries)**
Midea Group Co., Ltd.
Navien, Inc. (Kyung Dong One Co., Ltd.)
Noritz Corporation
Rheem Manufacturing Company (Paloma Co., Ltd.)
Rinnai Corporation
Stiebel Eltron GmbH & Co. KG (Dr. Theodor Stiebel Werke GmbH & Co. KG)**
Vatti Corporation Limited
Zhongshan Gastek Home Appliance Company Limited**
Zhongshan Yi Service Network Information Technology Go., Ltd.

*Parent company name included in parentheses ( ), if applicable.
**These manufacturers only make products sold in the United States that are subject to new UEF-based energy conservation standards translated from EF-based energy conservation standards (discussed in section 5.13 of this final rule TSD).

3.2.3.2 Small Business Impacts

Small businesses may be disproportionately affected by the promulgation of energy conservation standards for gas-fired instantaneous water heaters. The Small Business Administration (SBA) defines small business manufacturing enterprises for gas-fired instantaneous water heaters as those having 1,500 employees or fewer.[6] SBA lists small business size standards for industries as they are described in the North American Industry Classification System (NAICS). The size standard for an industry establishes the largest size that a for-profit entity can be while still qualifying as a small business for Federal Government programs. These size standards are generally expressed in terms of the average annual receipts or the average employment of a firm. Gas-fired instantaneous water heater manufacturing is classified under NAICS code 335220, “Major Household Appliance Manufacturing”.

Based on the SBA threshold applicable to gas-fired instantaneous water heaters, DOE did not identify any OEMs of gas-fired instantaneous water heaters that would qualify as a small, domestic business.

3.2.4 Distribution Channels

Analysis of the distribution channels of products covered by this rulemaking is an important facet of the market assessment. DOE gathered information from publicly available sources regarding the distribution channels for consumer water heaters.

Consumer water heaters can be distributed to two ends: replacement of existing units and new construction. Distribution to these two ends often occurs through either wholesalers or retailers. Wholesalers purchase consumer water heaters from manufacturers, then resell them to plumbing contractors, plumbing supply houses, local hardware stores, and other retail channels. Within the retail distribution channel, consumer water heaters are sold directly by consumer water heater manufacturers to home improvements stores, chain hardware stores, and other large retailers. Alternatively, customers may purchase a consumer water heater and install it themselves or hire a contractor to complete the installation. Homebuilders and plumbing contractors typically purchase consumer water heaters for new constructions. For a more detailed discussion of consumer water heater distribution channels, see chapter 6 of this TSD.

DOE used several sources to estimate the fraction of consumer water heater shipment at each of the distribution channels it considered. For this analysis, DOE estimated that 48 percent of gas-fired instantaneous water heaters will be purchased for use in new construction in 2030. The remaining 52 percent of sales will be retrofit units replacing existing consumer water heaters.

For analysis purposes, DOE defined four main distribution channels for consumer water heaters: Replacement A, Replacement B, New Homes A, and New Homes B. See Figure 3.2.1.

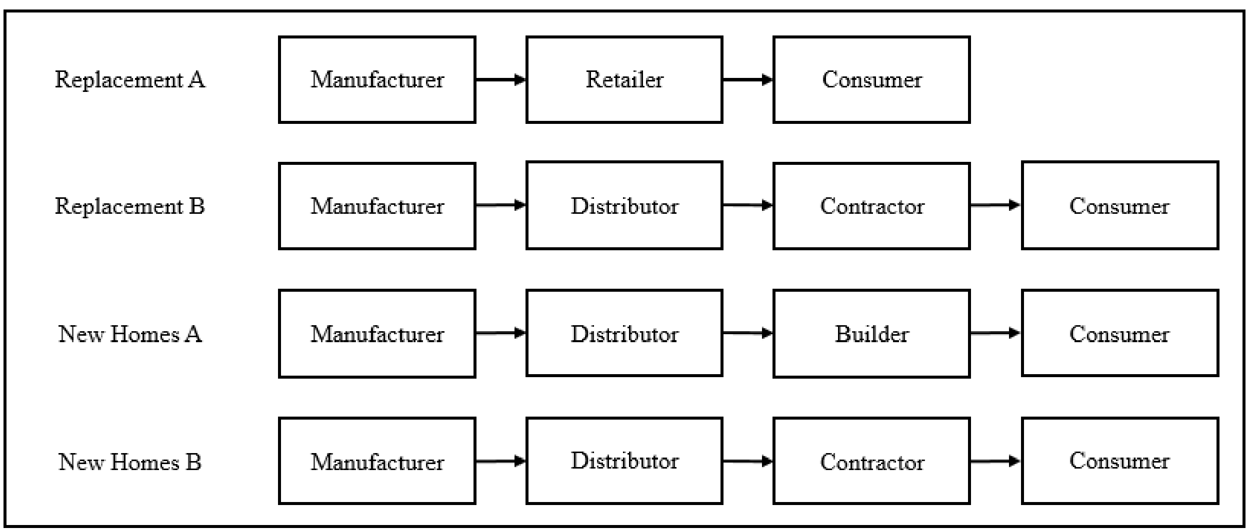

Figure 3.2.1 Water Heaters Distribution Channels

Chapter 6 of this TSD includes discussion regarding various markup factors associated with each distribution channel.

3.2.5 Regulatory Programs

The following section details current regulatory programs mandating energy conservation standards for consumer water heaters. Section 3.2.5.1 discusses current Federal energy conservation standards, and section 3.2.5.2 provides an overview of existing State standards. Sections 3.2.5.3 and 3.2.5.4 review standards in Canada and Mexico that may affect companies servicing the domestic market. Finally, sections 3.2.5.5, and 3.2.5.6 include information on standards in India, the European Union, and Brazil.

3.2.5.1 Current Federal Energy Conservation Standards

The current energy conservation standards for gas-fired instantaneous water heaters are shown in the table below. The energy conservation standards with UEF-based levels are found at 10 CFR 430.32(d)(1), and those products which do not meet the rated storage volume or input rate ranges included at 10 CFR 430.32(d)(1) are covered by the original energy conservation standards prescribed by EPCA, as amended. These products are also presented in Table 3.2.2 and have standards based on EF. V_r is the "Rated Storage Volume" (in gallons), which is currently determined pursuant to 10 CFR 429.17.

Table 3.2.2 Federal Energy Conservation Standards for Gas-fired Instantaneous Water Heaters

Product Class	Rated Storage Volume and Input Rate (if applicable)	Draw Pattern*	Energy Conservation Standard**
Gas-fired Instantaneous Water Heater	< 2 gal and > 50,000 Btu/h	Very Small	UEF = 0.80
		Low	UEF = 0.81
		Medium	UEF = 0.81
		High	UEF = 0.81
	≥ 2 gal or ≤ 50,000 Btu/h	-	EF = 0.6200 - 0.0019 x V_r

* Draw patterns vary based on hot water delivery capacity in the UEF test procedure, while the EF test procedure relies on a single draw pattern for all water heaters. As a result, UEF values and UEF energy conservation standards are different based on the draw pattern, while EF values and energy conservation standards are not.
** Energy conservation standards based on EF were established by EPCA. Energy conservation standards based on EF were established in the April 2010 Final Rule (75 FR 20112 (April 16, 2010)) and translated to equivalent UEF standards in the December 2016 Conversion Factor Final Rule (81 FR 96204 (Dec. 29, 2016)).

3.2.5.2 State Energy Conservation Standards

The following States (and Federal district) have established appliance energy efficiency and/or water conservation regulations: Arizona, California, Colorado, Connecticut, District of Columbia, Georgia, Hawaii, Maine, Massachusetts, Maryland, Nevada, New Hampshire, New Jersey, New York, Oregon, Rhode Island, Texas, Vermont, and Washington.[7] Of these, California is the only State that explicitly regulates products covered in this rulemaking.[8,]

The State of California mandates energy conservation standards for consumer water heaters. The California energy conservation standards at 20 California Code of Regulations

(CCR) 1605.1(f)(1) are identical to the Federal energy conservation standards at 10 CFR 430.32(d)(1) and cover the gas-fired instantaneous water heaters presented in

Table 3.2.2 with UEF-based standards. The California energy conservation standards at 20 CCR 1605.1(f)(2) are identical to the energy conservation standards established by EPCA, as amended, at 42 U.S.C. 6295(e)(1).

3.2.5.3 Canada

Natural Resources Canada (NRCan) develops policies and programs for the Canadian government that enhance the contribution of the natural resources sector to the economy, improve the quality of life for all Canadians, and conduct innovative science in facilities across Canada to generate ideas and transfer technologies. Among these policies are energy conservation standards for consumer water heaters, including gas-fired instantaneous water heaters, the subject of this rulemaking. The Canadian energy conservation standards were last updated on June 12, 2019 and are presented in Table 3.2.3.

Table 3.2.3 Canadian Energy Conservation Standards for Gas-fired Instantaneous Water Heaters[9]

Product Class	Rated Nominal Storage Capacity and Input Rate	Efficiency Standard Description*	
Gas-fired Instantaneous Water Heater	< 7.6 L (2 gal); < 58.56 kW (200,000 Btu/h)	Very Small Draw Pattern	UEF ≥ 0.86
		Low Draw Pattern	UEF ≥ 0.87
		Medium Draw Pattern	UEF ≥ 0.87
		High Draw Pattern	UEF ≥ 0.87

* Draw patterns are as determined when testing to CSA P.3-15.

3.2.5.4 Mexico

Mexico has specified energy conservation standards for gas water heaters, most recently updated in October 2021. The Mexican standards apply to both consumer and commercial gas water heaters and are divided into storage, fast recovery and instantaneous categories. The fast recovery and instantaneous categories are defined below and the corresponding standards are summarized in Table 3.2.4.

Instantaneous water heater is “a device for continuously heating water to a uniform temperature as the water passes through a coil.”

Fast recovery water heater is an “apparatus for heating water continuously to a uniform temperature, as the water passes through one or more heat exchangers.”

Table 3.2.4 Mexican Efficiency Standards for Water Heaters[10]

Water Heater Type	Efficiency Standard Description*
Fast Recovery	Minimum Thermal Efficiency: 82
Instantaneous	Minimum Thermal Efficiency: 85

*The Mexican and DOE test procedures for thermal efficiency are not identical.

3.2.5.5 European Union

The European Union outlines their minimum energy efficiency requirements for water heaters in EU Regulation No 814/2013. Regulation No 814 covers water heaters and hot water storage tanks. Standards are set according to a "water heating energy efficiency" which is calculated as follows:

$$\eta_{wh} = \frac{Q_{ref}}{(Q_{fuel} + CC \cdot Q_{elec})(1 - SCF \cdot smart) + Q_{cor}}$$

where:

Q_{ref} is the sum of the useful energy content of water draw-offs, expressed in kWh, in a particular load profile
Q_{fuel} is the total consumption of fuels over the 24-hr test period, expressed in kWh
Q_{elec} is the total consumption of electricity over the 24-hr test period, expressed in kWh
CC is the conversion coefficient (equal to 2.5) reflecting the estimated 40% average EU electricity generation efficiency
SCF is the estimated water heater efficiency gain due to smart control
Q_{cor} is the 'ambient correction' term which takes into account the fact that ambient test conditions are not isothermal, expressed in kWh

Notably, this efficiency calculation accounts for the energy lost in generating electricity and includes a parameter for efficiency gain due to smart control, two things which are out-of-scope in DOE's calculation. For that reason, a conversion would be required to compare between EU and DOE standards levels.

The test procedure which accompanies this standard specifies a 24-hour measurement cycle for each declared load profile, all of which follow the same general pattern of:

- Hours 0 - 7: no water drawn off
- Hours 7 - x: water drawn off according to load profile, ending time varies
- End of last draw – Hour 24: no water drawn off

In order to test the smart control features of water heaters whose manufacturers have declared them as "smart," a separate, 14-day test must be carried out. The test is designed to ensure the useful energy content of the water does not change to drastically with its smart control enabled, and is carried out as follows:

- Days 1 - 5: random sequence of load profiles chosen from the declared load profile and the load profile just below it; smart control *disabled*
- Days 6 - 7: no water drawn off; smart control *disabled*

- Days 8 - 12: repeat sequence use in days 1 - 5; smart control *enabled*
- Days 13 - 14: no water drawn off; smart control *enabled*

At the end of the 14-day test, the legislation states that the difference between the total useful energy content measured during days 1 to 7 and days 8 to 14 shall not exceed 2% of Q_{ref} for the declared load profile. For use in the equation above, *SCF*, or smart control factor, is calculated according to the equation below:

$$SCF = 1 - \frac{Q_{fuel,week,smart} + CC \cdot Q_{elec,week,smart}}{Q_{fuel,week} + CC \cdot Q_{elec,week}}$$

If the value of SCF, as calculated, is greater than or equal to 0.07, the value of *smart* in the water heating energy efficiency equation at the beginning of this section shall be 1 and the water heater will be considered smart, otherwise, the value of *smart* will be 0 and the water heater will not be considered smart.

While the European Union efficiency standards for water heaters specify that they apply to "storage" water heaters, some gas-fired instantaneous water heaters could have significant storage volume. Hence DOE reviewed these standards for reference as well.

Table 3.2.5 European Union Efficiency Standards for Water Heaters[11]

Water Heater Type	Declared Load Profile	Max Volume	Minimum Water Heating Efficiency
Storage	3XS	7 liters	32 %
	XXS	15 liters	32 %
	XS	15 liters	32 %
	S	36 liters	32 %
	M	65 liters	36 %
	L	130 liters	37 %
	XL	210 liters	37 %
	XXL	300 liters	60 %
	3XL	520 liters	64 %
	4XL	1040 liters	64 %

3.2.5.6 Brazil

Brazil outlines its energy conservation standards for gas water heaters in "Interministerial Ordinance No. 324 of May 2011," which are based on a thermal efficiency metric. The ordinance outlines minimum levels of efficiency for instantaneous water heaters.

Table 3.2.6 Brazilian Efficiency Standards for Gas-fired Instantaneous Water Heaters[12]

Water Heater Type	Minimum Thermal Efficiency
Instantaneous	76 %

3.2.6 Voluntary Programs

DOE reviewed several voluntary programs promoting energy efficient consumer water heaters in the United States, including the Consortium for Energy Efficiency (CEE) tier-based program, the Environmental Protection Agency (EPA) ENERGY STAR program, the Federal Energy Management Program's (FEMP) procurement program for energy-efficient products, and various rebate programs offered by local utilities.

The American Council for an Energy Efficiency Economy (ACEEE) maintains a database of state and local policy which includes appliance standards.[13]

3.2.6.1 Consortium for Energy Efficiency

The CEE is a nonprofit public benefits corporation that develops initiatives for its North American members to "accelerate energy efficient products and services in targeted markets".[14] The role of the organization is influence manufacturers, stakeholders, and government agencies to maximize the impact of efficiency programs with support for behavioral programs as well as evaluation.[15]

CEE organizes a summary of utility-sponsored rebate and incentive programs for efficient consumer water heaters. This summary is available online to encourage consumers to purchase efficient consumer water heaters and take advantage of utility rebates.[16] CEE also maintains its own residential water heating specification, which is organized in tiers, and is intended to complement the ENERGY STAR program. Table 3.2.7 lists the tiers corresponding to products covered by this rulemaking and their corresponding UEF criteria.

On August 16, 2022, the Inflation Reduction Act (IRA), Pub. L. 117-169, identified water heaters which meet or exceed the highest efficiency tier (not including any advanced tier) established by the CEE as products which are "qualified energy properties" for the taxpayer credits outlined in the IRA. On January 1, 2023, CEE published its 2023 Residential Water Heating specifications for gas-fired and heat pump water heaters.

Table 3.2.7 CEE Residential Water Heating Specification[17]

Product Type	CEE Tier	Tank Volume and Draw Pattern	UEF Criteria	Other Requirements
Gas-fired Residential Tankless Water Heater Specification	Tier 0	Any	≥ 0.87	ENERGY STAR Version 4.0 Compliance
	Tier 1	Any	≥ 0.92	
	Tier 2	Any	≥ 0.95	Prior to April 18, 2023: ENERGY STAR Version 4.0 or 5.0 Compliance; After April 18, 2023: ENERGY STAR Version 5.0 Compliance

3.2.6.2 ENERGY STAR

ENERGY STAR is a voluntary labeling program backed by the U.S. Environmental Protection Agency (EPA) and DOE that identifies energy efficient products through a qualification process.[e] To qualify, a product must exceed Federal energy efficiency standards by a specified amount, or if no Federal standard exists, exhibit selected energy-saving features. The ENERGY STAR program qualifies the top products on the market; approximately 15 percent of products on the market meet or exceed the ENERGY STAR levels. ENERGY STAR considers up-front costs and lifetime energy savings when setting required efficiency levels. On July 18, 2022, ENERGY STAR published Specification 5.0, which set requirements for consumer water heaters including gas-fired instantaneous water heaters and has an effective date of April 18, 2023. Table 3.2.8 summarizes the requirements of Specification 5.0 for gas-fired instantaneous water heaters.

[e] For more information, please visit www.energystar.gov (Last accessed September 26, 2024).

Table 3.2.8 ENERGY STAR Residential Gas-fired Instantaneous Water Heater Criteria and Requirements Effective on April 18, 2023

Product Type	Other Criteria	Warranty	ENERGY STAR Requirements*
Gas-fired Instantaneous Water Heaters	All	≥ 6 years on heat exchanger ≥ 5 years on parts	Max GPM ≥ 2.8 over a 67 °F rise UEF ≥ 0.95

*UEF means uniform energy factor and Max GPM means maximum gpm.

3.2.6.3 Federal Energy Management Program

FEMP works with stakeholders to enable federal agencies to meet energy related goals, identify affordable solutions, facilitate public-private partnerships, and provide energy leadership to the country by identifying government best practices.[18] FEMP helps Federal buyers identify and purchase energy-efficient equipment.

The FEMP guidance for consumer water heaters stipulates that Federal purchasers acquire ENERGY STAR-qualified products.[19]

3.2.6.4 Rebate Programs

Several utilities offer rebate programs for high-efficiency consumer water heaters including gas-fired instantaneous water heaters. However, not all programs have transitioned to the use of the UEF metric as of this final rule analysis. A small sample of these programs as of September 2024 is listed in Table 3.2.9.

Table 3.2.9 Sample Rebate Programs

State	Utility	Product	Requirement	Value
New York	Central Hudson Gas & Electric Corp[20]	Instantaneous Water Heater	UEF ≥ 0.90	$250
Mississippi	Atmos Energy[21]	Gas Instantaneous Water Heater	EF ≥ 0.92	$350
		Gas Instantaneous Water Heater	EF ≥ 0.80	$250

3.2.7 Product Lifetime

DOE reviewed available literature and consulted with manufacturers to establish typical product lifetimes. DOE used national survey data along with historical gas-fired instantaneous water heater shipment data to calculate lifetime distributions. (*See* the gas-fired instantaneous water heater lifetime determination, appendix 8F of this TSD, for additional details and sources used to determine the typical equipment lifetimes.) The average estimated lifetimes of these products were directly analyzed in this final rule; DOE estimates the average lifetime of a gas-fired instantaneous water heater to be 20 years. Chapter 8 and chapter 9 of the TSD provide more information about gas-fired instantaneous water heater lifetimes and how they are used in the analysis.

3.2.8 Market Performance Data

DOE combined information from its CCD with information from the AHRI directory and other publicly available data from manufacturers' catalogs of consumer water heaters to develop an understanding of the market. DOE ultimately compiled a database of all consumer water heater models on the market along with information such as the manufacturer or brand name, FHR or Max GPM, draw pattern, and uniform energy factor. Using the information from its database, DOE created plots to show the distribution of rated input capacity and uniform energy factor for gas-fired instantaneous water heaters.

Certification data are recent as of May 2023 and have been supplemented with further information collected in August 2024. The data depict those gas-fired instantaneous water heaters which are currently covered by UEF-based standards at 10 CFR 430.32(d). In this final rule analysis, DOE was able to conduct a more thorough analysis to determine the number of unique basic models on the market compared to the NOPR analysis. Certifications were reviewed against the basic model definition found at 10 CFR 430.2 to independently ascertain whether they met the criteria for unique basic models in the development of this analysis.

On December 29, 2016, DOE published a conversion factor final rule (December 2016 Conversion Factor Final Rule) which converted existing energy factor (EF) ratings and standards for consumer water heaters to the UEF metric which is used in the current standards. 81 FR 96204. In the December 2016 Conversion Factor Final Rule, DOE provided an enforcement policy to ensure that a model which complied with the EF standards is not harmed by the transition to UEF. 81 FR 96204, 96227. Models which were compliant with the previous EF standards continue to be subject to the enforcement policy as long as all units of the model manufactured remain identical to the units of that model that were being manufactured prior to July 13, 2015; these models will continue to remain subject to the enforcement policy until compliance with amended energy conservation standards is required. 81 FR 96204, 9622. The current Federal UEF standards are found at 10 CFR 430.32(d)(1). Any models with certified UEF ratings below the current minimum standard level are distinguished in scatterplots with an "x" symbol.

Figure 3.2.2 shows the distribution of UEFs for gas-fired instantaneous water heaters.

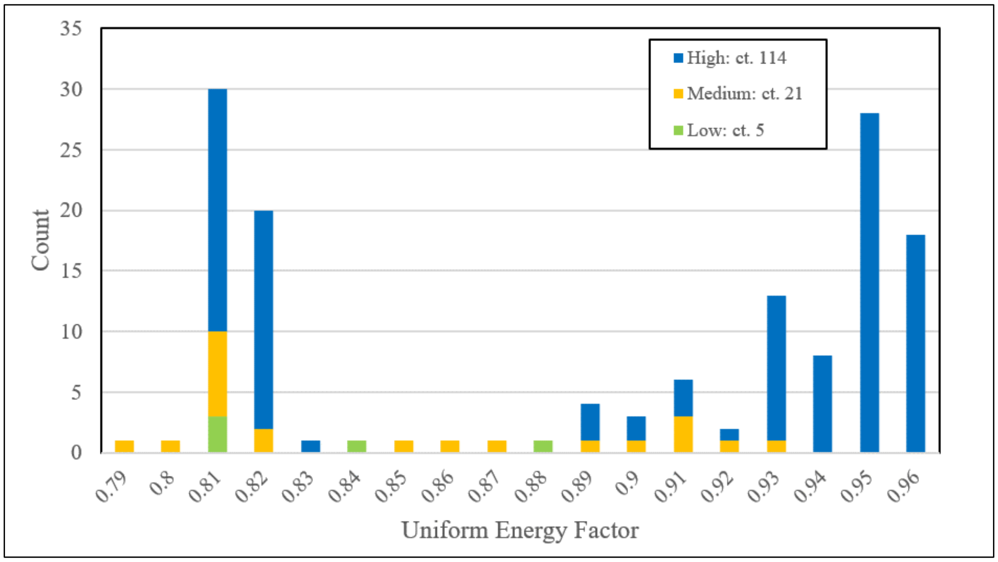

Figure 3.2.2 Distribution of Gas-Fired Instantaneous Water Heater Basic Models by UEF

Figure 3.2.3 shows the distribution of input ratings for consumer gas-fired instantaneous water heaters.

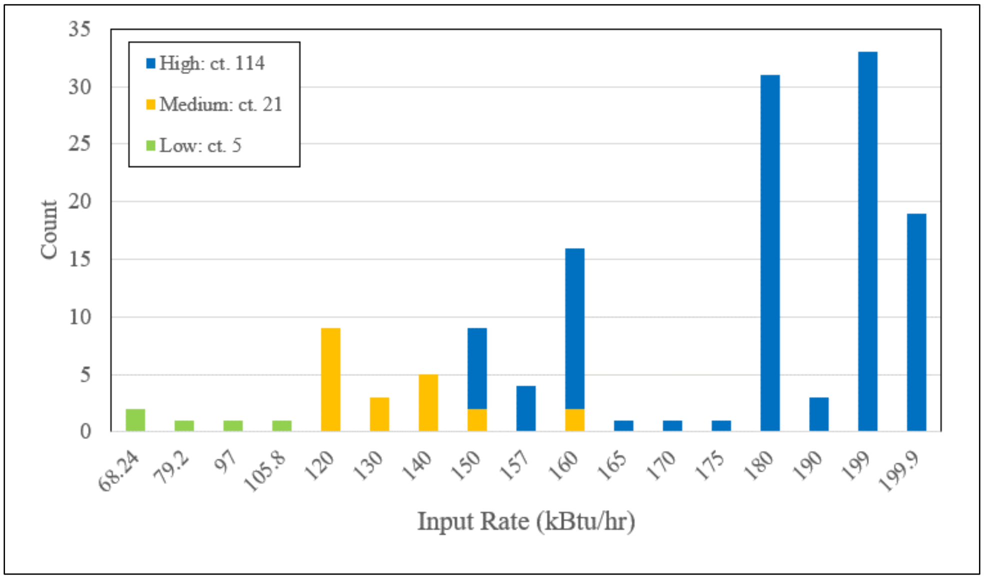

Figure 3.2.3 Distribution of Gas-Fired Instantaneous Water Heater Basic Models by Input Capacity

Figure 3.2.4 shows the distribution of gas-fired instantaneous water heaters UEFs by input rate, plotted alongside the Federal UEF standards at 10 CFR 430.32(d)(1).

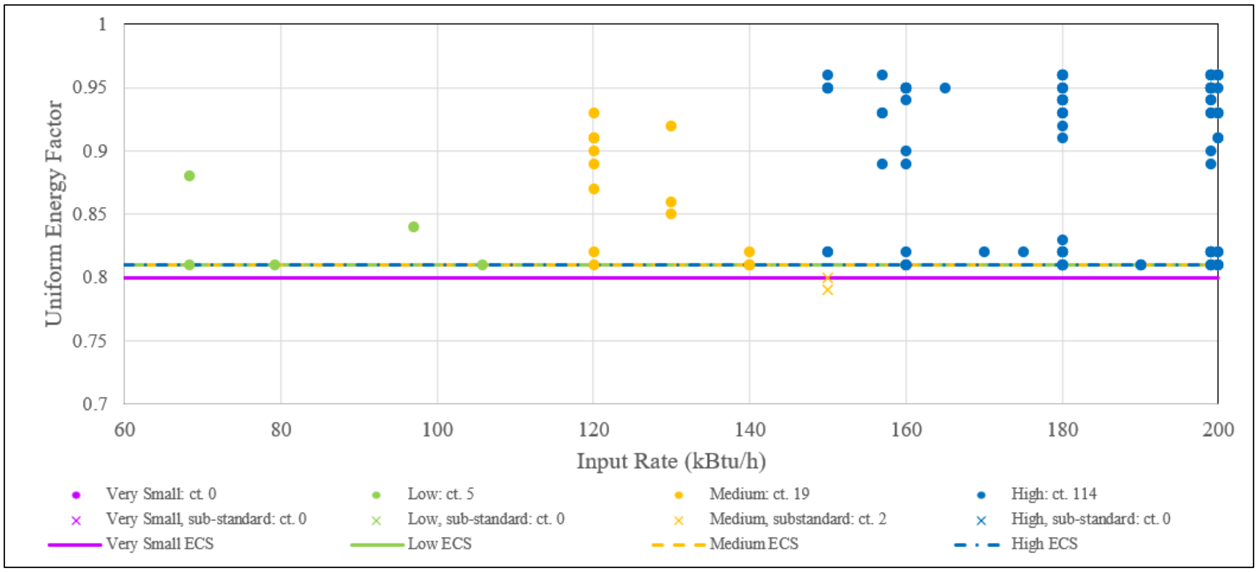

Figure 3.2.4 Distribution of Gas-Fired Instantaneous Water Heater Models by Input Capacity

3.3 TECHNOLOGY ASSESSMENT

The purpose of the technology assessment is to develop a list of technology options manufacturers can use to improve the efficiency of consumer gas-fired instantaneous water heaters. In preparation for the screening and engineering analyses, DOE identified several possible technology options and examined the most common efficiency-improving technologies used today. These technology options provide insight into the technological improvements typically used to increase the energy efficiency of consumer gas-fired instantaneous water heaters. This section provides a description of baseline gas-fired instantaneous water heater designs followed by descriptions of each technology DOE identified. While this rulemaking covers all consumer water heaters which meet the definition of gas-fired instantaneous water heater as codified at 10 CFR 430.2, the scope of the technology assessment is limited to products with current UEF-based standards, because, as noted in chapter 5, DOE did not have sufficient information at this time to address more-stringent standards for products with EF-based standards.

3.3.1 Baseline Equipment Components and Operation

The baseline model serves as a reference point for measuring changes resulting from energy conservation standards. DOE defines the baseline model as a product having an efficiency that just meets the existing Federal energy conservation standards. DOE also defines baseline models as having commonly available features.

A baseline gas-fired instantaneous water heater consists of a cold-water inlet, a hot water outlet, a combustion chamber, a copper heat exchanger, a burner, a combustion blower, a vent, an electronic ignition system, a flow detection device, a gas valve, a burner control thermostat, and an outer case. Manufacturers may differentiate gas-fired instantaneous water heaters by hot water delivery capacity, efficiency rating, input to the burners, and ability to modulate to meet the hot water demand.

Flow-activated water heaters, which constitute the vast majority of gas-fired instantaneous water heaters, have an operational scheme in which the water heater initiates and terminates heating based on sensing flow (i.e., a draw). Non-flow-activated water heaters are typically thermostatically operated instead. These products operate with a stored volume of hot water. When the temperature of the stored water goes below a setpoint, the heater activates. The location of the temperature sensor and the control algorithm determine how much thermal stratification would be present in a fully recovered tank.

Some gas-fired instantaneous water heaters can be configured for both flow- and thermal-activation—for example, products that can be installed in circulating water loops to continually provide hot water to fixtures. In these cases, thermal activation can occur using a sensor at the inlet or outlet of the water heater.

A typical setpoint for delivery is 120-125 °F, which is hot enough to meet household needs, but not hot enough to cause scalding in a very short amount of time. This delivery temperature can be achieved in flow-activated water heaters by having modulating heat input.

3.3.2 Technology Options to Improve Efficiency

DOE identified the technology options listed in Table 3.3.1 as having the potential to improve the efficiency of gas-fired instantaneous water heaters. In the engineering analysis of this final rule DOE does not analyze more-stringent standards for "tank-type" gas-fired instantaneous water heaters with 2 or more gallons of storage volume or "point-of-use" type gas-fired instantaneous water heaters with less than or equal to 50,000 Btu/h of input. Rather, DOE has conducted an analysis to translate the EF-based standards for these products to the UEF metric. As such, the technology options described in this chapter pertain specifically to "tankless" products with less than 2 gallons of stored water volume, with an input rating of more than 50,000 Btu/h, which comprise the vast majority of gas-fired instantaneous water heaters on the market today. Tank-type gas-fired instantaneous water heaters may employ additional technology options to limit standby losses, whereas point-of-use type gas-fired instantaneous water heaters may include designs that enable these products to be installed near where the hot water is being used.

Table 3.3.1 Potential Technologies for Increasing Efficiency

<table>
<tr><th colspan="3">Technology Option</th></tr>
<tr><td rowspan="3">Electronic ignition</td><td colspan="2">Intermittent pilot ignition</td></tr>
<tr><td colspan="2">Intermittent direct ignition</td></tr>
<tr><td colspan="2">Hot surface ignition</td></tr>
<tr><td rowspan="5">Improved burners</td><td colspan="2">Condensing pulse combustion</td></tr>
<tr><td colspan="2">Power burner</td></tr>
<tr><td colspan="2">Reduced burner size (burner derating)</td></tr>
<tr><td rowspan="2">Modulating burners</td><td>Fully modulating burners</td></tr>
<tr><td>Step modulating burners</td></tr>
<tr><td rowspan="3">Heat exchanger improvements</td><td colspan="2">Increased heat exchanger surface area</td></tr>
<tr><td colspan="2">Flue baffle</td></tr>
<tr><td colspan="2">Condensing technology</td></tr>
<tr><td rowspan="2">Improved venting</td><td colspan="2">Direct venting</td></tr>
<tr><td colspan="2">Concentric direct venting</td></tr>
<tr><td>Improved controls</td><td colspan="2">Modulating controls</td></tr>
</table>

3.3.2.1 Electronic Ignition Systems

Standing pilot ignitions systems burn gas continuously at a rate of about 1,000 Btu/h, and only part of this heat is converted to useful energy. Electronic ignition devices are alternative ignition systems that eliminate the need to continuously burn a pilot light. Although standing pilot ignitions systems are common on gas-fired storage water heaters, all gas-fired instantaneous water heaters on the market use electronic ignition. Electronic ignition systems are typically categorized as one of the following three types:

Intermittent Pilot Ignition. This is a device that lights a pilot by generating a spark, which in turn lights the main burner.

Intermittent Direct Ignition. This system lights the main burner directly by generating a spark.

Hot Surface Ignition. This system lights the main burner directly via a sufficiently hot surface.

Another variation of electronic ignition system is the hydroelectric ignition which uses a small turbine that is spun by flowing water to produce electricity to ignite a pilot or the main burner. The benefit of hydroelectric ignition systems relative to electronic ignition systems is that a separate power supply is not required.

Although there is no increase in the steady-state efficiency with the use of electronic ignition devices, they reduce overall fuel consumption. Burner on-time may increase, however, to make up for the heat the standing pilot would have supplied during standby periods.

3.3.2.2 Improved Burners

Condensing Pulse Combustion. Pulse combustion burners operate on self-sustaining resonating pressure waves that alternately rarefy the combustion chamber (drawing a fresh fuel/air mixture into the chamber) and pressurize it (causing ignition by compression heating of the mixture to its flash point). This process is initiated by a blower supplying an initial fuel and air mixture to the combustion chamber. A spark ignites the mixture. Once resonance is initiated, the process becomes self-sustaining.

Pulse combustion systems feature high heat transfer rates, can self-vent, and can draw outside air for combustion even when installed inside. Because the pulse combustion process is highly efficient, the burners are generally used with condensing appliances.

Power Burner. Fan-assisted combustion systems can be designed with power burner technology. Power burners, which are found in gas-fired instantaneous water heaters at baseline efficiency levels, use blowers upstream of the combustion chamber to supply a more efficient fuel-air mixture to the burner. Power burners also reduce off-cycle losses by restricting air flow and convection of warm air to the vent system, similar to a vent or combustion box damper.

Controlling the amount of primary air to the burner will also increase the energy efficiency of the water heater. Because the power burner can be designed to overcome relatively large pressure drops within the heat exchanger, further increases in efficiency can be attained by redesigning the heat exchanger system. The heat exchanger can be designed to be more compact with more restrictions so that more heat can be extracted from the combustion gases. As efficiency increases, condensation of combustion gases within the vent system becomes more likely. Condensation of combustion gases should be avoided unless the system is specifically designed to handle condensate. Efficiency levels can be further improved by the use of modulating burners.

Modulating Burners. Modulating burners can reduce energy consumption and improve overall performance by changing the operating conditions in response to hot water demand. Basic combustion systems (i.e., those without modulation or multiple stages) only operate at a single firing rate, turning on and off based on simple inputs from either the user or the water heater. When a gas-fired water heater cannot modulate the firing rate to match the hot water demand, it could fire at a rate that is greater than the demand, resulting in hot water that is above the desired delivery temperature. Instantaneous-type water heaters designed to produce hot water on-demand need to then temper down the heated water to the desired temperature using a mixing valve, which can be done automatically with components integrated into the unit.

Alternatively, modulation, which allows the burner to operate at one or more additional firing rates below the full firing rate, can reduce output to better match demand when only small temperature differentials or low flow rates need to be satisfied. By modulating the burner firing rate, the demand can be met more precisely. Modulating burners can be achieved by integrating a venturi into the burner. Modulating controls are a baseline feature in gas-fired instantaneous water heaters.

There are two types of burner modulation in gas-fired instantaneous water heaters on the market. First are step-modulating burners, which employ solenoids to open and close sections of the gas manifold and heat exchanger so that the burner can operate in multiple stages. Only the sections that remain open will fire. This results in only the corresponding section of the heat exchanger being heated at once, restricting the amount of heat input when the water flow rate is low. Step-modulation is, therefore, a control scheme that dictates both the combustion chamber and heat exchanger design. These designs are a baseline feature for gas-fired instantaneous water heaters.

Second are fully-modulating burners which have controls to modulate the gas valve and blower speed proportionally to a precise degree, maintaining an optimal air-to-fuel ratio, allowing the system to provide an input rate that matches the water flow rate exactly. Fully-modulating burners are commonly found in the most efficient gas-fired instantaneous water heaters. One advantage of this design is that it allows the entire heat exchanger to be active in heat transfer no matter what the flow rate is—and this improves the recovery efficiency compared to step-modulating systems. Because these systems engage the entire heat exchanger for lower input rates, the amount of condensation that occurs in the heat exchanger can increase significantly such that these systems are typically implemented with condensing heat exchangers.

Modulating Controls. Modulating controls are used in modulating burner systems. Modulating controls can operate the burner at a range of firing rates, and can reduce the firing rate to meet the demand so that excess energy is not wasted when only small temperature differentials or low flow rates need to be satisfied. By modulating the controls, the demand can be met more precisely. For example, a control will not open fully to correct a small differential; rather, the control will modulate to a lower, or stepped, position to match the load. Finally, duty cycling can be reduced, which can reduce the total amount of energy consumed.

Reduced Burner Size. Reducing burner size for gas-fired instantaneous water heaters while keeping heat exchanger geometry the same will increase the ratio of heat transfer surface area to energy input, thereby increasing the recovery efficiency. This design strategy can also be referred to as "burner derating."

3.3.2.3 Heat Exchanger Improvements

Heat transfer from the flue gases to the water can be enhanced by improving heat exchanger. The improved heat transfer leads to an increase in the recovery efficiency (the ratio of energy delivered to the water to the energy content of the fuel consumed by the water heater) of the water heater. If the recovery efficiency is increased to about 84 percent, condensation of the flue gases begins to occur in the flue or vent pipe. Condensation may cause the surfaces of the flue and vent pipe to corrode. To avoid such problems, materials that resist corrosion and methods to properly collect and dispose of condensate are incorporated into water heater designs.

***Increased Heat Exchanger Surface Area*.** The baseline design consists of a non-condensing tube-and-fin heat exchanger. This design can be improved by increasing the surface area of the heat exchanger, which increases heat transfer and recovery efficiency. This can be accomplished either by increasing the number of fins or using longer tubes. In other types of heat exchangers, such as flat plate and nested tube designs implemented for condensing heat exchangers, increasing the number of plates or tubes can further increase efficiency.

Flue Baffle. A flue baffle can be a twisted strip of metal inserted into the heat exchanger that increases the turbulence of flue gases and improves heat transfer. The geometry of the flue baffle can also be modified to increase its effectiveness by increasing the number of flow-altering features in the baffle. Improving the flue baffle so that air flow becomes more restricted and more turbulent can increase heat transfer, which increases recovery efficiency.

Condensing. Energy efficiency can be increased by extracting more heat from the flue gases. More energy can be extracted by condensing the combustion products in the flue gas, which extracts more heat in the form of latent energy, leading to an increase in the recovery efficiency of the water heater. Water heater technology options or a combination of technology options can be added to a water heater design to condense the combustion gases. The baseline gas-fired water heater design, which is non-condensing and typically contains a single, primary heat exchanger, can be made to condense through the addition of a secondary corrosion-resistant heat exchanger to further extract heat from the flue gases. In some designs, however, these stages are integrated into a single corrosion-resistant heat exchanger.

The flue-gas condensate is often acidic and corrosive. Therefore, special corrosion-resistant heat exchangers— typically made of stainless steel— and vent materials are required for safe and reliable operation of the water heater. Corrosion due to condensation of combustion gases limits the recovery efficiency of a gas-fired instantaneous water heater with a standard flue and vent system. Using corrosion-resistant heat exchangers or sidewall venting and lining the vent/masonry systems with corrosion-resistant material can extend the recovery efficiency.

Condensing appliances have flue gas temperatures less than the dew point (generally around 130 ºF to 140 ºF for gas-fired water heaters[22]) of the flue products. The recovery efficiency of condensing water heaters can be as high as 99 percent.

3.3.2.4 Improved Venting

In 2021, the National Fire Protection Association (NFPA) and American National Standards Institute (ANSI) published the NFPA 54/ANSI Z223.1, “National Fuel Gas Code.” (NFPA 54-2021).[23] Chapter 3 of NFPA 54-2021 divides the “vented appliance” definition into the four categories that are presented below.

> *Category I Vented Appliance.* An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.
>
> *Category II Vented Appliance.* An appliance that operates with a nonpositive vent static pressure and with a vent gas temperature that can cause excessive condensate production in the vent.
>
> *Category III Vented Appliance.* An appliance that operates with a positive vent static pressure and with a vent gas temperature that avoids excessive condensate production in the vent.
>
> *Category IV Vented Appliance.* An appliance that operates with a positive vent static pressure and with a vent gas temperature that can cause excessive condensate production in the vent.

Chapter 12 of NFPA 54-2021 describes the venting requirements to remove flue gases from the vented appliance (in this case a consumer water heater) outside of the residence for each venting category (i.e., I, II, III, or IV).

For gas-fired instantaneous water heaters, lower efficiency products typically use category III venting as condensate production is avoided. Higher efficiency products, including condensing gas-fired instantaneous water heaters, typically use category IV venting. DOE was unable to find gas-fired instantaneous water heaters on the market that use category I or II venting.

Direct Vent. A water heater using direct venting takes in air from the outside for combustion as opposed to using ambient air from the room the water heater is located. This prevents air that has been conditioned (either from the air conditioner or furnace) from being used in the combustion process and vented out of the house. Direct venting can also be used if the location the water heater is installed does not have adequate air flow for combustion. Direct venting may affect the level of condensation in the heat exchanger when installed in field conditions.

Concentric Venting. Concentric venting is a form of direct venting which heats up incoming air using the heated combustion air leaving the water heater. This is done using concentric inner and outer pipes in which inlet air is pulled through either the inner or outer ring and the combustion air is forced through the other ring. Heating the incoming air increases the efficiency of combustion which in turn increases the recovery efficiency.

3.3.3 Other Technologies

DOE reviewed the technologies presented in the previous assessment and considered their impacts on DOE's test procedure results as well as their impacts on energy use. Since UEF is the relevant performance metric in this rulemaking, DOE did not consider the technologies discussed in section 3.3.2 that have no effect on UEF in the downstream steps of the analyses including in the screening analysis and engineering analysis, because these technologies would not likely be implemented in response to potential amended UEF standards. However, DOE does not discourage manufacturers from using these technologies because they have the potential to reduce energy consumption in the field. In this section, DOE explains why these technologies do not affect UEF.

The following technologies either do not affect or do not increase the UEF of consumer water heaters: burner configuration (up-fired or down-fired burners) and time-based controls.

Burner configuration (Up-fired or Down-fired Burner). Gas-fired instantaneous water heaters on the market today are designed with one of two burner configurations: up-fired or down-fired (also known as bottom-fired and top-fired, respectively). The up-fired configuration, in which the burner is located at the bottom of the water heater, is used in traditional designs that vent the flue gases through buoyancy. However, modern designs, which use power burners, push the flue gases up through the heat exchanger(s) with a blower. In contrast, in the down-fired configuration the burner is located at the top of the water heater and the forced draft blower pushes the flue gases down through the heat exchanger(s). Down-fired burners can offer a benefit for condensing gas-fired instantaneous water heaters because, in this configuration, condensate can be removed more easily. In a down-fired configuration, the secondary (condensing) heat exchanger is at the bottom, so it is possible to allow the condensate to collect using gravity without causing corrosive damage to the primary (non-condensing) heat exchanger.

Down-fired configurations are found in models with higher efficiency ratings because these configurations tend to be implemented along with other energy-saving features (such as condensing heat exchangers and fully modulating burners). For example, the benefit that down-firing can provide with condensate collection can only be demonstrated in models that use condensing heat exchangers, and fully modulating burners are most commonly used in condensing models as well. DOE has not found evidence to suggest that the orientation of the burner alone can lead to an improvement in UEF.

Time-based Controls. Some otherwise flow-activated gas-fired instantaneous water heaters with recirculation capabilities may use time-based control systems to activate the recirculation function over a specified period.[24,25] This period of time may be selected in advance, during which the recirculation pump is activated automatically. Some units with time-based control systems also feature "learning" modes, which anticipate the need for hot water based on the consumer's typical daily usage and adjust the recirculation activation schedule accordingly.[26]

While some literature claims that these products are more efficient, DOE is not aware of any evidence confirming that time-based controls definitively improve efficiency in gas-fired instantaneous water heaters during field usage. In addition, the DOE test procedure for gas-fired instantaneous water heaters does not capture the effects of time-based controls because the DOE test procedure has a set draw pattern and usage for the water heater and specifies an inlet and outlet temperature for the water. As a result, products cannot demonstrate higher UEF efficiencies using time-based controls to anticipate loads. Consequently, DOE does not consider this as a technology for improving the UEF of gas-fired instantaneous water heaters.

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CHAPTER 4. SCREENING ANALYSIS

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CHAPTER 4. SCREENING ANALYSIS

4.1 INTRODUCTION

This chapter details the screening analysis that the U.S. Department of Energy (DOE) conducted for the technology options identified in the market and technology assessment (chapter 3 of this technical support document (TSD)) for consumer water heaters. In the market and technology assessment, DOE presented an initial list of technologies that can be used to increase the efficiency of the considered products. The goal of the screening analysis is to identify any technology options that will be eliminated from further consideration in the rulemaking analyses.

DOE must follow specific statutory criteria for prescribing new or amended standards for covered products. The Energy Policy and Conservation Act (EPCA) establishes criteria for prescribing new or amended standards designed to achieve the maximum improvement in energy efficiency. Further, EPCA directs the Secretary of Energy to determine whether a standard is technologically feasible and economically justified. (42 U.S.C. 6295(o)(2)(A)) EPCA also establishes guidelines for determining whether a standard is economically justified. (42 U.S.C. 6295(o)(2)(B)(i)) In view of these requirements,10 CFR part 430, subpart C, appendix A, "Procedures, Interpretations, and Policies for Consideration of New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Certain Commercial/Industrial Equipment" sets forth procedures to guide DOE in its consideration and promulgation of new or revised energy conservation standards. These procedures elaborate on the statutory criteria provided in EPCA and, in part, establish criteria to eliminate problematic technologies early in the process of prescribing or amending an energy conservation standard. In particular, 10 CFR 430, subpart C, appendix A, section 6(a)(3)(iii)(A)–(E) guide DOE in determining whether to eliminate from consideration any technologies that present unacceptable problems with respect to the following criteria:

1) *Technological feasibility.* Technologies that are not incorporated in commercial products or in working prototypes will not be considered further.

2) *Practicability to manufacture, install, and service.* If it is determined that mass production and reliable installation and servicing of a technology in commercial products could not be achieved on the scale necessary to serve the relevant market at the time of the projected compliance date of the standard, then that technology will not be considered further.

3) *Impacts on product utility or product availability.* If it is determined that a technology would have a significant adverse impact on the utility of the product for significant subgroups of consumers or would result in the unavailability of any covered product type with performance characteristics (including reliability), features, sizes, capacities, and volumes that are substantially the same as products generally available in the United States at the time, it will not be considered further.

4) *Adverse impacts on health or safety.* If it is determined that a technology would have significant adverse impacts on health or safety, it will not be considered further.

5) *Unique-Pathway Proprietary Technologies.* If a design option utilizes proprietary technology that represents a unique pathway to achieving a given efficiency level, that technology will not be considered further.

10 CFR part 430, subpart C, appendix A, 6(a)(3) and 7(b).

The candidate technology options are assessed based on DOE's analysis as well as inputs from interested parties, including manufacturers, trade organizations, and energy efficiency advocates. Technology options that are judged to be viable approaches for improving efficiency are retained as potential inputs to the subsequent engineering analysis. Technology options that are not incorporated in consumer water heaters or in working prototypes, or that fail to meet certain criteria, as to practicability to manufacture, install and service, as to impacts on equipment utility or availability, or as to health or safety were eliminated from consideration according to these criteria. The rationale for either screening out or retaining each technology option is detailed in the following sections of this chapter.

4.2 SCREENED-OUT TECHNOLOGY OPTIONS

The following subsections describe the technologies that DOE eliminated for failure to meet one of the following five factors: (1) technological feasibility; (2) practicability to manufacture, install, and service; (3) impacts on equipment utility or equipment availability; (4) adverse impacts on health or safety; and (5) unique-pathway proprietary technologies.

DOE eliminated the following technology options from further consideration: condensing pulse combustion and reduced burner size (burner derating).

Table 4.2.1 Screened Out Technology Options

Technology Option	EPCA Criterion (X = basis for screening out)				
	Technological Feasibility	Practicability to Manufacture, Install, and Service	Adverse Impacts on Utility or Availability	Adverse Impacts on Health and Safety	Unique-Pathway Proprietary Technologies
Condensing pulse combustion	X	X			
Reduced burner size (burner derating)			X		

4.2.1 Condensing Pulse Combustion

Pulse combustion burners operate on self-sustaining resonating pressure waves that alternately rarefy the combustion chamber. Pulse combustion systems are capable of self-venting and can draw outside air for combustion even when installed inside. Although condensing pulse combustion technology shows promising results in increasing efficiency, it has not yet penetrated the instantaneous water heater market, and DOE notes that similar efficiencies are achievable with other technologies that have already been introduced on the market.

Therefore, DOE has determined it is not technologically feasible and not practicable to manufacture, install, and service condensing pulse combustion technology on the scale necessary to serve the relevant market at the time of the effective date of this standard.

4.2.2 Reduced Burner Size

Decreasing the burner size to increase the ratio of heat transfer area to energy input can increase the recovery efficiency of fossil fuel-fired water heaters leading to higher UEF.

However, the decreased input decreases the recovery rate, which in turn, would most likely reduce the maximum GPM rating, and thus, the water heater's ability to deliver hot water. Therefore, DOE concludes that such derating could adversely impact consumer utility because it reduces the amount of hot water that a water heater can provide. As a result, DOE has determined to not consider this technology option because it adversely impacts consumer utility.

4.3 REMAINING TECHNOLOGIES

After eliminating those technologies that have no effect on or do not increase energy efficiency and screening out those technologies that do not meet the five screening criteria described in section 4.1, DOE considered the design options in Table 4.3.1 in the engineering analysis (see chapter 5 of this TSD).

Table 4.3.1 Remaining Technology Options

<table>
<tr><th colspan="3">Technology Option</th></tr>
<tr><td rowspan="3">Electronic ignition</td><td colspan="2">Intermittent pilot ignition</td></tr>
<tr><td colspan="2">Intermittent direct ignition</td></tr>
<tr><td colspan="2">Hot surface ignition</td></tr>
<tr><td rowspan="3">Improved burners</td><td colspan="2">Power burner</td></tr>
<tr><td rowspan="2">Modulating burners</td><td>Fully modulating burners</td></tr>
<tr><td>Step modulating burners</td></tr>
<tr><td rowspan="3">Heat exchanger improvements</td><td colspan="2">Increased heat exchanger surface area</td></tr>
<tr><td colspan="2">Flue baffle</td></tr>
<tr><td colspan="2">Condensing technology</td></tr>
<tr><td rowspan="2">Improved venting</td><td colspan="2">Direct venting</td></tr>
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<tr><td>Improved controls</td><td colspan="2">Modulating controls</td></tr>
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CHAPTER 5. ENGINEERING ANALYSIS

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CHAPTER 5. ENGINEERING ANALYSIS

5.1 INTRODUCTION

The U.S. Department of Energy (DOE) performed an engineering analysis to establish the relationship between the manufacturer production cost (MPC) and the energy efficiency of gas-fired instantaneous water heaters. The relationship between the MPC and energy efficiency, or cost-efficiency relationship, serves as the basis for cost-benefit calculations for individual consumers, manufacturers, and the Nation. This section provides an overview of the engineering analysis (section 5.4), discusses the product classes (sections 5.2 and 5.3), explains the methodology used for data gathering (section 5.4), establishes baseline unit specifications (section 5.5.1), discusses incremental efficiency levels (section 5.5.2), and presents the analysis and results (section 5.12).

The primary inputs of the engineering analysis are information from the market and technology assessment (chapter 3) and the technologies from the screening analysis (chapter 4). Additional inputs include cost and efficiency data derived from the physical teardown analysis and engineering interviews with manufacturers. The primary output of the engineering analysis is a set of cost-efficiency curves.

DOE typically uses one of two approaches to develop efficiency levels for the engineering analysis: (1) relying on observed efficiency levels in the market (i.e., the efficiency-level approach), or (2) determining the incremental efficiency improvements associated with incorporating specific design options to a baseline model (i.e., the design-option approach). Using the efficiency-level approach, the efficiency levels established for the analysis are determined based on the market distribution of existing products (in other words, based on the range of efficiencies and efficiency level "clusters" that already exist on the market). Using the design option approach, the efficiency levels established for the analysis are determined through detailed engineering calculations and/or computer simulations of the efficiency improvements from implementing specific design options that have been identified in the technology assessment. DOE may also rely on a combination of these two approaches. For example, the efficiency-level approach (based on actual products on the market) may be extended using the design option approach to interpolate to define "gap fill" levels (to bridge large gaps between other identified efficiency levels) and/or to extrapolate to the maximum technologically feasible (max-tech) level (particularly in cases where the max-tech level exceeds the maximum efficiency level currently available on the market).

For this final rule analysis, just as in previous stages, DOE used a combination of these engineering approaches. This involved physically disassembling commercially available products, reviewing publicly available cost information, and modeling production costs. From this information, DOE estimated the MPCs for a range of products currently available on the market. DOE then considered the incremental steps manufacturers may take to reach higher efficiency levels. DOE started with the baseline MPC and added the expected design options at each higher efficiency level to estimate incremental MPCs. The engineering analysis did not factor in the additional higher-cost features with no impact on efficiency that are included in some models. However, at efficiency levels where the product designs significantly deviated from the baseline product, DOE used the efficiency-level approach to determine an MPC estimate, while removing the costs associated with non-efficiency-related components or features. This approach provided useful information, including identification of potential technology paths manufacturers might use to increase energy efficiency. DOE generated detailed bills of materials (BOMs) by disassembling multiple manufacturers' products that span a range of efficiency levels for each of the product classes examined. The BOMs describe the product in detail, including all manufacturing steps required to make and/or assemble each part. Subsequently, DOE converted the BOMs and efficiency levels into MPCs. By applying derived manufacturer markups to the MPCs, DOE calculated the manufacturer selling prices (MSPs) and constructed industry cost-efficiency curves.

In a subsequent life-cycle cost analysis (chapter 8), DOE used the industry cost-efficiency curves to determine consumer prices for each of the covered gas-fired instantaneous water heaters by applying the appropriate distribution channel markups.

5.2 PRODUCT CLASSES

Chapter 3 of this technical support document (TSD) provides a detailed description of the product classes DOE considered in this rulemaking. Currently, UEF-based standards have been established for gas-fired instantaneous water heaters with rated storage volumes less than 2 gallons and input rates greater than 50,000 Btu/h. These standards consist of a product class for each draw pattern (i.e., very small, low, medium, and high). Draw patterns are assigned based on the maximum gallons per minute (GPM) or the first-hour rating of a given gas-fired instantaneous water heater, and include very small, low, medium, and high patterns (corresponding to the representative consumer usage patterns that are simulated in the appendix E test procedure). They serve to distinguish gas-fired instantaneous water heater product classes on the basis of delivery capacity.

Presently, there are additional gas-fired water heaters on the market with configurations analogous to those in the current product classes, but with rated storage volumes and input rates that are not currently subject to UEF-based energy conservation standards. Such products meet the EPCA definition of instantaneous-type water heater (discussed in chapter 3 of this TSD). EPCA does not place storage volume limitations on the coverage of consumer water heaters (see 42 U.S.C. 6291(27)), but the current UEF-based standards for gas-fired instantaneous water heaters at 10 CFR 430.32(d)(1) cover only models with rated storage volumes less than 2 gallons and input rates greater than 50,000 Btu/h. As discussed in chapter 3 of this TSD, the remaining models (rated storage volumes greater than or equal to 2 gallons or input rates less than or equal to 50,000 Btu/h) thus form two additional groups of product classes of gas-fired instantaneous water heaters which are addressed in this final rule analysis.

On June 21, 2023, DOE published a test procedure final rule for consumer water heaters and residential-duty commercial water heaters (June 2023 TP Final Rule), which established the effective storage volume (V_{eff}) metric. 88 FR 40406. In a final rule published on May 7, 2024 (the "May 2024 Final Rule"), DOE amended the definition for circulating water heaters to clarify that, paired with a separate storage tank, a circulating water heater constitutes a storage-type water heater. 89 FR 49058, 49086. As such, DOE is not addressing standards for circulating water heaters in this final rule.

5.3 PRODUCT CLASSES ANALYZED

DOE reviewed each gas-fired instantaneous water heater product class for the engineering analysis. Because the storage volume and input capacity affect the energy efficiency of the product classes differently, DOE examined each product class separately, using a two-pronged approach for the engineering analysis, as described in the subsections that follow.

5.3.1 Product Classes with Established UEF Standards

For gas-fired instantaneous water heaters with established UEF standards (and where the standards are reflective of determinations made in accordance with the amended appendix E test procedure), DOE conducted the engineering analysis for baseline and higher efficiency levels as discussed in sections 5.5 through 5.12, analyzing models that represent a cross section of each product class. These representative products allowed DOE to analyze specific characteristics common to the products in a range of input capacities. DOE then expanded the analysis to include all covered products in each of the product classes currently subject to UEF standards. DOE's analytical approach for these consumer water heaters is described as follows.

Table 5.3.1 Federal Energy Conservation Standards for Gas-fired Instantaneous Water Heaters

Product Class	Rated Storage Volume and Input Rating	Draw Pattern	Uniform Energy Factor
Instantaneous Gas-fired Water Heater	<2 gal and >50,000 Btu/h	Very Small	0.80
		Low	0.81
		Medium	0.81
		High	0.81

5.3.1.1 Representative Input Rates

As stated previously, DOE established provisions to calculate V_{eff} for all consumer water heaters in the June 2023 TP Final Rule. 88 FR 40406. The aim of this provision is to account for the performance of water heaters that increase the storage tank temperature beyond the delivered water temperature. Gas-fired instantaneous water heaters with very little storage volume (*i.e.*, "tankless" models with $V_r < 2$ gallons) do not increase the storage tank temperature beyond the delivered water temperature. Thus, for this analysis, V_{eff} is considered to be equivalent to V_r. The energy conservation standards established in the final rule are written in terms of V_{eff}; however, any representative size based on V_r would equal V_{eff} based on an analysis of products on the market.

To determine representative sizes for the analysis of gas-fired instantaneous water heaters, DOE relied on input ratings instead of rated storage volumes. The products analyzed all have minimal storage volumes (less than 2 gallons), and a review of rated storage volumes certified to DOE show that all products with established UEF-based standards are rated as having either 0 or 1 gallon of storage volume. Therefore, there is hardly any variation in size from a storage volume perspective. Instead of having larger storage volumes to meet increased demand for hot water, gas-fired instantaneous water heaters have larger burners with higher input rates. DOE used its market assessment to determine representative input rates for each product class with established UEF-based standards. Table 5.3.2 presents the representative input rates for gas-fired instantaneous water heaters with established UEF based standards.

For draw patterns presented in Table 5.3.2 with "N/A," DOE was unable to find multiple models on the market. DOE developed efficiency levels for these draw patterns as discussed in section 5.5.4 of this chapter.

Table 5.3.2 Representative Consumer Water Heaters for Product Classes with Current UEF-Based Standards

Product Class	Distinguishing Characteristics (Effective Storage Volume and Input Rating)	Draw Pattern	Representative Input Rate
Gas-fired Instantaneous Water Heater	< 2 gal and > 50,000 Btu/h	Very Small	N/A
		Low	N/A
		Medium	120,000 Btu/h
		High	199,000 Btu/h

5.3.2 Product Classes with only Statutory EF Standards

For gas-fired instantaneous water heaters currently without UEF-based standards, in the December 2016 Conversion Factor Final Rule, DOE affirmed its interpretation that the standards initially established in EPCA are applicable to consumer water heaters, including gas-fired instantaneous water heaters. DOE also stated that these standards would not be enforced until conversion factors and converted standards are adopted. Conversion factors and converted standards were not adopted in the December 2016 Conversion Factor Final Rule and DOE has determined to develop converted standards through the course of this rulemaking. DOE discusses the conversion methodology and subsequent UEF-based standards in section 5.13.

5.4 METHODOLOGY OVERVIEW

For the product classes with UEF-based energy conservation standards established at 10 CFR 430.32(d)(1), the engineering analysis process is described in the following paragraphs. The results of the engineering analysis are cost-efficiency curves for each representative product. The methodology for product classes without UEF-based energy conservation standards established at 10 CFR 430.32(d)(1), for which DOE is translating the existing energy conservation standards to the UEF metric and is not considering more stringent standards, is discussed in section 5.13.

DOE started by identifying gas-fired instantaneous water heaters available on the market and the energy efficiency level associated with each (see chapter 3 of this TSD). DOE also identified the technologies and features typically incorporated into products at the baseline level and various energy efficiency levels above the baseline (see chapter 3 of this TSD). Next, DOE selected products at the representative input capacities for the physical teardown analysis—representative of the overall market— and gathered the information from the physical teardown analysis to create bills of materials (BOMs) for each product using reverse engineering methods (see section 5.6). DOE then used the physical teardown analysis to identify the design pathways manufacturers use to increase the UEF of gas-fired instantaneous water heaters (see section 5.7). DOE converted the information recorded in the BOMs to dollar values to calculate the MPC for products spanning the full range of efficiencies from the baseline to the maximum technology available (see section 5.8). DOE also identified the technology or combination of technologies mainly responsible for improving the energy efficiency of each product class. Comparing the increase in MPC to the increase in energy efficiency determined the cost-effectiveness of each technology (see section 5.10).

DOE interviewed manufacturers to gain insight into the gas-fired instantaneous water heating industry and requested comments on the engineering approach DOE used for the analysis (section 5.9). DOE used the information gathered from these interviews to refine BOMs, efficiency levels, and potential technology pathways. Next, DOE converted the MPCs into MSPs (section 5.11.1) using publicly available industry financial data, along with manufacturer feedback.

5.5 EFFICIENCY LEVELS (PRODUCT CLASSES WITH CURRENT UEF STANDARDS)

5.5.1 Baseline Efficiency Levels

DOE selected baseline units as reference points for each product class with established UEF-based standards, against which changes resulting from potential amended energy conservation standards could be measured. The baseline unit in each product class represents the characteristics of common or typical products in that class. Typically, baseline units just meet and do not exceed current Federal energy conservation standards and provide basic consumer utility.

DOE uses baseline units for comparison in several phases of the analyses, including the engineering analysis, life-cycle cost (LCC) analysis, payback period (PBP) analysis, and national impact analysis (NIA). To determine energy savings that will result from an amended energy conservation standard, DOE compares energy use at each of the higher energy efficiency levels to the energy consumption of the baseline unit for each product class. Similarly, to determine the changes in price to the consumer that result from amended energy conservation standards, DOE compares the price of a baseline unit to the price of a unit at each higher efficiency level. The identification of baseline units requires establishing the baseline efficiency level. For products with existing energy conservation standards based on UEF, the baseline efficiency level analyzed corresponded to the current minimum energy conservation standards as codified in 10 CFR Part 430.32(d)(1). Table 5.5.1 presents the baseline efficiency levels for each product class of gas-fired instantaneous water heaters that was directly analyzed in the engineering analysis.

Table 5.5.1 Baseline Efficiency Levels of Gas-fired Instantaneous Water Heaters with Established UEF Based Standards

Product Class	Distinguishing Characteristics (Effective Storage Volume and Input Rating)	Draw Pattern	UEF
Gas-fired Instantaneous Water Heater	< 2 gal and > 50,000 Btu/h	Medium	0.81
		High	0.81

5.5.2 Intermediate Energy Efficiency Levels

DOE conducted a survey of the gas-fired instantaneous water heater market to determine the designs and efficiencies of products that are currently available to consumers. For each representative product, DOE surveyed various manufacturers' product offerings to identify the efficiency levels that correspond to the highest number of models. By identifying the most prevalent energy efficiencies in the range of available products and examining the designs used at those efficiencies, DOE was able to establish a technology path that manufacturers would typically use to increase the energy efficiency of gas-fired instantaneous water heaters.

DOE established intermediate energy efficiency levels for each directly analyzed product class with current UEF energy conservation standards. The intermediate efficiency levels are representative of the most commonly available efficiency levels, and generally follow technology paths that manufacturers of gas-fired instantaneous water heaters commonly use to maintain cost-effective designs while increasing energy efficiency. DOE reviewed the DOE Certification Compliance Database (CCD); the Air-Conditioning, Heating, and Refrigeration Institute (AHRI) directory; manufacturer catalogs; and other publicly available literature to determine which efficiency levels are the most prevalent for each representative product class. Additionally, DOE associated each efficiency level with a particular technology or combination of technologies to make the engineering analysis more transparent. For gas-fired instantaneous water heaters with current UEF conservation standards, DOE analyzed the three efficiency levels presented in Table 5.5.2 between the baseline and max-tech. For medium and high draw patterns, manufacturers typically first increase energy efficiency above the baseline by using a condensing design which connects a condensing heat exchanger to the non-condensing heat exchanger. Manufacturers reach higher efficiency levels for these draw patterns by increasing the surface area of the condensing heat exchanger. In the July 2023 NOPR analysis, DOE analyzed an efficiency level (EL 3) to align with the current ENERGY STAR criteria for gas-fired instantaneous water heaters. In this final rule analysis, DOE maintains the ENERGY STAR level in its efficiency level analysis.

Based on the results of the market assessment, DOE has determined that there are very few models in the low draw pattern, with only one manufacturer making these products. There are no very small draw pattern gas-fired instantaneous water heaters greater than 50,000 Btu/h in input rating. DOE's teardown analyses have shown that the design option pathways and MPC versus efficiency curves are generally similar between different draw pattern classes of gas-fired instantaneous water heaters, such that the results from a direct analysis of the medium and high draw patterns would be representative for the very small and low draw patterns as well. Thus, the very small and low draw patterns were not directly analyzed product classes in this final rule.

DOE maintained the same efficiency levels in the final rule analysis as were assessed in the July 2023 NOPR. For information on the technologies associated with each efficiency level, see section 5.7.

Table 5.5.2 Intermediate Efficiency Levels for Gas-fired Instantaneous Water Heaters with Current UEF Standards (Effective Storage Volume Less Than 2 Gallons and an Input Rate Greater Than 50,000 Btu/h)

Efficiency Level	UEF*	
	Medium (120,000 Btu/h)	High (199,000 Btu/h)
1	0.87	0.89
2	0.91	0.93
3**	0.92	0.95

*There are no gas-fired instantaneous water heaters on the market within the very small draw pattern.
** The efficiency level corresponds to the current ENERGY STAR version 5.0 criteria for gas-fired instantaneous water heaters in the high draw pattern. DOE extrapolated a corresponding equivalent UEF value for gas-fired instantaneous water heaters in the medium draw pattern.

5.5.3 Max-Tech Efficiency Levels

As part of the engineering analysis and as required by EPCA, DOE determined the maximum technologically feasible improvement in energy efficiency for gas-fired instantaneous water heaters. (42 U.S.C. 6295(o)) In order to determine these efficiency levels, DOE relied on a combination of market efficiency ratings (examining ratings at all input capacities and estimating the corresponding efficiency at the selected representative input capacities), actual product availability at the time of this analysis, and feedback from manufacturers collected during the interview process (see chapter 12 and appendix 12A of this TSD). For example, DOE conducted a survey of the gas-fired instantaneous water heater market and the research fields that support the market. For the representative product within a given product class, no working products or prototypes at efficiency levels above the max-tech level were identified that could be manufactured using technologies considered from the screening analysis. Table 5.5.3 lists the max-tech levels DOE determined for the directly analyzed product classes of gas-fired instantaneous water heaters. Market efficiency distributions are depicted in chapter 3 of this TSD and are based on data available at the time of this analysis.

DOE has determined that the max-tech efficiency levels presented in Table 5.5.3 for gas-fired instantaneous water heaters use condensing technology and reach the max-tech levels by increasing the surface area of the condensing heat exchanger and incorporating modulating controls with a combustion chamber design that has an evenly distributed flame pattern.

Table 5.5.3 Max-Tech Efficiency Levels

Product Type	Distinguishing Characteristics (Effective Storage Volume and Input Rating)	Draw Pattern	UEF*
Gas-fired Instantaneous Water Heater	< 2 gal and > 50,000 Btu/h	Medium	0.93
		High	0.96

*UEF ratings are listed at the representative capacity (storage volume or input rating) for each product class and draw pattern (see section 5.3.1.1).

5.5.4 Efficiency Level Equations

Many of the existing energy conservation standard equations for consumer water heaters are specified where the required UEF is a function of storage volume. However, DOE's existing standards for consumer instantaneous water heaters are single UEF values independent of storage volume because "tankless" instantaneous water heaters experience minimal standby losses due to having very low storage volumes (less than 2 gallons). Additionally, the recovery efficiencies of a gas instantaneous water heater tend not to vary significantly with input rate. In this final rule, DOE maintained its approach of defining efficiency levels for gas-fired instantaneous water heaters as UEF values that do not vary as a function of storage volume.

Therefore, the UEF ratings of representative units for each directly analyzed product class constitute the efficiency level equations for those product classes. As discussed in previous sections, these levels are the result of DOE's review of the CCD, AHRI directory, manufacturer catalogs, and other publicly available literature to find efficiency clusters in the market.

DOE conducts cost-efficiency analyses for each draw pattern separately for those draw patterns where products were found available on the market. However, as discussed in section 5.5.2, there are no models on the market in the very low draw pattern and very few models on the market in the low draw pattern. In these cases, similar technology pathways can be implemented as those identified for product classes that do have products available on the market. Thus, in order to assign efficiency levels to draw patterns where there are no models on the market, DOE uses the efficiency levels from populated draw patterns and extrapolates to those neighboring, unpopulated draw patterns. This approach takes into account how efficiency correlates to delivery capacity and recovery efficiency and allows DOE to analyze potential amended standards for product classes that are not directly analyzed. No cost-efficiency curves are generated for the very small or low draw patterns because the limited model availability would result in very low shipments for these draw patterns. A nationwide cost-benefit analysis based on the medium and high draw patterns is representative of the results for the entire market. Table 5.5.4 shows the efficiency levels DOE arrived at for all gas-fired instantaneous water heater product classes after conducting this efficiency analysis.

Table 5.5.4 Efficiency Levels for Gas-fired Instantaneous Water Heaters with an Effective Storage Volume Less Than 2 Gallons and Rated Input Greater than 50,000 Btu/h

EL	Draw Pattern			
	Very Small	Low	Medium	High
0	0.80	0.81	0.81	0.81
1	0.86	0.87	0.87	0.89
2	0.89	0.91	0.91	0.93
3	0.90	0.92	0.92	0.95
4	0.91	0.93	0.93	0.96

5.6 TEARDOWN ANALYSIS

To assemble BOMs and calculate the manufacturing costs of the different components in gas-fired instantaneous water heaters, DOE disassembled multiple units into their components and estimated the material and labor cost of each component. This process is referred to as a "physical teardown." A supplementary method, called a "virtual teardown," uses published manufacturer catalogs and supplementary component data to estimate the major physical differences between a product that was physically disassembled and a similar product that was not to develop a BOM for the product. The teardown analysis for this final rule engineering analysis included 31 physical and 5 virtual teardowns of gas-fired instantaneous water heaters.

5.6.1 Selection of Units

DOE adopted the following criteria for selecting units for the teardown analysis:

- The selected products should span the full range of efficiency levels for each directly analyzed product class and draw pattern under consideration.
- If possible, the selected products within each directly analyzed product class and draw pattern should come from the same manufacturer and be within the same model series so that the design options that improve efficiency can be more accurately determined.
- The selected products should come primarily from manufacturers with large market share in that product class, although the highest efficiency products were chosen irrespective of manufacturer.
- The selected products should have non-efficiency related features that are the same or similar to features of other products in the same product class and draw pattern and for a range of efficiency levels.

DOE surveyed the gas-fired instantaneous water heater industry and identified products available to consumers as well as prototypes developed by manufacturers' research efforts. DOE then applied the aforementioned criteria and selected baseline, intermediate, and max-tech units that met the energy efficiency levels and included the technologies identified in market surveys. DOE selected numerous examples of gas-fired instantaneous water heaters from multiple manufacturers to represent the market and used these for physical teardowns in the engineering analysis.

In several cases, DOE substituted a virtual teardown in the place of a physical teardown. For example, if DOE physically tore down a model with an input capacity that was slightly different from the representative capacity for its product class, a virtual teardown would estimate the design differences (e.g., sheet metal or component dimensions) required to scale the physical teardown to the representative input capacity.

Using the data gathered from the physical teardowns, DOE characterized each component according to its weight, dimensions, material, quantity, and the manufacturing processes used to fabricate and assemble it. For supplementary virtual teardowns, DOE gathered product data such as dimensions, weight, and design features from publicly available manufacturer catalogs. DOE obtained information and data not typically found in catalogs and brochures, such as fan motor details, gas manifold specifications, and assembly details, from the physical teardowns of similar products or by estimations based on industry knowledge. DOE collected additional component information during the manufacturer interviews.

5.6.2 Baseline Units

DOE selected baseline units for the teardown analysis to determine the technologies manufacturers typically incorporate into products at energy efficiencies equal to the current Federal energy conservation standards. Typically, the baseline units are representative of the minimum technology and lowest-cost product that manufacturers can produce. DOE compared the cost of products at the baseline and technologies used in those products to those at higher energy efficiency levels. The efficiencies of the baseline units are presented in section 5.5.1.

As discussed in chapter 3 of this final rule TSD, DOE gathered information from the physical and virtual teardowns and from published information and data to determine which features manufacturers typically incorporate into units at the baseline efficiency levels. DOE also identified the general characteristics common to gas-fired instantaneous water heaters and the operating features of the baseline units. See chapter 3 for further details.

5.7 TECHNOLOGY OPTIONS

Technology options are technology and design changes manufacturers use to improve product energy efficiency. These technologies provide different ways to increase product energy efficiency from the baseline to the max-tech efficiency. While manufacturers use many different technologies and approaches to increase the energy efficiency of gas-fired instantaneous water heaters, the technologies and combinations of technologies presented in the following sections, and their ordering is one possible way manufacturers could increase efficiency all the way up to the max-tech levels.

For the engineering analysis, DOE calculated the manufacturing costs for each efficiency level between the baseline and max-tech at each of the levels specified in sections 5.5.2 and 5.5.3. Using the teardown analysis and discussions with manufacturers, DOE identified each technology typically incorporated at each energy efficiency level, and calculated the cost required to achieve each efficiency level. DOE input the components, materials, and labor required for manufacturing units that can achieve each efficiency level (as determined from the teardown analysis) to calculate the MPC at each efficiency level analyzed in the final rule analysis. After determining the MPC at each efficiency level, DOE created the cost-efficiency curves (section 5.10).

DOE considered and analyzed various technologies for improving the energy efficiency of gas-fired instantaneous water heaters (see chapter 3 of this TSD). Two of the technologies DOE considered for improving energy efficiency were screened out during the screening analysis—condensing pulse combustion and reduced burner size (see chapter 4 of this TSD). DOE used information from the teardown analysis, manufacturer interviews, and publicly available product literature to determine which technologies are used in commercially available products so that DOE could most accurately represent the current market. DOE also determined which technologies manufacturers would be most likely to include in future products based on the cost effectiveness of these technologies. Several technologies are not included in the engineering analysis (e.g., enhanced flue baffles) because they were not identified as a critical design option pathway to achieve higher UEF ratings for gas-fired instantaneous water heaters.

Manufacturers of gas-fired instantaneous water heaters primarily increase energy efficiency by increasing the heat exchanger area to increase the rate of heat transfer. Higher efficiencies require heat exchangers that condense the flue gases and category IV venting (i.e., positive vent pressure and condensate in the vent).

Gas-fired instantaneous water heaters that do not condense the combustion gases have one non-condensing heat exchanger typically made from copper. To increase energy efficiency, manufacturers will usually add a condensing heat exchanger made from stainless steel, which is resistant to the acidic condensate from condensing flue gases. In both heat exchanger designs (i.e., non-condensing and condensing), water flows in the opposite direction as the combustion gases (i.e., counter flow heat exchanger), with the condensing heat exchanger being placed after the non-condensing heat exchanger with respect to the direction of flow of flue gases. This allows the heat exchanger to maintain a large temperature difference near both the inlet and the outlet, leading to more heat transfer and higher efficiencies. To increase the efficiency of a condensing gas-fired instantaneous water heater, the heat exchanger area of the condensing heat exchanger is increased and/or a more efficient heat exchanger design is used (DOE evaluated replacing a tube heat exchanger with a flat plate heat exchanger at EL 3).

A manufacturer can also increase efficiency by replacing a step-modulating burner with a fully modulating burner, including associated controls and combustion chamber design. These changes would be expected to improve efficiency because the 24-hour simulated use test in the DOE consumer water heater test procedure consists of a series of draws at different flow rates that cause the unit to operate at less than the full firing rate at times. A step-modulating burner (e.g., the burner design for ELs 0 through 3) uses a series of solenoids and a manifold to divert gas to different section of the combustion chamber, creating areas within the combustion chamber that do not have a flame when the unit is not operating at the full firing rate. The combustion chamber design with a fully modulating burner creates an even flame pattern across the heat exchanger to avoid "cold" spots when the burner is not operating at full firing rate. DOE's teardown analyses and review of product literature indicated that step-modulating burners can be implemented in models that achieve efficiencies as high as EL 3,[a] though some manufacturers choose to implement fully modulating burners at lower condensing efficiency levels. Because step-modulating designs can be more cost-effective to implement for large-scale production of EL 3 models in a standards-case-scenario—these designs are more compatible with legacy production lines for non-condensing models— and DOE's cost-efficiency relationship assumes the least-cost approach to achieve each efficiency level, step-modulating burners are modeled as the design option at EL 3. By EL 4 (max-tech), DOE expects all designs manufactured in a standards-case-scenario would implement fully modulating burners because its simpler production process would significantly ease the investment costs of ramp up in production of max-tech gas-fired instantaneous water heaters. DOE used physical teardowns of comparable models with step-modulating burners and fully modulating burners to estimate the cost differential between the burner assemblies. This differential was applied to the EL 3 MPC, along with a cost increase for a larger heat exchanger, to obtain the EL 4 MPC.

Table 5.7.1 shows the technologies incorporated into gas-fired instantaneous water heaters.

Table 5.7.1 Gas-Fired Instantaneous Water Heaters with an Effective Storage Volume Less than 2 Gallons and an Input Rating Greater Than 50,000 Btu/h

ELs	UEF*		Technology Options
	Medium (120,000 Btu/h)	High (199,000 Btu/h)	
0	0.81	0.81	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: N/A
1	0.87	0.89	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube
2	0.91	0.93	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube, Increased Heat Exchange Area (compared to EL1)
3	0.92	0.95	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Flat Plate, Increased Heat Exchange Area (compared to EL2)
4	0.93	0.96	Burner: Fully Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Flat Plate, Increased Heat Exchange Area (compared to EL3)

*There are no gas-fired instantaneous water heaters on the market within the very small draw pattern, and very few in the low draw pattern. DOE did not conduct a direct analysis of either the very small or low draw pattern.

[a] For example, BWC's Infiniti® model line, which appears to use a step-modulating burner design, includes products in two sizes rated to 0.95 UEF, which would meet EL 3 for the high draw pattern. Product ratings are available online at: s3.amazonaws.com/bradfordwhitecorp/wp-content/uploads/residential_tankless_infiniti_k_n1_indoor_specsheet_1152.pdf. (Last accessed on August 29, 2024).

5.8 COST ESTIMATES

5.8.1 Generation of Bills of Materials

During teardowns, every layer of the product is peeled back, cataloged, photographed, and examined. The BOM captures every part, every value-added step, and the likely assembly order of components to accurately model the resources required to make a product.

The BOM incorporates all materials, components, and fasteners classified as either raw materials (i.e., materials that are modified by the manufacturer from a basic state as part of a fabrication process) or purchased parts and assemblies, which the manufacturer simply assembles into a product. The designations as raw materials or purchased parts were based on DOE's previous industry experience, recent information in trade publications, and discussions with high- and low-volume original equipment manufacturers (OEMs).

The BOM also categorizes the parts by sub-assembly, allowing comparisons between various suppliers by sub-assembly. Breaking out sub-assemblies in this manner also allows further analysis, such as the most likely cost for an out-sourced solution versus in-house production. The result of each teardown is a structured BOM, which describes each product part and its relationship to the other parts in the estimated order in which the manufacturer would have assembled them.

The BOM describes each fabrication and assembly operation in detail, including the type of equipment needed (e.g., presses, drills), process cycle times, and labor associated with each manufacturing step. The result is a thorough and explicit model of the production process, including space, conveyor, equipment, and tooling requirements by planned production level. DOE developed structured BOMs for each of the physical and catalog teardowns.

The price of purchased parts is estimated based on volume-variable price quotations and detailed discussions with manufacturers and component suppliers. For fabricated parts, non-metal raw materials are based on the most current prices available to DOE. Metal prices are averaged over a 5-year period to reduce impacts of recent price fluctuations on the estimated MPC (see section 5.8.4.4). The cost of transforming the intermediate materials into finished parts is estimated based on current industry pricing.

5.8.2 Structure for Development of Cost Estimates

DOE estimated the cost of labor, materials, depreciation, and overhead for each part. To determine the costs, DOE followed one of two different paths, depending on whether a subassembly was purchased (outsourced) or produced in-house. For purchased parts, DOE gathered price quotations from major suppliers at different production volumes. For parts produced in-house, DOE reconstructed manufacturing processes for each part based on internal expertise. For example, for an access panel, DOE deduced the time required for setup, handling, changeover, and punching holes, as well as the number of holes and hits. By repeating this process, DOE was able to assign labor time, equipment utilization, and other important factors to each subassembly in each of the units considered for this analysis. The last step was to convert the information into dollar values. To perform this task, DOE collected information on such factors as labor rates, tooling depreciation, and costs of purchased raw materials. DOE estimated the values for these parameters using internal expertise and feedback from manufacturers.

In sum, DOE assigned costs of labor, materials, and overhead to each part, whether purchased or produced in-house. DOE then aggregated single-part costs into major assemblies (e.g., packaging, cabinet assembly, heat exchanger, burner system, exhaust subassembly, fan system, controls) and summarized these costs in a spreadsheet. DOE repeated this same process to calculate an MPC estimate for each unit in the engineering analysis, representing a specific efficiency level at the chosen capacity, and mapped the resulting cost-efficiency points to use as a basis for developing the cost-efficiency relationships.

During engineering interviews with manufacturers, DOE contractors typically share cost estimates of purchased parts, raw materials, and assemblies with manufacturers under non-disclosure agreements. Manufacturers provide feedback that is reviewed and, as appropriate, incorporated into the analysis.

5.8.3 Definitions for Development of Cost Estimates

As mentioned in previous sections, DOE used a bottom-up approach to develop cost estimates and divided factory costs into costs for materials, labor, depreciation, and overhead, as well the sub-categories listed in Table 5.8.1.

Table 5.8.1 Categories and Descriptions for Development of Cost Estimates

Major Category	Sub-Category	Description
Material Costs	Direct	Raw materials (e.g., coils of sheet metal) and purchased parts (e.g., fan motors, gas valves)
	Indirect	Material used during manufacturing (e.g., welding rods, press die oil, release media)
Manufacturing Labor	Assembly	Part/unit assembly on manufacturing line
	Fabrication	Conversion of raw materials into parts ready for assembly
	Indirect	Fraction of overall labor not associated directly with product manufacturing (e.g., forklift drivers, quality control)
	Supervisory	Labor required to supervise all other labor categories.
Depreciation	Equipment, Conveyor, Building	Straight line depreciation over expected life
	Tooling	Cost is allocated on a per-use basis or obsolescence, whichever results in a higher cost
Other Overhead	Utilities	A fixed fraction of all material costs meant to cover electricity and other utility costs
	Maintenance	Based on installed equipment and tooling investment
	Property Tax and Insurance	A fixed fraction based on total unit costs

5.8.4 Overview of Cost Estimate Development

As discussed in the previous section, manufacturer practices and cost structure play an important role in estimating the final product cost. Results varied among manufacturers, depending on market position, manufacturing practices, and manufacturing volume.

In converting physical information about the product into cost information, DOE reconstructed manufacturing processes for each component using internal expertise and knowledge of the methods used by the industry. For example, DOE recreates all process steps needed to convert a piece of raw material into a finished part, ready for assembly. The requirements for manufacturing process equipment, labor, *etc.* are tallied and used to determine the most likely cost for the part prior to assembly.

DOE then summed the values of the components into assembly costs and, finally, the MPC. The MPC includes the material, labor, depreciation, and overhead costs associated with the manufacturing facility. DOE refined its labor and overhead cost estimates using information obtained during interviews with gas-fired instantaneous water heater manufacturers. The next sections discuss fabrication estimates, production volumes, factory parameters, and material prices. The inputs into the analysis are aggregated to represent industry averages and to prevent the disclosure of business-sensitive information.

5.8.4.1 Fabrication Estimates

DOE characterized parts based on whether manufacturers purchased them from outside suppliers or fabricated them in-house. For purchased parts, DOE estimated the purchase price. For fabricated parts, DOE estimated the price of raw materials (*e.g.*, tube, sheet metal) and the cost of transforming them into finished parts. DOE bases its modeling of manufacturing operations on internal expertise, interviews with manufacturers, and visits to manufacturing facilities. Table 5.8.2 presents the major manufacturer processes identified and developed for the spreadsheet model. Fabrication process cycle times were estimated and entered into the BOM.

Table 5.8.2 Major Manufacturing Processes for Gas-fired Instantaneous Water Heaters

Fabrication	Finishing	Assembly/Joining	Quality Control
Fixturing	Powder Coating	Adhesive Bonding	Inspection and Testing
Stamping/Pressing	De-Burring	Spot Welding	Water/gas leak testing
Turret Punch	Polishing	Packaging	
Tube Forming	Washing	Clinching	
Brake Forming	Painting	Brazing	
Laser Cutting		Tig/Mig Welding	
Cutting and Shearing		Lacing	
Manual Bending		Tube Expansion	

Variability in the costs of purchased parts can account for large changes in the overall MPC estimates calculated. The purchased part prices used in this analysis were typical values based on estimated purchased part volumes and other factors. Some parts may be produced in-house by some manufacturers and purchased by others. The choice between these options would result in changes to the calculated overall system costs. Manufacturer feedback was solicited on these costs and used to further calibrate the numbers prior to conducting the analyses to minimize the uncertainty caused by the variability in costs.

5.8.4.2 Production Volume Inputs for Cost Estimates

Manufacturer production volumes vary depending on several factors, including overall market size, individual company market share, the product or equipment produced, and whether the manufacturer produces other similar products or equipment that utilize the same materials and components. DOE based the production volumes it used for gas-fired instantaneous water heaters on industry knowledge and information gathered during manufacturer interviews. Additionally, shipments can be general indicators of production volumes. The shipments analysis is discussed in chapter 9 of this TSD.

For the annual production volume, DOE included in its estimates similar products or equipment that are manufactured by a manufacturer but not within the scope of this rulemaking (e.g., residential boilers) to estimate depreciation costs for equipment that is shared across all products being made by a manufacturer. Because DOE assumes that tooling is product-specific (i.e., for gas-fired instantaneous water heaters only), the tooling production volume is smaller than the annual production volume and is used to estimate tooling depreciation costs DOE's average production volume estimates are shown in Table 5.8.3.

Table 5.8.3 Production Volumes Used for Gas-fired Instantaneous Water Heater MPC Estimates

Annual Production Volume	Tooling Production Volume
800,000	400,000

5.8.4.3 Factory Parameters

DOE used information gathered from publicly available literature, manufacturer interviews, and analysis of common industry practices to formulate industry-average factory parameters, which were reviewed by manufacturers, and revised as necessary. Table 5.8.4 lists DOE's estimates for factory parameters for manufacturers of gas-fired instantaneous water heaters.

Table 5.8.4 Gas-fired Instantaneous Water Heater Parameters Used in Analysis

Parameter	Estimate
Work Days Per Year (days)	250
Assembly Shifts Per Day (shifts)	2.0
Fabrication Shifts Per Day (shifts)	2.0
Assembly Labor Wages ($/h)	22.00
Fabrication Labor Wages ($/h)	24.00
Length of Shift (hrs)	8
Average Manufacturing Equipment Installation Cost (% of purchase price)	10%
Fringe Benefits Ratio	50%
Indirect to Direct Labor Ratio	33%
Average Scrap Recovery Value	30%

Parameter	Estimate
Worker Downtime per shift	10%
Burdened Assembly Labor Wage ($/h)	33.00
Burdened Fabrication Labor Wage ($/h)	36.00
Supervisor Span (workers/supervisor)	25
Supervisor Wage Premium (over fabrication and assembly wage)	30%

5.8.4.4 Material Prices

DOE determined the cost of raw materials using publicly available information such as MEPS Intl. (www.meps.co.uk), PolymerUpdate (www.polymerupdate.com), WestMetall (www.westmetall.com), Investing.com (www.investing.com), and the Bureau of Labor Statistics (BLS) (www.bls.gov/ppi), interviews with manufacturers, and discussions with material suppliers. DOE also uses the Saint Louis Federal Reserve (fred.stlouis.org) for exchange rates. The fabricated parts that DOE observed in its analysis of gas-fired instantaneous water heater products were predominantly made from raw metals, insulation, and plastic. To minimize the impact of large fluctuations in metal prices in recent years, DOE uses a 5-year average for its metal prices. Table 5.8.5 shows the 5-year average material metal prices DOE used for the analysis. Table 5.8.6 and Table 5.8.7 show current market price estimates for non-metal raw material inputs into the analysis.

Table 5.8.5 Five-Year Average Metal Material Prices (7/2018–6/2023)

Metal	Five-Year Cost Avg. (7/2018-6/2023) 2023$/lb
Cold Rolled Steel (CRS)	0.62
Hot Rolled Steel (HRS)	0.52
Aluminized CRS	0.76
Galvanized CRS	0.76
Pre-Painted CRS	0.88
Stainless Steel 409	1.02
Stainless Steel 316	2.39
Aluminum	1.84
Copper	4.36
HRS Tube	0.83
CRS Tube	1.28
SS316 Tube	3.58
Plain Copper Tube, ≤0.75” OD	3.45

Table 5.8.6 Plastics Raw Material Prices

Resin	Cost As of 6/2023 2023$/lb
ABS	0.61
ABS with Glass Fiber	1.06
EPDM Rubber	1.35
Polypropylene (PP)	0.60
PP with Glass Fiber	1.15
Polystyrene (PS)	0.73
HDPE	0.64
LDPE	0.72
Styrofoam	1.02
PVC (Hard)	0.70
PVC (Flexible)	1.00
High Temperature Silicone	2.65
Silicone	1.68
SBR Rubber (Buna)	0.64

Table 5.8.7 Other Raw Material Prices

Material Description	Cost As of 6/2023 2023$/lb
Plain Cardboard for Shipping	0.34
Two-Color Cardboard for Shipping	0.62
Paper	0.85
Wood for Shipping	0.38
Fiberglass	1.32
Foil Faced Fiberglass	1.66
Flexible high-alumina ceramic (i.e., “Fiberfrax”)	2.41
Molded high-alumina ceramic (i.e., “Durafrax”)	4.79
Glass Enamel	1.51

5.8.5 Manufacturer Production Cost

DOE totaled the cost of materials, labor, depreciation, and overhead used to manufacture each analyzed model of gas-fired instantaneous water heater to calculate the MPC. DOE used the cost estimates from teardowns on a market-share weighted average basis to determine the MPC increase to move from one efficiency level to the next for each directly analyzed product class.

The full cost of gas-fired instantaneous water heater products is broken down into two main costs: the full production cost or MPC, and the non-production cost. The non-production cost is equal to the manufacturer markup minus profits. The manufacturer markup is discussed further in section 5.12. Figure 5.8.1 shows the breakdown of production and non-production costs by sub-categories.

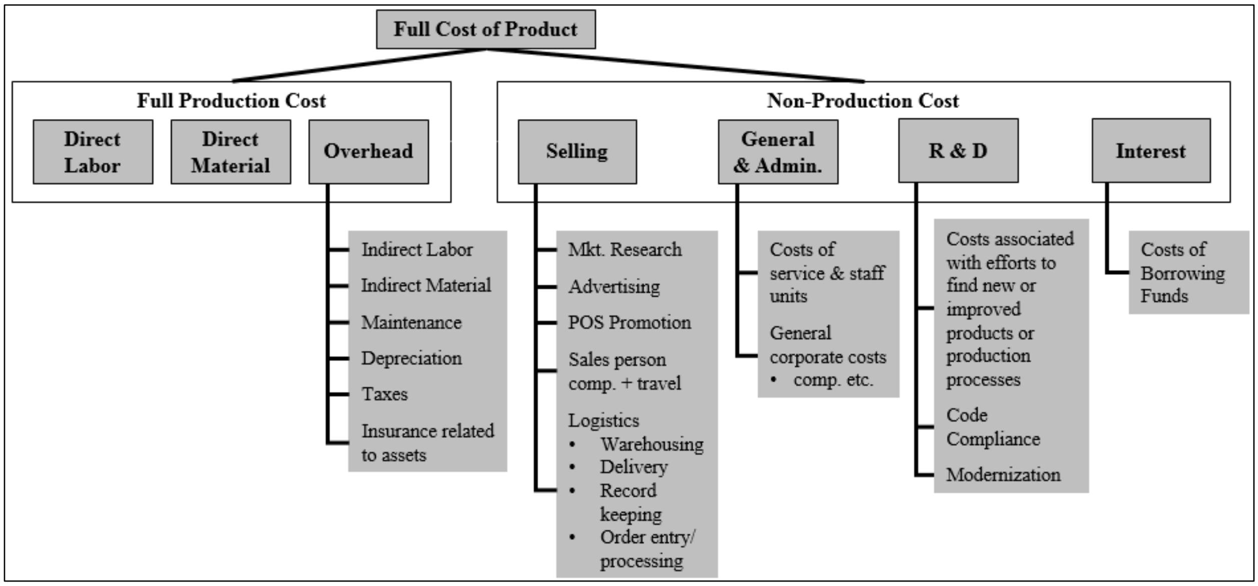

Figure 5.8.1 Breakdown of Costs Associated with Manufacturing Gas-fired Instantaneous Water Heaters

5.9 MANUFACTURING INTERVIEWS

DOE sought feedback and insight from interested parties to improve the information used in the analyses. For the engineering analysis, DOE discussed the analysis assumptions and estimates and the cost-efficiency curves with manufacturers of gas-fired instantaneous water heaters. When refining the BOMs, DOE considered all the information manufacturers provided. DOE incorporated equipment and manufacturing process figures into the analysis in the form of averages to avoid disclosing sensitive information about individual manufacturers' products or manufacturing processes.

Before the interviews, DOE gave manufacturers interview guides (see appendix 12A of this TSD), which included questions and topics to be discussed during the interview, along with assumptions, estimates, and cost-efficiency results. DOE asked manufacturers to provide feedback on the representation of the market and to supply any data that could improve DOE's estimates and assumptions.

During the interviews performed in preparation for this final rule analysis, DOE engaged manufacturers in open discussions so that all issues regarding the rulemaking would be covered. In addition to responding to DOE's specific questions about the engineering analysis and MPCs, manufacturers also commented on a range of other issues affecting the engineering analysis. DOE compiled all of the issues manufacturers discussed and presents those manufacturers consider paramount. Analysis of these key issues allowed DOE to refine the engineering analysis. Manufacturers presented one key issue concerning the cost-efficiency analysis for gas-fired instantaneous water heaters: recent material price increases. To address this, DOE used recent material prices for non-metals (which tend not to vary much over time) and 5-year averages for metals (which tend to have more price fluctuations that would even out over the rulemaking analysis period). See chapter 12 of the TSD for additional details on the manufacturer interview process.

5.10 MANUFACTURER PRODUCTION COST BREAKDOWN

After calculating the MPC, DOE calculated the production cost percentages. The production cost percentages validate the assumptions by comparing them to manufacturers' actual financial data published in annual reports, along with feedback from manufacturers during interviews. DOE also used these figures in the manufacturer impact analysis (chapter 12 of this TSD). DOE calculated the average production cost percentages for gas-fired instantaneous water heaters for both of the draw patterns included in the direct analysis. Table 5.10.1 and Table 5.10.2 show the different percentages for the production costs that make up the total product MPC.

In general, material cost increases have caused the fraction of the MPC attributed to materials to increase for every gas-fired instantaneous water heater type as compared to the March 2022 Preliminary Analysis.

Table 5.10.1 Gas-fired Instantaneous Water Heater MPC Breakdown, Medium Draw

EL	Material	Labor	Depreciation	Overhead
0	59%	28%	8%	5%
1	56%	29%	9%	6%
2	56%	29%	9%	6%
3	57%	28%	9%	6%
4	62%	26%	6%	6%

Table 5.10.2 Gas-fired Instantaneous Water Heater MPC Breakdown, High Draw

EL	Material	Labor	Depreciation	Overhead
0	61%	25%	9%	5%
1	57%	28%	9%	6%
2	57%	28%	9%	6%
3	57%	28%	9%	6%
4	63%	26%	6%	6%

5.11 MANUFACTURER SELLING PRICE

5.11.1 Manufacturer Markup

To account for manufacturers' non-production costs and profit margin, DOE applies a multiplier (the manufacturer markup) to the MPC. The resulting manufacturer selling price (MSP) is the price at which the manufacturer distributes a unit into commerce. DOE developed an average manufacturer markup by examining the annual Securities and Exchange Commission (SEC) 10-K reports filed by publicly traded manufacturers that produce gas-fired instantaneous water heaters, the manufacturer markups from the April 2010 Final Rule, and feedback from confidential manufacturer interviews. 75 FR 20112. For gas-fired instantaneous water heaters, DOE determined an average manufacturer markup of 1.45. See chapter 12 of the TSD for additional detail on the manufacturer markup.

5.11.2 Shipping Costs

Shipping costs for each directly analyzed gas-fired instantaneous water heater product classes were determined based on the area of floor space occupied by the unit. DOE research suggests that gas-fired instantaneous water heaters are usually shipped together in fully loaded trailers, rather than in less than truckload (LTL) configurations, where the gas-fired instantaneous water heaters occupy only a portion of the trailer volume. Therefore, shipping costs were calculated based on a as full a trailer as possible within the volume or weight constraints.

To calculate these shipping costs, DOE calculated the cost per area of a trailer, based on the standard dimensions of a 40-foot trailer and an estimated the most recent cost per shipping load that approximates the cost of shipping the products from Asia to the Midwest of the U.S. Next, DOE examined the sizes of products in each product class at each efficiency level and determined the number of units that would fit in a trailer. DOE then calculated the average shipping cost per unit using the cost per trailer load. DOE modeled that gas-fired instantaneous water heaters could be stacked, due to their smaller size and weight as compared to other consumer water heaters.

The number of units that will fit in a trailer load is limited either by the physical volume of the trailer being filled to capacity or by the combined weight of the units reaching the maximum capacity that the trailer can carry. Typically, DOE estimates that the maximum number of units that would fit in a trailer is dictated by the external shipping dimensions (including packaging) of each gas-fired instantaneous water heater, rather than the weight. However, for high draw pattern models, modeling results show that some gas-fired instantaneous water heaters could potentially “weigh-out”, or reach the maximum payload capacity of the trailer, before the maximum number of units allowable by volume is reached if units are heavier and packed closely.

Table 5.11.1 shows the average shipping dimensions and shipping costs estimated by DOE for gas-fired instantaneous water heaters.

Table 5.11.1 Shipping Dimensions and Cost for Gas-fired Instantaneous Water Heaters with an Effective Storage Volume Less than 2 Gallons and an Input Rating Greater Than 50,000 Btu/h

ELs	Medium*		High	
	HxWxD (inches)	Shipping Costs (2023$)	HxWxD (inches)	Shipping Costs (2023$)
0	25x18x13	4.52	25x18x13	7.63
1	31x22x13	7.07	31x22x13	9.49
2	32x23x14	10.17	32x23x14	11.45
3	34x25x16	10.17	34x25x16	11.45
4	34x25x16	10.17	34x25x16	11.45

*Shipping costs were not calculated for the very small and low draw patterns because there were no or few models in these draw patterns. DOE did not conduct a direct analysis of either the very small or low draw patter.

5.12 ENGINEERING ANALYSIS SUMMARY OF RESULTS

As described in section 5.8.5, DOE first estimated the MPC of the baseline units for each directly analyzed product class. DOE then determined the intermediate efficiency levels, up to max-tech, that represent the gas-fired instantaneous water heater market and identified the MPCs for each of these intermediate efficiency levels.

The results from the engineering analysis, the cost-efficiency curves representing the product classes examined for this final rule analysis, are used in the LCC analysis to determine consumer prices for gas-fired instantaneous water heaters. Using the calculated manufacturer markup, DOE calculated the MSPs of the representative gas-fired instantaneous water heaters at the baseline and more efficient levels.

Each of the MPCs and MSPs developed in the engineering analysis for the representative capacity in each directly analyzed product class are shown in Table 5.12.1. DOE was able to receive manufacturer feedback on these MPCs and MSPs during the manufacturer interviews (see chapter 12 of this TSD). As described in section 5.11, the MSP for gas-fired instantaneous water heaters is calculated by multiplying the MPC by the manufacturer markup.

Table 5.12.1 MPC and MSP for Gas-fired Instantaneous Water Heaters with an Effective Storage Volume Less than 2 Gallons and an Input Rating Greater Than 50,000 Btu/h (2023$)

EL	UEF		MPC (2023$)	Shipping (2023$)	MSP (2023$)
	Medium 120 kBtu/h	High 199 kBtu/h			
0	0.81	0.81	Med: 310.51 High: 327.89	Med: 4.52 High: 7.63	Med: 450.24 High: 475.44
1	0.87	0.89	Med: 441.74 High: 461.02	Med: 7.07 High: 9.49	Med: 640.52 High: 668.48
2	0.91	0.93	Med: 445.63 High: 466.00	Med: 10.17 High: 11.45	Med: 646.16 High: 675.71
3	0.92	0.95	Med: 451.39 High: 473.22	Med: 10.17 High: 11.45	Med: 654.52 High: 686.17
4	0.93	0.96	Med: 490.04 High:514.99	Med: 10.17 High: 11.45	Med: 710.56 High: 746.74

*MPCs and MSPs were not calculated for the very small and low draw patterns because there were no or very few models in these draw patterns.

5.13 CONVERTED STANDARDS FOR PRODUCT CLASSES WITHOUT CURRENT UEF-BASED STANDARDS

Table 5.13.1 presents the consumer gas-fired instantaneous water heater product classes without current UEF-based energy conservation standards which DOE evaluated for potential UEF-based energy conservation standards in this final rule analysis, and their current EF-based energy conservation standards. In the December 2016 Conversion Factor Final Rule, DOE affirmed its interpretation that the standards established in EPCA are applicable to consumer water heaters, including the gas-fired instantaneous water heaters listed in Table 5.13.1. 81 FR 96204, 96209–96211. DOE also stated that these standards would not be enforced until conversion factors and converted standards are adopted. Conversion factors and converted standards were not adopted in the December 2016 Conversion Factor Final Rule and DOE has determined to develop converted standards for gas-fired instantaneous water heaters through the course of this rulemaking. For the purpose of this conversion, DOE has determined that values of rated storage volume would be equivalent to values of effective storage volume for the reasons discussed earlier in this chapter.

Table 5.13.1 Current EF-Based Standards for Gas-fired Instantaneous Water Heater Product Classes without Current UEF-Based Standards by Rated Storage Volume and Input Rate

Product Class	Nominal Input	Rated Storage Volume	Energy Factor
Instantaneous Gas-fired Water Heater	≤ 50,000 Btu/h	< 2 gal	$0.62 - (0.0019 \times V_r)$
	≤ 200,000 Btu/h	≥ 2 gal	$0.62 - (0.0019 \times V_r)$

To convert the EF-based energy conservation standards presented in Table 5.13.1 DOE applied an analytical approach that began with evaluating the conversion equations developed in the December 2016 Conversion Factor Final Rule. Then, DOE determined the range of characteristics that could be present in baseline models of the product classes to be converted to the UEF metric. Finally, DOE applied the conversion factors to an array of hypothetical baseline models and derived the UEF-based energy conservation standards (section 5.13.3) from the converted UEF values.

5.13.1 Conversion Equations

For the December 2016 Conversion Factor Final Rule, DOE developed mathematical equations which convert tested EF values to translated UEF values and allowed manufacturers to certify their consumer water heaters using these converted UEF values for 1 year after the publication of the December 2016 Conversion Factor Final Rule (i.e., December 29, 2017). 81 FR 96204, 96232–96235. The conversion equations consisted of a two-step process: first an analytical model was used to estimate an initial converted value (“UEF_{WHAM}” or “UEF_{model},” depending on the type of consumer water heater), taking into account known changes between the DOE test procedure in effect prior to and after the July 2014 Final Rule; second, the results of the analytical model were adjusted using a regression based on test data.

Two different conversion equations were developed that are applicable to gas-fired instantaneous water heaters without current UEF standards, with the applicable equation selected based on the rated storage volume and nominal input rate of the product. Gas-fired storage water heaters and gas-fired instantaneous water heaters were used in the development of the conversion equations from the December 2016 Conversion Factor Final Rule. Although the test data used to develop these equations did not come from gas-fired instantaneous water heaters DOE is analyzing in this final rule (products with 2 or more gallons of storage volume or 50,000 Btu/h or less of input), the designs of models used in the December 2016 Conversion Factor Final Rule are similar enough to allow the use of these equations for this analysis.

The first conversion equation is used for water heaters with 2 or more gallons of storage volume. For this final rule analysis, the equation developed for gas-fired storage water heaters (equation 5.1) was applied to crosswalk the energy conservation standards from EF to UEF for “tank-type” gas-fired instantaneous water heaters with a rated storage volume greater than or equal to 2 gallons and a nominal input rate less than or equal to 200,000 Btu/h.

$$UEF_{WHAM} = \left[\frac{1}{\eta_r} + \left(\frac{1}{EF} - \frac{1}{\eta_r}\right)\left(\frac{a\,P\,\eta_r - b}{c\,P\,\eta_r - d}\right)\right]^{-1}$$

Eq. 5.1

Where,

UEF_{WHAM} = uniform energy factor based on the Water Heater Analysis Model (WHAM);
η_r = Recovery Efficiency, %;
EF = Energy Factor;
P = input rate, Btu/hr; and

a, b, c, and d are the coefficients for water heaters with 2 or more gallons of storage volume, listed in Table 5.13.2.

Table 5.13.2 Coefficients for the UEF Conversion Factor for Water Heaters with 2 or More Gallons

Draw Pattern	a	b	c	d
Very Small	0.250266	57.5	0.039864	67.5
Low	0.065860	57.5	0.039864	67.5
Medium	0.045503	57.5	0.039864	67.5
High	0.029794	57.5	0.039864	67.5

Second, the conversion equation developed based on an analytical model for the presented below (equation 5.2). The conversion factor for consumer instantaneous water heaters is applicable to all such water heaters with a storage volume small enough that standby losses do not directly affect the UEF value, and DOE assumes this value to be less than 2 gallons (i.e., the current storage volume limit for UEF standards covering gas-fired instantaneous water heaters). Therefore, for this final rule analysis, equation 5.2 was applied to crosswalk the energy conservation standards from EF to UEF for gas-fired instantaneous water heaters with a rated storage volume less than 2 gallons and a nominal input rate less than or equal to 50,000 Btu/h. This equation can be used to estimate the UEF of an instantaneous water heater if the recovery efficiency is known. For instantaneous water heaters with very little storage volume, there is a strong correlation between the recovery efficiency and EF rating such that it is possible to estimate the recovery efficiencies of models that would meet the EF-based standards.

$$UEF_{model} = \frac{\eta_r}{1 + A\,\eta_r}$$

Eq. 5.2

Where,

UEF_{model} = uniform energy factor based on a DOE developed analytical model; and
A is the coefficient for gas-fired instantaneous water heaters listed in Table 5.13.3.

Table 5.13.3 Coefficients for the UEF Conversion Factor for Consumer Gas-fired Instantaneous Water Heaters

Draw Pattern	A
Very Small	0.026915
Low	0.010917
Medium	0.008362
High	0.005534

5.13.2 Defining Baseline Models

DOE conducted the translation of EF-based standards to UEF-based equivalents for gas-fired instantaneous water heaters that would meet, but not exceed, the EF-based standards. As shown in Equations 5.1 and 5.2, the formulas used to estimate the UEF of a model depend on the recovery efficiency and draw pattern for both types of gas-fired instantaneous water heaters, and additionally on the EF and input rate for gas-fired instantaneous water heaters with a rated storage volume greater than or equal to 2 gallons and a nominal input rate less than or equal to 200,000 Btu/h.

DOE estimated an average recovery efficiency for a baseline model based on two factors: the minimum possible recovery efficiency (which is equivalent to the minimum required EF at the limit where standby and other losses would be zero), adjusted by the average percentage difference in recovery efficiency and UEF for similarly designed[b] consumer water heaters on the market. This value for recovery efficiency represents the typical recovery efficiency of a baseline model at the current EF-based standard. Input rate is an inherent characteristic of the water heater which is directly used in the conversion equations. Another inherent characteristic is storage volume, and for instantaneous-type water heaters this value must be no more than 1 gallon per 4,000 Btu/h of input. The EF and draw pattern (delivery capacity) of the water heater primarily depend on input rate, storage volume, and recovery efficiency. DOE analyzed each possible combination of input rate and storage volume to generate a matrix of simulated gas-fired instantaneous water heaters spanning the range of characteristics applicable to each product class and draw pattern. DOE determined the EF of each simulated baseline model by evaluating the EF-based standards for the model's storage volume (since the EF-based standards are a function of storage volume as shown in Table 5.13.1). Table 5.13.4 shows the range of characteristics DOE simulated for gas-fired instantaneous water heaters.

Table 5.13.4 Range of Characteristics Modeled

Product Class	Input Rates*	Rated Storage Volumes**	Baseline Recovery Efficiency
Gas-Fired Instantaneous Water Heaters: Rated input ≤ 50,000 Btu/h; Rated storage volume < 2 gal	5,000 Btu/h – 50,000 Btu/h	0 gal – 2 gal	65%
Gas-Fired Instantaneous Water Heaters: Rated input ≤ 200,000 Btu/h; Rated storage volume ≥ 2 gal	5,000 Btu/h – 200,000 Btu/h	2 gal – 50 gal	79%

*Input rates were modeled in increments of 5,000 Btu/h.
**Storage volumes were modeled in increments of 1 gallon. DOE included an adjustment to account for how storage volumes were certified differently when the EF-based standards first went into effect. [c]

[b] Taking into account fuel type and whether the product class range has a rated storage volume less than or greater than or equal to 2 gallons.
[c] In the July 2014 TP Final Rule, DOE required that the rated storage volume "must be equal to the mean of the measured storage volumes of all the units within the sample" tested for certification. 79 FR 40542, 40565 (July 11, 2014); 10 CFR 429.17(a)(C).

5.13.3 Translated UEF-Based Energy Conservation Standard Equations

After calculating all of the parameters for each simulated gas-fired instantaneous water heater, DOE used the conversion equations from section 5.13.1 to estimate the UEF of each simulated gas-fired instantaneous water heater. In this analysis, DOE sought to develop UEF-based standards that would allow all models compliant with the EF-based standards to remain compliant. Therefore, DOE used the simulated UEF ratings to derive a standard level that all of the simulated units in the product class would pass—either by selecting the minimum simulated UEF value or by drawing a linear relationship. DOE determined that gas-fired instantaneous water heaters with storage volumes less than 2 gallons experience minimal standby losses and the recovery efficiencies of a gas instantaneous water heater tend not to vary significantly with input rate (i.e., the slope of the linear regression of minimum UEF as a function of storage volume is essentially zero). For these reasons, in this final rule, DOE is establishing constant values for the translated UEF-based energy conservation standards for gas-fired instantaneous water heaters with a V_{eff} less than 2 gallons and a nominal input rate less than or equal to 50,000 Btu/h.

Lastly, DOE conducted a limited comparison between the resultant standards levels and ratings for products available on the market today to verify that the translated standards are reasonable to be met.

The results of this conversion are presented in Table 5.13.5, noting that DOE presumes in this analysis that for gas-fired instantaneous water heaters, $V_r = V_{eff}$ (see section 5.3.1.1).

Table 5.13.5 Translated UEF-based Energy Conservation Standards for Gas-fired Instantaneous Water Heater Product Classes Without Established UEF-based Standards

Product Class	Nominal Input	Effective Storage Volume	Draw Pattern	Uniform Energy Factor
Instantaneous Gas-fired Water Heater	≤ 50,000 Btu/h	< 2 gal	Very Small	0.64
			Low	0.64
			Medium	0.64
			High	0.64
	≤ 200,000 Btu/h	≥ 2 gal	Very Small	0.2534 - (0.0018 x V_{eff})
			Low	0.5226 - (0.0022 x V_{eff})
			Medium	0.5919 - (0.0020 x V_{eff})
			High	0.6540 - (0.0017 x V_{eff})

CHAPTER 6. MARKUPS ANALYSIS

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CHAPTER 6. MARKUPS ANALYSIS

6.1 INTRODUCTION

To carry out its analyses, the U.S. Department of Energy (DOE) determined the cost to the consumer of baseline products and the cost of more efficient units the consumer would purchase under new energy conservation standards. DOE calculated such costs based on engineering estimates of manufacturing costs, a manufacturer markup to calculate the manufacturer sales price (i.e*.,* the price to the manufacturer's first customer), and appropriate markups for the various distribution channels.

DOE estimated a baseline markup and an incremental markup for each market participant besides manufacturers. DOE defined a baseline markup as a multiplier that converts the total manufacturer price (manufacturer selling price plus shipping cost) of products with baseline efficiency to the consumer purchase price for the product at the same baseline efficiency level. An incremental markup is defined as the multiplier to convert the incremental increase in the total manufacturer price of higher efficiency equipment to the consumer purchase price for the same equipment. Because companies mark up the price at each point in the distribution channel, both overall baseline and incremental markups are dependent on the distribution channel, as described in section 6.2. The incremental markup is typically less than the baseline markup and is designed to maintain similar per-unit operating profit before and after new or amended standards.[a]

Generally, companies mark up the price of a product to cover their business costs and profit margin. In financial statements, gross margin is the difference between the company revenue and the company cost of sales or cost of goods sold (*CGS*). The gross margin takes account of the expenses of companies in the distribution channel, including overhead costs (sales, general, and administration); research and development (R&D); interest expenses; depreciation; and taxes—and company profits. In order for sales of a product to contribute positively to company cash flow, the product's markup must be greater than the corporate gross margin. Products command lower or higher markups, depending on company expenses associated with the product and the degree of market competition.

6.2 DISTRIBUTION CHANNELS

A distribution channel is a chain of market participants through which a gas-fired instantaneous water heater passes until it reaches the consumer. The appropriate markups for determining consumer product prices depend on the type of distribution channels through which products move from manufacturers to purchasers.

The appropriate markups for determining consumer equipment prices depend on the type of distribution channels through which products move from manufacturers to purchasers. For this

[a] Because the projected price of standards-compliant products is typically higher than the price of baseline products, using the same markup for the incremental cost and the baseline cost would result in higher per-unit operating profit. While such an outcome is possible, DOE maintains that in markets that are reasonably competitive it is unlikely that standards would lead to a sustainable increase in profitability in the long run.

analysis, DOE did an extensive literature review as well as input from a consultant report (see appendix 6A). For gas-fired instantaneous water heaters, the main market participants in the distribution chain are: (1) manufacturers; (2) manufacturer's representatives; (3) plumbing wholesalers or distributors; (4) buying groups;[b] (5) retailers; (6) online retailers; (7) plumbing contractors; (8) HVAC specialist; (9) whole home energy efficiency performance contractors/raters; (10) remodelers; (11) builders/developers; (12) utilities; (13) manufactured home manufacturer; and (14) manufactured home dealer/retailer. Note that not all of them have significant presence in the market or have a similar markup. DOE assumes that many of these market participants have the same overall markups as the more conventional market participants. Although through some of the distribution chains some market participants may have lower margin, wholesalers and retailers tend to redistribute the profit throughout the distribution channel to have the final retail price comparable with products sold through conventional distribution channels. Therefore, due to the small market representation of some of these market participants, DOE did not consider them separately in this analysis.

As discussed in appendix 6A, DOE considered (1) manufacturers; (2) wholesalers; (3) retailers; (4) plumbing contractors; (5) builders; (6) manufactured home manufacturer; and (7) manufactured home dealer/retailer as the main market participants for its markups analysis by assuming the following:

- The manufacturer representative's incentives or payments are already included in the manufacturer markup;
- DOE assumed that the distribution channels and markups associated with wholesalers or distributors would be similar to buying groups for wholesalers;[c]
- DOE assumed that the distribution channels and markups associated with a retailer would be similar to online retailers and buying groups for retailers;
- DOE assumed that the distribution channels and markups associated with a plumbing contractor would be similar to a HVAC specialist, whole home energy efficiency performance contractor/rater, and remodeler; and
- Utilities typically do not markup the equipment.

DOE also considered separate distribution channels by market sectors (residential and commercial applications) and market segments (new construction and replacement/new owner). In the case of gas-fired instantaneous water heaters, the majority of units are purchased for residential use, but a fraction of them are purchased to be installed in small to mid-size commercial buildings, that have low hot water needs and where 180ºF water isn't required by code. For example, retail stores with restrooms, convenience store/gas stations, strip malls with businesses having restrooms or small break kitchens, etc. shows DOE's estimated fraction in 2030 of gas-fired instantaneous water heaters installed in commercial applications based on its

[b] Buying groups are intermediaries between the manufacturers and contractors. A buying group is a coalition of companies within a shared category who leverage their collective purchasing power to negotiate price reductions from manufacturers. For gas-fired instantaneous water heaters, the main types of buying groups involve small regional distributors (buying groups for distributors) and plumbing/hardware stores (retailer buying groups).
[c] This could also include rebranding distribution channel where wholesalers or retailers negotiate good pricing from the gas-fired instantaneous water heater manufacturer based on high volumes and have the product customized to carry their name, and then send it through their normal distribution channel to the contractors.

shipment analysis and other references (see appendix 6A and chapter 9). The distribution channels for gas-fired instantaneous water heaters sold in commercial applications differs, hence, DOE calculated the markups separately for residential and commercial applications.

Table 6.2.1 Estimated Fraction of Gas-fired Instantaneous Water Heaters in Residential and Commercial Applications in 2030

Product Class	Rated Storage Volume and Input Rating (if applicable)	Residential	Commercial
Gas-fired Instantaneous Water Hearer (GIWH)	<2 gal and >50 kBtu/h	94%	6%

Within each application, there are also two primary types of markets describing the way most products pass from the manufacturer to the consumer, one applying to gas-fired instantaneous water heaters installed in replacement markets or by new owners[d] and the other applying to gas-fired instantaneous water heaters that are installed in new construction. For gas-fired instantaneous water heaters, the distribution channel differs for replacement or new owner and new construction applications. DOE estimated the fraction of gas-fired instantaneous water heater shipments installed in the replacement or new owner and new construction market based on the shipments analysis (see chapter 9).

Table 6.2.2 Estimated Fraction of Gas-fired Instantaneous Water Heaters in Replacement and New Construction in 2030

Product Class	Rated Storage Volume and Input Rating (if applicable	Residential		Commercial	
		Repl./New Owner	New Construction	Repl./New Owner	New Construction
GIWH	<2 gal and >50 kBtu/h	52%	48%	81%	19%

For replacement or new owner applications in residential housing (not including mobile homes), manufacturers sell to wholesalers or retail outlets (typically large home-supply stores).[e] Two possible paths follow: (1) a retail outlet sells a water heater to the customer, who either hires someone to install it or self-installs it;[f] or (2) a wholesaler and a buying group sells a water heater to a plumbing contractor, who then sells it to a consumer and installs it. Some contractors will buy from retailers but they prefer wholesalers who can provide all the products and supplies they need and offer discounts and services that the retailers don't provide such as payment terms,

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[d] New owners account for homes adding a new water heater where there wasn't previously one (e.g., adding a secondary water heater, but also for switching between water heater product classes (e.g., gas storage to gas instantaneous or gas storage to electric storage.)

[e] As discussed earlier, manufacturer representatives facilitate some of the sales from manufacturers to distributors, buying group, and retailers, but they work on commission and thus DOE does not include them for purposes of estimating markups.

[f] In some cases, the retail outlet provides installation as part of a package. In others, the retail outlet links the customer to a contractor for installation. Self-installation is likely more common for electric than for gas water heaters due to the greater complexity of replacing a gas unit.

delivery, easy warranty claims, quantity incentives, etc. Figure 6.2.1 shows the distribution channels for gas-fired instantaneous water heaters in residential applications and shows the market share of each distribution channel in the replacement and new owner market for gas-fired instantaneous water heaters in residential applications.

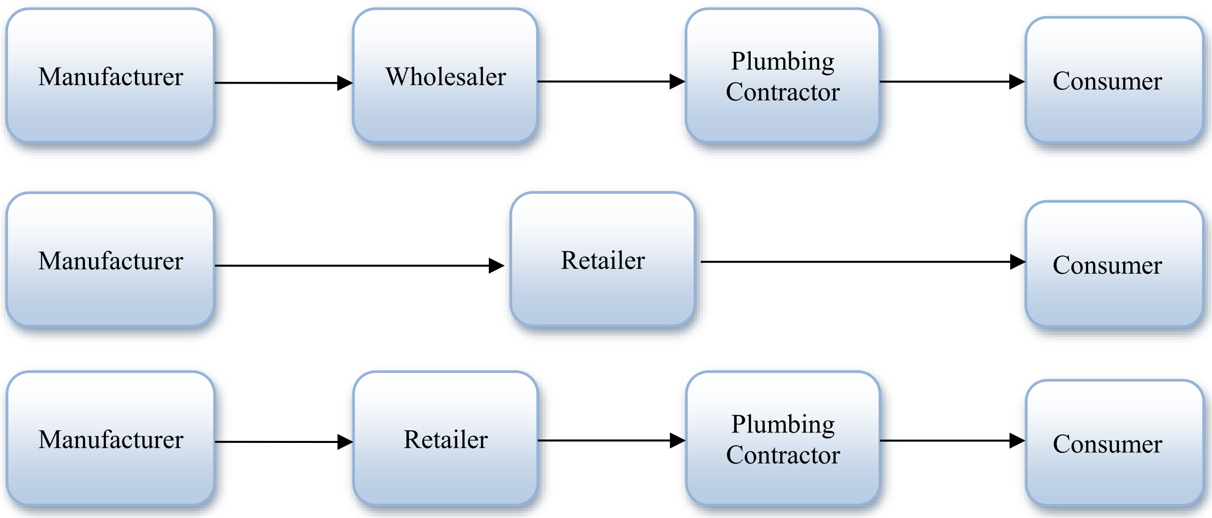

Figure 6.2.1 Distribution Channels for Gas-fired Instantaneous Water Heaters in Residential Applications (Replacement and New Owner)

Table 6.2.3 Market Shares for Distribution Channels in the Replacement and New Owner Market in Residential Applications (Not Including Mobile Home)

Distribution Channel	Market Share (%)
Mfr → Wholesaler → Contractor → Consumer	55
Mfr → Retailer → Consumer	40
Mfr → Retailer → Contractor → Consumer	5

For mobile homes in replacement or new owner applications, the distribution channels are assumed to be the same as the replacement distribution channel for regular gas-fired instantaneous water heaters. Table 6.2.4 shows the market share of each distribution channel in the replacement and new owner market for gas-fired instantaneous water heaters installed in mobile homes.

Table 6.2.4 Market Shares for Distribution Channels in the Replacement and New Owner Market in Residential Applications (Mobile Homes)

Distribution Channel	Market Share (%)
Mfr → Wholesaler → Contractor → Consumer	55
Mfr → Retailer → Consumer	40
Mfr → Retailer → Contractor → Consumer	5

Mainly for gas-fired instantaneous water heaters in commercial applications, DOE considers an additional distribution channel for which the manufacturer sells the equipment to the wholesaler and then to the consumer through a national account under both replacement and new construction markets. This national account distribution channel is applicable to multi-family and small to mid-size commercial buildings where the on-site staff or internal personnel generally purchase equipment from wholesalers at lower prices due to the large volume purchased and perform the installation themselves. Occasionally, the equipment manufacturers and wholesalers can be the same entity, so the consumer selling price could potentially be even lower than the usual for national account channel. Figure 6.2.2 shows the national account distribution channels for gas-fired instantaneous water heaters. Table 6.2.5 shows the market share of each distribution channel in the replacement and new owner market for gas-fired instantaneous water heaters in commercial applications.

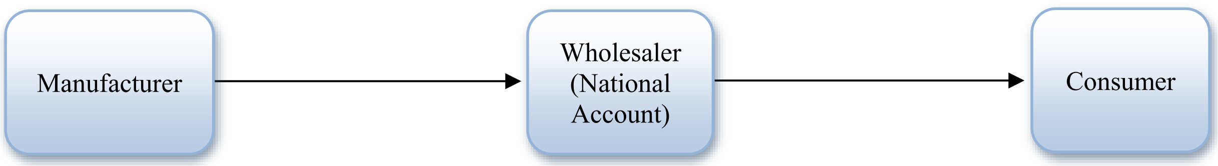

Figure 6.2.2 National Account Distribution Channel for Gas-fired Instantaneous Water Heaters Mostly in Commercial Applications (for Replacement, New Owner, or New Construction)

Table 6.2.5 Market Shares for Distribution Channels in the Replacement and New Owner Market in Commercial Applications

Distribution Channel	Market Share (%)
	GIWH
Mfr → Wholesaler → Contractor → Consumer	75
Mfr → Retailer → Consumer	5
Mfr → Retailer → Contractor → Consumer	5
Mfr → Consumer (National Account)	15

The new construction distribution channel includes an additional link in the chain—the builder. In the new construction distribution channel, the manufacturer sells the equipment to a wholesaler, who in turn sells it to a mechanical contractor, who in turn sells it to a builder then to the consumer. In most new home applications, the water heater is part of the overall plumbing package installed[g] by a plumbing contractor or, in the case of large building companies, by its own master plumber and crew. DOE believes that many builders are large enough to have a master plumber and not hire a separate contractor, and assigned about half of gas-fired instantaneous water heater shipments to new construction to this channel. DOE estimated that in the new construction market, 90 percent of the residential (not including mobile homes) and 80 percent in commercial applications goes through a wholesaler to builder channel and the rest go through national account distribution channel (Figure 6.2.3).

[g] Includes not just the water heater but also all cold and hot water piping, faucets, toilets, etc.

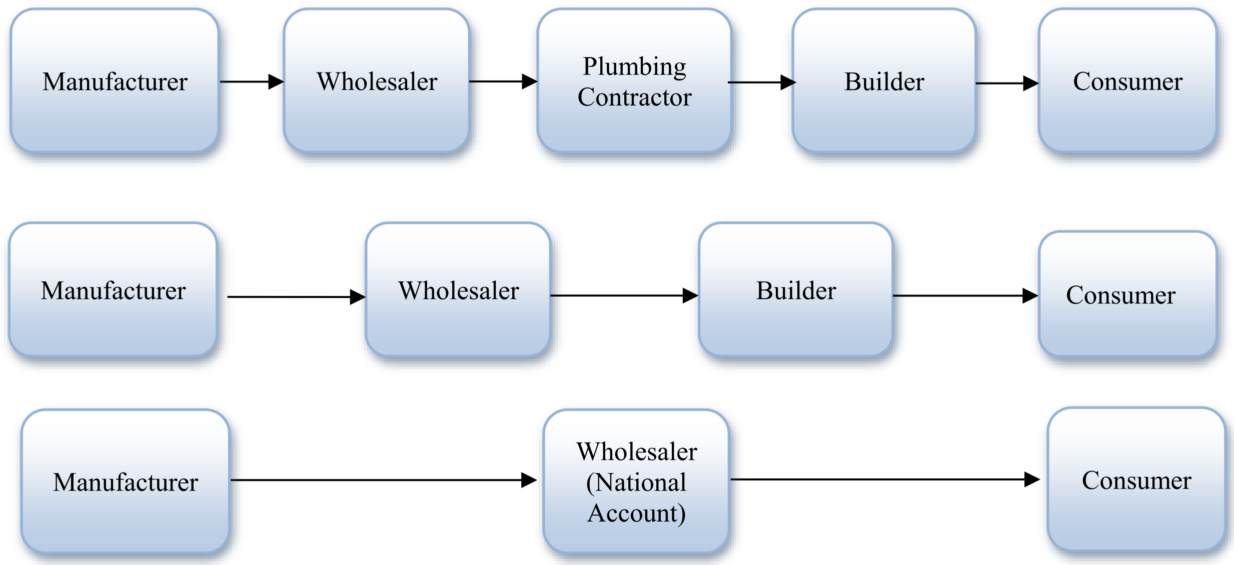

Figure 6.2.3 Distribution Channels for Gas-fired Instantaneous Water Heaters in New Construction (Residential and Commercial Applications, Not Including Mobile Homes)

DOE estimated that there is no gas-instantaneous water heater for mobile home in the new construction application.

6.3 MANUFACTURER MARKUP

DOE uses manufacturer markups to transform a manufacturer's product cost into a manufacturer selling price. A detailed description of the methodology used to derive manufacturer markups were described in chapter 12, Manufacturer Impact Analysis.

6.4 APPROACH FOR WHOLESALER, RETAILER AND CONTRACTOR MARKUPS

A change in energy efficiency standards usually increases the manufacturer selling price that wholesalers pay, and in turn the wholesale price that contractors would pay. In the past, DOE used the same markups as for baseline products to estimate the product price of more efficient product. Applying a fixed markup on higher manufacturer selling price would imply an increase in the dollar margin earned by wholesalers and contractors, and an increase in per-unit profit.

Based on microeconomic theory, the degree to which firms can pass along a cost increase depends on the level of market competition, as well as the market structure on both supply and demand side (e.g., supply and demand elasticity). DOE examined industry data from IBISWorld and the results suggest that most of the industries relevant to heating and air-conditioning wholesalers and contractors are generally quite competitive (see appendix 6B).[1] In addition, consumer demand for heating and air conditioning is relatively inelastic (i.e., demand is not expected to decrease substantially with an increase in the price of equipment). Under relatively competitive markets, it may be tenable for HVAC wholesalers and contractors to maintain a fixed markup for a short period of time after the input price increases, but the market competition should eventually force them to readjust their markups to reach a medium-term equilibrium of which per-unit profit is relatively unchanged before and after standards are implemented.

Thus, DOE concluded that applying fixed markups for both baseline products and higher-priced products meeting a standard is not viable in the medium to long term considering the competitive nature of the HVAC wholesale and contractor industry. DOE developed the incremental markup approach based on the widely accepted economic view that firms are not able to sustain a persistently higher dollar margin in a competitive market in the medium term. If the price of the product increases under standards, the only way to maintain the same dollar margin as before is for the markup (and percent gross margin) to decline.

To estimate the markup under standards, DOE derived an incremental markup that is applied to the incremental equipment costs of higher efficiency products. The overall markup on the products meeting standards is an average of the markup on the component of the cost that is equal to the baseline product and the markup on the incremental cost, weighted by the share of each in the total cost of the standards-compliant product.

DOE's incremental markup approach allows the part of the cost that is thought to be affected by the standard to scale with the change in manufacturer price. The income statements DOE used to develop wholesaler and contractor markups itemize firm costs into a number of expense categories, including direct costs to purchase or install the equipment, operating labor and occupancy costs, and other operating costs and profit. Although HVAC and plumbing wholesalers and contractors tend to handle multiple commodity lines, including room air conditioners, furnaces, central air conditioners and heat pumps, boilers, and water heaters, DOE contends that these aggregated data provide the most accurate available indication of the expenses associated with gas-fired instantaneous water heaters and the cost structure of distribution channel participants.

DOE uses these income statements to divide firm costs between those that are not likely to scale with the manufacturer price of equipment (labor and occupancy expenses, or "invariant" costs) and those that are (operating expenses and profit, or "variant" costs). For example, when the manufacturer selling price of equipment increases, only a fraction of a wholesaler's expenses increases (operating expenses and profit), while the remainder can be expected to stay relatively constant (labor and occupancy expenses). If the unit price of a gas-fired instantaneous water heater increases by 20 percent under standards, it is unlikely that the cost of secretarial support in an administrative office or office rental expenses will increase proportionally.

DOE reiterates that the incremental markup approach is most robust when modeling a highly competitive market with inelastic demand. See appendix 6B for further evidence supporting the use of incremental markups in this analysis. The derivation of incremental markups for wholesalers and contractors is described in the following sections.

6.4.1 Wholesaler Markups

DOE developed baseline and incremental wholesaler markups using the firm income statement for hardware and plumbing and heating equipment and supplies merchant wholesale sector from the 2017 U.S. Census *Annual Wholesale Trade Report (AWTR)*[2]. Baseline markups cover all the wholesaler's costs (both fixed and variable). DOE calculated the baseline markup for wholesalers using the following equation.

$$MU_{BASE} = \frac{CGS_{WHOLE} + GM_{WHOLE}}{CGS_{WHOLE}} = \frac{CGS_{WHOLE} + (IVC_{WHOLE} + VC_{WHOLE})}{CGS_{WHOLE}}$$

Eq. 6.1

Where:

MU_{BASE} = baseline wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold,
GM_{WHOLE} = wholesaler gross margin,
IVC_{WHOLE} = wholesaler invariant costs, and
VC_{WHOLE} = wholesaler variant costs.

Incremental markups are multipliers that relate the change in the MSP of products that meet the requirements of new efficiency standards to the change in the wholesaler sales price. Incremental markups cover only those costs that scale with a change in the MSP (i.e., variant costs, *VC*). DOE calculated the incremental markup (MU_{INCR}) for wholesalers using the following equation:

$$MU_{INCR} = \frac{CGS_{WHOLE} + VC_{WHOLE}}{CGS_{WHOLE}}$$

Eq. 6.2

Where:

MU_{INCR} = incremental wholesaler markup,
CGS_{WHOLE} = wholesaler cost of goods sold, and
VC_{WHOLE}= wholesaler variant costs.

6.4.2 Retailer Markups

According to the market assessment analysis and inputs from manufacturers, Home Depot and Lowe's comprise the majority of gas-fired instantaneous water heater sales that go through the retailer channel. Hence, DOE assumed that the markups used by Home Depot and Lowe's are representative of the markups for gas-fired instantaneous water heater retail industry. Both Home Depot and Lowe's are publicly owned company, so they are required by law to disclose financial information on a regular basis by the U.S. Securities and Exchange Commission (SEC). The annual 10-K report provides a comprehensive overview of the company's business and financial conditions. Relevant information required for calculating the markups includes the company's revenues and direct and indirect costs which are all available in the income statement section of the 10-K reports. Using the above assumptions, DOE applied the following two equations to calculate baseline and incremental markups with the financial data available from 10-K reports:

$$MU_{BASE} = \frac{Net\ Sales}{Cost\ of\ Sales}$$

Eq. 6.3

Incremental markups are coefficients that relate the change in the MSP of more energy-efficient models, or those products that meet the requirements of new energy conservation standards, to the change in the wholesaler sales price. DOE assumed that expenses like labor and occupancy costs remain fixed and need not be covered in the incremental markup. Profit and other operating costs were assumed to be variant and to scale with MSP. The SEC 10-K reports did not typically separate labor and occupancy costs from overall expenses, so DOE assumed that these fixed costs are encompassed by "selling, distribution and administrative expenses." DOE also assumed that "operating profit" (operating income) covers other operating costs and profit (i.e. variant cost). Each company's incremental markup was calculated as:

$$MU_{INCR} = 1 + \frac{Operating\ Profit}{Cost\ of\ Sales}$$

Eq. 6.4

6.4.3 Mechanical Contractor and Builder Markups

As both mechanical and general construction industries are relatively competitive, DOE used similar approach to develop contractor markups. The type of itemized financial data used to estimate wholesaler markups are also available for mechanical contractors and builders from 2017 Economic Census. DOE collected financial data from the Plumbing and HVAC Contractors (NAICS 238220) series[3], Residential Building Construction series (NAICS 236110),[4] and Commercial Building Construction series (NAICS 236220)[5] to estimate national average markups for mechanical contractors, residential builder, and commercial builder, respectively.

DOE calculated the national average baseline markup for mechanical and builders using the following equation:

$$MU_{BASE} = \frac{CGS_{CONT} + GM_{CONT}}{CGS_{CONT}} = \frac{CGS_{CONT} + (IVC_{CONT} + VC_{CONT})}{CGS_{CONT}}$$

Eq. 6.5

Where:

MU_{BASE}= baseline mechanical/builder markup,
CGS_{CONT}= mechanical/builder cost of goods sold,
GM_{CONT}= mechanical/builder gross margin,
IVC_{CONT}= mechanical/builder invariant cost, and
VC_{CONT} = mechanical/builder variant costs.

Analogously to wholesalers, DOE estimated the incremental mechanical contractor and builder markups by only marking up those costs that scale with a change in the MSP (variant costs, *VC*) for more energy-efficient products. As above, DOE assumed a division of costs between those that do not scale with the manufacturer price (labor and occupancy expenses), and those that do (other operating expenses and profit). Hence, DOE categorized the Census data into each major cost category and estimated incremental markups using the following equation:

$$MU_{INCR} = \frac{CGS_{CONT} + VC_{CONT}}{CGS_{CONT}}$$

Eq. 6.6

Where:

MU_{INCR} = incremental mechanical/builder markup,
CGS_{CONT} = mechanical/builder cost of goods sold, and
VC_{CONT} = mechanical/builder variant costs.

To differentiate mechanical contractor markups between replacement and new construction market, DOE relied on ACCA 2005 Financial Analysis as it provides gross margin as percent of sales for replacement and new construction market separately.[6] Therefore, the baseline markup for both markets can be derived with the following equation:

$$MU_{BASE} = \frac{Sales(\%)}{Sales(\%) - GM(\%)}$$

Eq. 6.7

DOE then calculated the markup ratios of replacement and new construction market to all mechanical contractors derived from ACCA 2005 Financial Analysis and applied those ratios to the national average markup results from 2017 Economic Census to develop the baseline and incremental markups for replacement and new construction markets.

6.5 DERIVATION OF MARKUPS

6.5.1 Derivation of Wholesaler Markups

The 2017 AWTS data for hardware and plumbing and heating equipment and supplies merchant wholesale provide total sales data and detailed operating expenses that are most relevant to gas-fired instantaneous water heater wholesalers. To construct a complete data set for estimating markups, DOE took the historical sales and gross margins published separated from the 2017 AWTS to construct a complete income statement for hardware and plumbing and heating equipment and supplies merchant to estimate both baseline and incremental markups. Table 6.5.1 summarizes the data and the calculation of the baseline and incremental wholesaler markups (see appendix 6A for cost details). These wholesaler markups are applicable to all gas-fired instantaneous water heaters in both residential and commercial applications.

Table 6.5.1 Wholesaler Expenses and Markups

Descriptions	Per Dollar Sales Revenue $	Per Dollar Cost of Goods $
Direct Cost of Equipment Sales	0.713	1.000
Labor and Occupancy Expenses	0.161	0.226
Other Operating Expenses	0.066	0.092
Operating Profit	0.061	0.085
Wholesaler Baseline Markup ($MU_{WHOLE\ BASE}$)		**1.403**
Incremental Markup ($MU_{WHOLE\ INCR}$)		**1.177**

Source: U.S. Census, 2017 Annual Wholesale Trade Survey

6.5.2 Derivation of Retailer Markups

DOE estimated the retailer markups based on 10-K reports for Home Depot and Lowe's. Table 6.5.2 summarizes the baseline and incremental markups for these two major home improvement centers respectively. The weighted average value is also shown in the table below.

Table 6.5.2 Home Improvement Center Expenses and Markups

Company	Financial Figures $1,000,000	Year				
		2018	**2019**	**2020**	**2021**	**2022**
The Home Depot	**Net Sales**	108,203	110,225	132,110	151,157	157,403
	Cost of Sales	71,043	72,653	87,257	100,325	104,625
	Operating Profit	15,530	15,843	18,278	23,040	24,039
	Baseline MU	1.52	1.52	1.51	1.51	1.50
	Incremental MU	1.22	1.22	1.21	1.23	1.23
	Average (Baseline/Incremental)	1.51/1.22				
Lowe's	**Net Sales**	71,309	72,148	89,597	96,250	97,059
	Cost of Sales	48,401	49,205	60,025	64,194	64,802
	Operating Profit	3,394	5,623	9,647	12,093	10,159
	Baseline MU	1.47	1.47	1.49	1.50	1.50
	Incremental MU	1.07	1.11	1.16	1.19	1.16
	Average (Baseline/Incremental)	1.49/1.14				
Weighted Average (Baseline/Incremental)		1.50/1.19				

Source: U.S. Securities and Exchange Commission, 10-K reports 2018 to 2022.[7]

6.5.3 Derivation of Mechanical Contractor Markups

6.5.3.1 Aggregate Markups for Mechanical Contractors

The 2017 Economic Census provides Geographic Area Series for the *Plumbing and HVAC Contractors* (NAICS 238220) sector, which contains national average sales and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the cost breakdown of gross margin, including labor expenses, occupancy expenses, other operating expenses, and profit. The gross margin provided by the U.S. Census is disaggregated enough that DOE was able to determine the invariant (labor and occupancy expenses) and variant (other operating expenses and profits) costs for this particular sector. By using the equation mentioned above, baseline and incremental markups were estimated. The markup results representing the plumbing and HVAC contractor industry at the national aggregated level are presented in Table 6.5.3. (Appendix 6A contains the full set of data.)

Table 6.5.3 Mechanical Contractor Expenses and Markups Based on Census Bureau Data

Description	**Mechanical Contractor Expenses or Revenue**	
	Per Dollar Sales Revenue ***$***	**Per Dollar Cost of Goods** ***$***
Direct Cost of Equipment Sales: Cost of goods sold	0.706	1.000
Labor Expenses: Salaries (indirect) and benefits	0.119	0.168
Occupancy Expense: Rent, maintenance, and utilities	0.014	0.021
Other Operating Expenses: Depreciation, advertising, and insurance.	0.073	0.103
Net Profit Before Taxes	0.088	0.124
Baseline Markup (*MUMECH BASE*): Revenue per dollar cost of goods		**1.416**
Incremental Markup (*MUMECH INCR*): Increased revenue per dollar increase in cost of goods sold		**1.227**

Source: U.S. Census Bureau. 2017. Plumbing, Heating, and Air-Conditioning Contractors. Sector 23: 238220. Construction: Industry Series, Preliminary Detailed Statistics for Establishments, 2017.

6.5.3.2 Markups for Mechanical Contractors in the Replacement and New Construction Markets

DOE derived the baseline and incremental markups for both replacement and new construction markets using the 2017 Economic Census industrial cost data supplemented with the most recent ACCA 2005 financial data. The 2017 Economic Census provides sufficient detailed cost breakdown for the *Plumbing and HVAC Contractors* (NAICS 238220) sector so that DOE was able to estimate baseline and incremental markups for mechanical contractors. However, the 2017 Economic Census does not separate the mechanical contractor market into replacement and new construction markets. To calculate markups for these two markets, DOE utilized 2005 ACCA financial data, which reports gross margin data for the entire mechanical contractor market and for both the replacement and new construction markets.

The HVAC contractors, defined here as mechanical contractors, reported median cost data in an ACCA 2005 financial analysis of the HVAC industry. These data are shown in Table 6.5.4.

Table 6.5.4 Baseline Markup, All Mechanical Contractors

Description	Contractor Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.7286	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2714	0.372
Revenue: Baseline revenue earned per dollar cost of goods		**1.372**
Baseline Markup (*$MU_{MECH\ CONT\ BASE}$*)		**1.372**

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.

Table 6.5.5 summarizes the gross margin and resulting baseline markup data for all mechanical contractors that serve the replacement and new construction markets.

Table 6.5.5 Baseline Markups for the Replacement and New Construction Markets, All Mechanical Contractors

Description	Contractor Expenses or Revenue by Market Type			
	Replacement		New Construction	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.7031	1.000	0.745	1.000
Gross Margin: Labor, occupancy, operating expenses, and profit	0.2969	0.422	0.255	0.342
Baseline Markup (*MUMECH CONT BASE*): Revenue per dollar cost of goods	NA	1.422	NA	1.342
% Difference from Aggregate Mechanical Contractor Baseline MU	NA	3.63%	NA	-2.20%

Source: Air Conditioning Contractors of America. 2005. Financial Analysis for the HVACR Contracting Industry.

Using the average baseline markups estimated for replacement and new construction market from Table 6.5.5 and the average baseline markup for all mechanical contractors from Table 6.5.4, DOE calculated that the baseline markups for the replacement and new construction markets are 3.63 percent higher and 2.20 percent lower, respectively, than for all mechanical contractors serving all markets.

The markup deviations (i.e., 3.63 percent higher and 2.20 percent lower for the replacement and new construction markets, respectively) derived for all mechanical contractors were then applied to the baseline markup of 1.416 and the incremental markup of 1.227 estimated for the *Plumbing and HVAC Contractors* (NAICS 238220) sector in Table 6.5.3. DOE assumed that this deviation applies equally to the baseline and incremental markups calculated from the 2017 Economic Census. The results of the baseline and incremental markups for the replacement and new construction markets served by mechanical contractors are shown in Table 6.5.6.

Table 6.5.6 Markups for the Replacement and New Construction Markets

	Baseline Markup	Incremental Markup
Replacement Market	1.471	1.274
New Construction Market	1.388	1.203

6.5.4 Derivation of Builder Markups

DOE derived markups for builders from U.S. Census Bureau data for the residential building construction and commercial building construction sectors to reflect the residential and commercial application of gas-fired instantaneous water heaters. The residential construction sector includes establishments primarily engaged in construction work, including new construction work, additions, alterations, and repairs of residential buildings, whereas the commercial construction sector includes establishments primarily responsible for the construction of commercial and institutional buildings. The U.S. Census Bureau data for the construction sector include detailed statistics for establishments with payrolls. The primary difference is that the U.S. Census Bureau reports itemized revenues and expenses for the construction industry as a whole in total dollars rather than in typical values for an average or representative business. Because of this, DOE assumed that the total dollar values that the U.S. Census Bureau reported, once converted to a percentage basis, represent revenues and expenses for an average or typical contracting business. Similar to the data for wholesalers, Table 6.5.7 summarizes the expenses for builders in residential building construction at the national aggregated level as expenses per dollar sales revenue in the first data column. (Appendix 6A contains the full set of data.)

Table 6.5.7 Residential Building Builders Expenses and Markups

Description	Builder Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.755	1.000
Labor Expenses: Salaries (indirect) and benefits	0.068	0.090
Occupancy Expense: Rent, maintenance, and utilities	0.010	0.013
Other Operating Expenses: Depreciation, advertising, and insurance.	0.053	0.070
Net Profit Before Taxes	0.114	0.151
Baseline Markup (*MUGEN CONT BASE*): Revenue per dollar cost of goods		**1.324**
Incremental Markup (*MUGEN CONT INCR*): Increased revenue per dollar increase in cost of goods sold		**1.221**

Source: U.S. Census Bureau. 2017. Residential Building Construction. Sector 23: 236115-236118. Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2017.

Table 6.5.8 summarizes the expenses for builders in commercial building construction at the national aggregated level as expenses per dollar sales revenue in the first data column. (Appendix 6A contains the full set of data.)

Table 6.5.8 Commercial Building Builder Expenses and Markups

Description	Builder Expenses or Revenue	
	Per Dollar Sales Revenue *$*	Per Dollar Cost of Goods *$*
Direct Cost of Equipment Sales: Cost of goods sold	0.793	1.000
Labor Expenses: Salaries (indirect) and benefits	0.062	0.079
Occupancy Expense: Rent, maintenance, and utilities	0.005	0.007
Other Operating Expenses: Depreciation, advertising, and insurance.	0.033	0.042
Net Profit Before Taxes	0.106	0.134
Baseline Markup (*MUGEN CONT BASE*): Revenue per dollar cost of goods		**1.261**
Incremental Markup (*MUGEN CONT INCR*): Increased revenue per dollar increase cost of goods sold		**1.176**

Source: U.S. Census Bureau. 2017. Sector 236220 (Commercial Building Construction). Construction: Industry Series: Preliminary Detailed Statistics for Establishments: 2017.

6.6 DERIVATION OF REGIONAL MARKUPS

DOE assumed a market saturation rate for gas-fired instantaneous water heaters that varies by state. Hence, to make the analysis more accurate, state-level markups were calculated for gas-fired instantaneous water heaters in residential applications as well as commercial applications.

6.6.1 Estimation of Wholesaler Markups

The 2017 AWTS does not provide state-level data; hence DOE developed the regional wholesaler markups based on the regional income statement from the 2013 HARDI Profit Report.[8] DOE estimated baseline and incremental markups for each of the seven HARDI regions (Northeastern, Mid-Atlantic, Southwestern, Great Lakes, Central, Southwestern, and Western) as well as at the national level using the methodology shown in Table 6.5.1. Next, the national to regional markup ratio was calculated, and each state in each region was assigned the corresponding ratio for the region to which it belongs. Then, DOE applied that ratio to the national average wholesaler baseline and incremental markups estimated in section 6.5.1 to derive the state-level wholesaler baseline and incremental markups. The results are summarized in Table 6.6.1.

Table 6.6.1 Wholesaler Markups for Gas-fired Instantaneous Water Heater in Residential Applications by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.370	1.173	Montana	1.447	1.186
Alaska	1.447	1.186	Nebraska	1.405	1.191
Arizona	1.447	1.186	Nevada	1.447	1.186
Arkansas	1.388	1.189	New Hampshire	1.407	1.146
California	1.447	1.186	New Jersey	1.396	1.167
Colorado	1.405	1.191	New Mexico	1.388	1.189
Connecticut	1.407	1.146	New York	1.407	1.146
Delaware	1.396	1.167	North Carolina	1.370	1.173
District of Colum.	1.396	1.167	North Dakota	1.405	1.191
Florida	1.370	1.173	Ohio	1.394	1.173
Georgia	1.370	1.173	Oklahoma	1.388	1.189
Hawaii	1.447	1.186	Oregon	1.447	1.186
Idaho	1.447	1.186	Pennsylvania	1.395	1.170
Illinois	1.405	1.191	Rhode Island	1.407	1.146
Indiana	1.394	1.173	South Carolina	1.370	1.173
Iowa	1.405	1.191	South Dakota	1.405	1.191
Kansas	1.405	1.191	Tennessee	1.370	1.173
Kentucky	1.394	1.173	Texas	1.388	1.189
Louisiana	1.388	1.189	Utah	1.447	1.186
Maine	1.407	1.146	Vermont	1.407	1.146
Maryland	1.396	1.167	Virginia	1.396	1.167
Massachusetts	1.407	1.146	Washington	1.447	1.186
Michigan	1.394	1.173	West Virginia	1.394	1.173
Minnesota	1.405	1.191	Wisconsin	1.405	1.191
Mississippi	1.370	1.173	Wyoming	1.405	1.191
Missouri	1.405	1.191			

6.6.2 Estimation of Mechanical Contractor Markups

The 2017 Economic Census provides Geographic Area Series for the *Plumbing and HVAC Contractors* (NAICS 23822) sector, which contains state-level sale and cost data, including value of construction, cost of subcontract work, cost of materials, and payroll for construction workers. It also provides the same cost breakdown of gross margin as described in section 6.4.1 including labor expenses, occupancy expenses, other operating expenses, and profit. With this level of disaggregation in data available, DOE was able to estimate statewide baseline and incremental markups by using the equation mentioned in section 6.4.2.

To estimate the baseline and incremental markups for both replacement and new construction markets for each state, DOE applied the markup deviations (i.e., 3.6 percent higher and 2.2 percent lower for the replacement and new construction markets, respectively) derived in section 6.5.3.2 to the statewide baseline and incremental markups. DOE assumed that this deviation of replacement and new construction markets applies equally to the baseline and incremental markups. The results are summarized in Table 6.6.2.

Table 6.6.2 Mechanical Contractor Markups for Gas-fired Instantaneous Water Heater by State

State	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
Alabama	1.491	1.294	1.408	1.221
Alaska	1.590	1.381	1.501	1.303
Arizona	1.376	1.198	1.298	1.130
Arkansas	1.376	1.209	1.298	1.141
California	1.530	1.323	1.444	1.249
Colorado	1.432	1.234	1.351	1.164
Connecticut	1.482	1.266	1.399	1.195
Delaware	1.492	1.281	1.409	1.209
District of Colum.	1.441	1.289	1.360	1.217
Florida	1.472	1.262	1.390	1.191
Georgia	1.552	1.361	1.465	1.285
Hawaii	1.517	1.324	1.431	1.250
Idaho	1.419	1.255	1.339	1.185
Illinois	1.456	1.267	1.374	1.196
Indiana	1.418	1.244	1.338	1.174
Iowa	1.369	1.195	1.292	1.128
Kansas	1.408	1.237	1.329	1.167
Kentucky	1.477	1.290	1.394	1.218
Louisiana	1.511	1.302	1.426	1.229
Maine	1.367	1.210	1.290	1.142
Maryland	1.441	1.258	1.360	1.188
Massachusetts	1.431	1.251	1.351	1.181
Michigan	1.530	1.320	1.444	1.246
Minnesota	1.396	1.230	1.318	1.161
Mississippi	1.348	1.185	1.273	1.118
Missouri	1.326	1.155	1.251	1.090
Montana	1.477	1.311	1.394	1.237
Nebraska	1.463	1.287	1.381	1.214
Nevada	1.421	1.231	1.341	1.162
New Hampshire	1.411	1.216	1.332	1.147
New Jersey	1.537	1.335	1.451	1.260
New Mexico	1.404	1.221	1.325	1.153

State	Replacement Baseline MU	Replacement Incremental MU	New Const. Baseline MU	New Const. Incremental MU
New York	1.496	1.310	1.412	1.236
North Carolina	1.469	1.270	1.387	1.198
North Dakota	1.363	1.193	1.286	1.126
Ohio	1.461	1.258	1.379	1.187
Oklahoma	1.451	1.233	1.369	1.164
Oregon	1.539	1.326	1.453	1.252
Pennsylvania	1.507	1.287	1.422	1.214
Rhode Island	1.399	1.212	1.320	1.144
South Carolina	1.513	1.307	1.427	1.234
South Dakota	1.393	1.214	1.315	1.146
Tennessee	1.467	1.232	1.384	1.162
Texas	1.475	1.277	1.392	1.205
Utah	1.386	1.226	1.308	1.157
Vermont	1.421	1.234	1.341	1.165
Virginia	1.501	1.303	1.417	1.230
Washington	1.371	1.168	1.294	1.102
West Virginia	1.484	1.263	1.401	1.192
Wisconsin	1.435	1.257	1.354	1.186
Wyoming	1.397	1.208	1.319	1.140

6.6.3 Estimation of Builder Markups

The 2017 Economic Census provide the state-level sale and cost data necessary to develop the baseline and incremental markups by state for commercial builders. However, only the regional level sale and cost data are available for residential builders. DOE used similar approach as described in section 6.6.2 to estimate the regional and state-level markups for residential and commercial builders. The results are summarized in Table 6.6.3 for residential application Table 6.6.4 for commercial application.

Table 6.6.3 Builder Markups for Gas-fired Instantaneous Water Heater in Residential Applications by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.356	1.263	Montana	1.339	1.240
Alaska	1.339	1.240	Nebraska	1.274	1.169
Arizona	1.339	1.240	Nevada	1.339	1.240
Arkansas	1.356	1.263	New Hampshire	1.261	1.144
California	1.339	1.240	New Jersey	1.261	1.144
Colorado	1.339	1.240	New Mexico	1.339	1.240
Connecticut	1.261	1.144	New York	1.261	1.144
Delaware	1.356	1.263	North Carolina	1.356	1.263
District of Colum.	1.356	1.263	North Dakota	1.274	1.169
Florida	1.356	1.263	Ohio	1.274	1.169
Georgia	1.356	1.263	Oklahoma	1.356	1.263
Hawaii	1.339	1.240	Oregon	1.339	1.240
Idaho	1.339	1.240	Pennsylvania	1.261	1.144
Illinois	1.274	1.169	Rhode Island	1.261	1.144
Indiana	1.274	1.169	South Carolina	1.356	1.263
Iowa	1.274	1.169	South Dakota	1.274	1.169
Kansas	1.274	1.169	Tennessee	1.356	1.263
Kentucky	1.356	1.263	Texas	1.356	1.263
Louisiana	1.356	1.263	Utah	1.339	1.240
Maine	1.261	1.144	Vermont	1.261	1.144
Maryland	1.356	1.263	Virginia	1.356	1.263
Massachusetts	1.261	1.144	Washington	1.339	1.240
Michigan	1.274	1.169	West Virginia	1.356	1.263
Minnesota	1.274	1.169	Wisconsin	1.274	1.169
Mississippi	1.356	1.263	Wyoming	1.339	1.240
Missouri	1.274	1.169			

Table 6.6.4 Builder Markups for Gas-fired Instantaneous Water Heaters in Commercial Applications by State

State	Baseline MU	Incremental MU	State	Baseline MU	Incremental MU
Alabama	1.308	1.230	Montana	1.385	1.294
Alaska	1.257	1.120	Nebraska	1.172	1.097
Arizona	1.257	1.179	Nevada	1.359	1.267
Arkansas	1.258	1.184	New Hampshire	1.303	1.193
California	1.257	1.162	New Jersey	1.243	1.152
Colorado	1.257	1.194	New Mexico	1.110	1.030
Connecticut	1.243	1.153	New York	1.229	1.131
Delaware	1.258	1.151	North Carolina	1.258	1.188
District of Colum.	1.258	1.152	North Dakota	1.266	1.170
Florida	1.231	1.144	Ohio	1.249	1.164
Georgia	1.258	1.187	Oklahoma	1.173	1.097
Hawaii	1.257	1.157	Oregon	1.131	1.057
Idaho	1.257	1.158	Pennsylvania	1.257	1.162
Illinois	1.261	1.185	Rhode Island	1.243	1.172
Indiana	1.337	1.228	South Carolina	1.259	1.183
Iowa	1.266	1.192	South Dakota	1.266	1.192
Kansas	1.266	1.200	Tennessee	1.185	1.107
Kentucky	1.215	1.142	Texas	1.208	1.129
Louisiana	1.258	1.170	Utah	1.741	1.657
Maine	1.243	1.153	Vermont	1.243	1.128
Maryland	1.680	1.577	Virginia	1.305	1.238
Massachusetts	1.243	1.161	Washington	1.182	1.100
Michigan	1.266	1.181	West Virginia	1.258	1.150
Minnesota	1.266	1.171	Wisconsin	1.278	1.191
Mississippi	1.258	1.150	Wyoming	1.257	1.152
Missouri	1.266	1.162			

6.7 SALES TAX

The sales tax represents state and local sales taxes that are applied to the consumer price of the equipment. The sales tax is a multiplicative factor that increases the consumer equipment price. DOE only applied the sales tax to the consumer price of the equipment in the replacement market, not the new construction market. The common practice for selling larger residential appliances like gas-fired instantaneous water heaters in the new construction market is that builders (or general contractors) bear the added sales tax for equipment, in addition to the cost of equipment, and then mark up the entire cost in the final listing price to consumers. Therefore, no additional sales tax is necessary to calculate the consumer equipment price for the new construction market.

DOE derived state and local taxes from data provided by the Sales Tax Clearinghouse.[9] These data represent weighted averages that include county and city rates. DOE applied the state sales taxes to match the state-level markups for wholesalers and mechanical and builders, as shown in Table 6.7.1.

Table 6.7.1 State Sales Tax Rates

State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %	State	Combined State and Local Tax Rate %
Alabama	8.75%	Kentucky	6.00%	North Dakota	6.25%
Alaska	1.30%	Louisiana	9.40%	Ohio	7.25%
Arizona	7.30%	Maine	5.50%	Oklahoma	8.60%
Arkansas	9.15%	Maryland	6.00%	Oregon	--
California	8.80%	Massachusetts	6.25%	Pennsylvania	6.35%
Colorado	6.40%	Michigan	6.00%	Rhode Island	7.00%
Connecticut	6.35%	Minnesota	7.50%	South Carolina	7.45%
Delaware	--	Mississippi	7.05%	South Dakota	6.00%
Dist. of Columbia	6.00%	Missouri	7.10%	Tennessee	9.50%
Florida	7.00%	Montana	--	Texas	8.00%
Georgia	7.45%	Nebraska	6.10%	Utah	7.15%
Hawaii	4.45%	Nevada	8.25%	Vermont	6.10%
Idaho	6.05%	New Hampshire	--	Virginia	5.75%
Illinois	8.60%	New Jersey	6.60%	Washington	9.35%
Indiana	7.00%	New Mexico	6.90%	West Virginia	6.15%
Iowa	6.95%	New York	8.45%	Wisconsin	5.45%
Kansas	8.45%	North Carolina	7.00%	Wyoming	5.45%

6.8 OVERALL MARKUPS

The overall markup for each distribution channel is the product of the appropriate markups, as well as the sales tax in the case of replacement applications (Table 6.7.1).

DOE used the overall baseline markup to estimate the consumer product price of baseline models, given the manufacturer cost of the baseline models. As stated previously, DOE considers baseline models to be products sold under existing market conditions (i.e., without new energy conservation standards). The following equation shows how DOE used the overall baseline markup to determine the product price for baseline models.

$$CPP_{BASE} = COST_{MFG} \times \left(MU_{MFG} \times MU_{BASE} \times Tax_{SALES}\right) = COST_{MFG} \times MU_{OVERALL\_BASE}$$

Eq. 6.8

Where:

CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
MU_{MFG} = manufacturer markup,
MU_{BASE} = baseline replacement or new home channel markup,

Tax_{SALES} = sales tax (replacement applications only), and
$MU_{OVERALL\_BASE}$ = baseline overall markup.

Similarly, DOE used the overall incremental markup to estimate changes in the consumer product price, given changes in the manufacturer cost from the baseline model cost resulting from an energy conservation standard to raise product energy efficiency. The total consumer product price for more energy-efficient models is composed of two components: the consumer product price of the baseline model and the change in consumer product price associated with the increase in manufacturer cost to meet the new energy conservation standard. The following equation shows how DOE used the overall incremental markup to determine the consumer product price for more energy-efficient models (i.e., models meeting new energy conservation standards).

$$\begin{aligned} CPP_{STD} &= COST_{MFG} \times MU_{OVERALL\_BASE} + \Delta COST_{MFG} \times \left(MU_{MFG} \times MU_{INCR} \times Tax_{SALES} \right) \\ &= CPP_{BASE} + \Delta COST_{MFG} \times MU_{OVERALL\_INCR} \end{aligned}$$

Eq. 6.9

Where:

CPP_{STD} = consumer product price for models meeting new energy conservation standards,
CPP_{BASE} = consumer product price for baseline models,
$COST_{MFG}$ = manufacturer cost for baseline models,
$\Delta COST_{MFG}$ = change in manufacturer cost for more energy-efficient models,
MU_{MFG} = manufacturer markup,
MU_{INCR} = incremental replacement or new home channel markup,
Tax_{SALES} = sales tax (replacement applications only),
$MU_{OVERALL\_BASE}$ = baseline overall markup (product of manufacturer markup, baseline replacement or new home channel markup, and sales tax), and
$MU_{OVERALL\_INCR}$ = incremental overall markup.

National weighted average baseline and incremental markups for each market participant are summarized in Table 6.8.1 to Table 6.8.3 for gas-fired instantaneous water heaters. These values represent the weighted average markups based on the state-level markup values. Based on gas-fired instantaneous water heater shipment forecasts for the year 2030, DOE estimated the fraction that go to new construction and replacement/new owner market as well as residential and commercial applications (see Table 6.2.1 and Table 6.2.2). By weighing the markups by the market shares for gas-fired instantaneous water heaters, total markups are listed in Table 6.8.5.

Table 6.8.1 Summary of Overall Markups on Gas-fired Instantaneous Water Heaters (Including Mobile Home) for Replacements and New Owners in Residential Applications

Replacement and New Owner Market	Manufacturer → Wholesaler → Plumbing Contractor → Consumer		Manufacturer → Retailer → Plumbing Contractor → Consumer	
Market Share	55%		5%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.45		1.45	
Wholesaler/Distributor	1.40	1.18		
Retailer			1.51	1.18
Mechanical Contractor	1.47	1.27	1.47	1.27
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup				
GIWH	**3.20**	**2.33**	**3.45**	**2.33**

Replacement and New Owner Market	Manufacturer → Retailer → Consumer	
Market Share	40%	
	Baseline	Incremental
Manufacturer	1.45	
National Account		
Retailer	1.51	1.18
Sales Tax	1.073	1.073
Overall Markup		
GIWH	**2.35**	**1.84**

Note: Components may not multiply to the total markup due to rounding.

Table 6.8.2 Summary of Overall Markups on Gas-fired Instantaneous Water Heaters for Replacements and New Owners in Commercial Applications

Replacement and New Owner Market	Manufacturer → Wholesaler → Mechanical Contractor → Consumer		Manufacturer → Retailer → Mechanical Contractor → Consumer	
Market Share	75%		5%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.45		1.45	
Wholesaler/Distributor	1.40	1.18		
National Account				
Retailer			1.51	1.18
Mechanical Contractor	1.47	1.27	1.47	1.27
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup				
GIWH	**3.20**	**2.33**	**3.43**	**2.35**
Replacement and New Owner Market	Manufacturer →Retailer → Consumer		Manufacturer → National Account → Consumer	
Market Share	5%		15%	
	Baseline	Incremental	Baseline	Incremental
Manufacturer	1.45		1.45	
Wholesaler/Distributor				
National Account*			1.20	1.09
Retailer	1.51	1.18		
Mechanical Contractor				
Sales Tax	1.073	1.073	1.073	1.073
Overall Markup				
GIWH	**2.35**	**1.84**	**1.87**	**1.70**

* DOE assumed that the markups for national account is half of the wholesaler markups.
Note: Components may not multiply to the total markup due to rounding.

Table 6.8.3 Summary of Overall Markups on Gas-fired Instantaneous Water Heaters (Not Including Mobile Home) for New Construction in Residential Applications

New Construction	Manufacturer →Wholesaler → Mechanical Contractor → Builder → Consumer		Manufacturer →Wholesaler → Builder → Consumer		Manufacturer → National Account → Consumer	
Market Share	45%		45%		10%	
	Baseline	Incr.	Baseline	Incr.	Baseline	Incr.
Manufacturer	1.45		1.45		1.45	
Wholesaler/Distributor	1.40	1.18	1.40	1.18		
National Account*					1.20	1.09
Mechanical Contractor	1.39	1.20				
Builder	1.32	1.22	1.32	1.22		
Overall Markup						
GIWH	**3.70**	**2.50**	**2.68**	**2.09**	**1.74**	**1.58**

* DOE assumed that the markups for national account is half of the wholesaler markups.
Note: Components may not multiply to the total markup due to rounding.

Table 6.8.4 Summary of Overall Markups on Gas-fired Instantaneous Water Heaters for New Construction in Commercial Applications

New Construction	Manufacturer →Wholesaler → Mechanical Contractor → Builder → Consumer		Manufacturer →Wholesaler → Builder → Consumer		Manufacturer → National Account → Consumer	
Market Share	40%		40%		20%	
	Baseline	Incr.	Baseline	Incr.	Baseline	Incr.
Manufacturer	1.45		1.45		1.45	
Wholesaler/Distributor	1.40	1.18	1.40	1.18		
National Account*					1.20	1.09
Mechanical Contractor	1.39	1.20				
Builder	1.26	1.17	1.26	1.17		
Overall Markup						
GIWH	**3.56**	**2.40**	**2.56**	**2.00**	**1.74**	**1.58**

* DOE assumed that the markups for national account is half of the wholesaler markups.
Note: Components may not multiply to the total markup due to rounding.

Table 6.8.5 Summary of Total Markup of Gas-fired Instantaneous Water Heaters

Product Class	Distinguishing Characteristics (Rated Storage Volume and Input Rating)	Baseline Markup	Incremental Markup
GIWH	<2 gal and >50 kBtu/h	2.98	2.19

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CHAPTER 7. ENERGY USE ANALYSIS

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CHAPTER 7. ENERGY USE ANALYSIS

7.1 INTRODUCTION

The purpose of the energy use analysis is to determine the annual energy consumption of consumer gas-fired instantaneous water heaters in use in the United States and to assess the energy savings potential of increases in Uniform Energy Factor (UEF). These annual energy consumption estimates are used in life-cycle cost (LCC) and payback period (PBP) analysis described in chapter 8 to determine the operating cost savings[a] consumers would realize from more energy-efficient products and in the national impact analysis (NIA) described in chapter 10 to determine the unit energy consumption and the operating cost savings to estimate the national energy savings (NES) and net present value (NPV) respectively. In contrast to the current federal test procedure, which uses typical operating conditions in a laboratory setting, the energy use analysis in this chapter seeks to estimate the distribution of annual energy consumption for gas-fired instantaneous water heaters (GIWHs) in the field across a range of climate zones, building characteristics, and applications.

DOE calculated the energy use of gas-fired instantaneous water heaters. The calculation considers the primary factors that determine energy use:

- hot water use per household,
- the energy efficiency characteristics of the water heater, and
- water heater operating conditions.

As described in section 7.2, to represent actual residential and commercial consumers[b] likely to purchase and use of gas-fired instantaneous water heaters, U.S. Department of Energy (DOE) developed a water heater sample based primarily on data from the Energy Information Administration's (EIA) 2020 Residential Energy Consumption Survey (RECS 2020)[1] and EIA's 2018 Commercial Building Energy Consumption Survey (CBECS 2018).[2] These are the latest available surveys for residential households and commercial buildings. DOE used the samples not only to determine water heater annual energy consumption, but also as the basis for conducting the LCC analysis.

DOE used RECS 2020- or CBECS 2018-reported water heating energy consumption (based on the existing water heating system) to determine the daily hot water use of each household or building. The characteristics of each water heater's energy efficiency were taken from the engineering analysis. DOE developed water heater operating conditions from weather data and other relevant sources. Section 7.2 discusses the gas-fired instantaneous water heater consumer samples; section 7.3 discusses the relevant characteristics of water heater energy efficiency and operating conditions to calculate the annual energy consumption for water heaters.

[a] Energy costs, calculated using annual energy consumption and energy prices, are the most significant component of consumer operating costs.
[b] To accurately estimate the costs and benefits of potential standards, DOE must consider all applications of the covered product, including commercial-sector usage of a consumer product.

To complete the analysis, DOE calculated the energy savings of the more energy efficient water heaters compared to the baseline.

7.2 GAS-FIRED INSTANTANEOUS WATER HEATER SAMPLES

DOE's calculation of the annual energy use of gas-fired instantaneous water heaters relied on data from the Residential Energy Consumption Survey 2020[1] (RECS 2020), which was conducted by DOE's Energy Information Administration (EIA). RECS 2020 includes energy-related data from nearly 18,500 housing units that represent almost 123.5 million occupied households. RECS 2020 includes information such as the household or building owner demographics, fuel types used, energy consumption and expenditures, and other relevant data. DOE's calculation of the annual energy use of gas-fired instantaneous water heaters in commercial applications relied on data from the Commercial Building Energy Consumption Survey 2018 (CBECS 2018) [1], which was conducted by DOE's Energy Information Administration (EIA). CBECS 2018 includes energy-related data from 6,436 commercial buildings that represent almost 5.9 million buildings. Both RECS 2020 and CBECS 2018 weighting indicate how commonly each household configuration occurred in the general population in 2020 or 2018, respectively. DOE believes that the household records, along with their weightings, are representative of housing nationwide (see appendix 7A for details).

The subset of RECS 2020 and CBECS 2018 records used to study gas-fired instantaneous water heaters that met the following criteria.

- A tankless water heater served as the primary or secondary source of heated water.
- The water heater used one of two heating fuels (gas or propane).
- The water heater's energy consumption was greater than zero.

Table 7.2.1 and Table 7.2.2 summarize the gas-fired instantaneous water heater records in RECS 2020 and CBECS 2018, respectively. DOE adjusted the weights to account for boilers used for water heating in residential applications and commercial water heaters used in commercial applications. Appendix 7A presents the variables included and their definitions, as well as further information about the derivation of the samples.

Table 7.2.1 Selection of RECS 2020 Records for Gas-fired Instantaneous Water Heaters

Product Class	Algorithm*	No. of Records	RECS 2020 No. of U.S. Households Represented *(million)*	DOE 2030 No. of U.S. Shipments Represented *(million)*
Replacement				
Gas-fired instantaneous water heaters	(WHEATSIZ = 4 AND FUELH2O 1 or 2)	807	4.9	0.454
New Construction				
Gas-fired instantaneous water heaters	(WHEATSIZ = 4 AND FUELH2O 1 or 2), while YEARMADERANGE >= 7	307	1.6	0.421

* RECS 2020 variable definitions: WHEATSIZ = Main water heater size (4 = tankless); FUELH2O = Fuel used by main water heater (1 = Natural Gas; 2 = Propane); YEARMADERANGE = Range when housing unit was built (7 = 2000 to 2009; 8 = 2010 to 2015; 9 = 2016 to 2020). See appendix 7A for more details.

Table 7.2.2 Selection of CBECS 2018 Records for Gas-fired Instantaneous Water Heaters

Product Class	Algorithm	No. of Records	CBECS 2018 No. of U.S. Buildings Represented *(million)*	DOE 2030 No. of U.S. Shipments Represented *(million)*
Replacement				
Gas-fired instantaneous water heaters	WTHTEQ = 2 or 3 AND NGWATR = 1 or PRWATR = 1 AND 500 < NGWTBTU < 200,000	542	0.3	0.117
New Construction				
Gas-fired instantaneous water heaters	(WTHTEQ = 2 or 3 AND NGWATR = 1 or PRWATR = 1 AND 500 < NGWTBTU < 200,000), while YEARCON >=7	262	0.1	0.011

* CBECS 2018 variable definitions: WTHTEQ = Water heating equipment (1=Centralized water heaters; 2=Point-of-use water heaters; 3=Both types); NGWATR = Natural gas used for water heating (1 = Yes; 2 = No); PRWATR = Propane used for water heating (1 = Yes; 2 = No); YEARCON = Year of construction category (7 = 1990 to 1999, 8 = 2000 to 2012; 9 = 2013 to 2018). See appendix 7A for more details.

7.3 CALCULATION OF ENERGY CONSUMPTION

To calculate the energy use of gas-fired instantaneous water heaters, DOE determined the energy consumption associated with water heating and any auxiliary electrical use. The calculation used for determining total gas-fired instantaneous water heater energy use is:

$$Energy\ Use_{Total} = FuelUse + ElecUse$$

Eq. 7.1

Where:

$FuelUse$ = total fuel consumption as a result of hot water use (MMBtu/yr), and
$ElecUse$ = electrical consumption of all electrical components, including standby mode and off mode consumption (kWh/yr).

DOE calculated the energy use of gas instantaneous water heaters using a simplified and revised energy equation, the water heater analysis model (WHAM).[3] WHAM accounts for a range of operating conditions and energy efficiency characteristics of water heaters. To describe energy efficiency characteristics of GIWHs, WHAM uses parameters that are also used in the DOE test procedure:[4] recovery efficiency (RE) and rated input power (P_{ON}). Water heater operating conditions are indicated by the daily hot water draw volume, inlet water temperature, and thermostat setting.

7.3.1 Approach to Calculating Water Heater Energy Use

The WHAM equation yields average daily water heater energy consumption (Q_{in}). The equation is expressed as follows.

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Eq. 7.2

Where:

Q_{in} = total water heater energy consumption in British thermal units per day, Btu/day,
RE = recovery efficiency, %,
P_{ON} = rated input power, Btu/h,
UA = standby heat-loss coefficient, set as 0 for GIWHs, Btu/h-°F,
T_{tank} = thermostat set point temperature, °F,
T_{in} = inlet water temperature, °F,
T_{amb} = temperature of the ambient air, °F,
vol = volume of hot water drawn in 24 hours, gal/day,
den = density of stored water, set constant at 8.29 pounds per gallon, lb/gal, and
C_P = specific heat of stored water, set constant at 1.000743, Btu/lb-°F.

WHAM provides total water heater energy consumption. For gas-fired instantaneous water heaters, Q_{in} is the sum of fuel and electricity consumption, and the values for electricity and fuel consumption must be disaggregated. DOE calculated electricity consumption as follows:

$$Q_{electricity} = \frac{Q_{in}}{P_{ON}} \times \left(P_{aux} - P_{standby}\right) - P_{standby} \times 24$$

Eq. 7.3

Where:

$Q_{electricity}$ = electricity consumption, kWh/day,
Q_{in} = total water heater energy consumption, kWh/day,
P_{ON} = rated input power, kW,
P_{aux} = electricity demand when burner is on, kW, and
$P_{standby}$ = electricity demand when burner is off, kW.

7.3.2 Description of Key Variables

The following is a description of the key variables for calculating energy use by water heaters.

- ***Recovery Efficiency (RE)***. The recovery efficiency (*RE*) is the ratio of energy added to the water compared to the energy input to the water heater. It represents how efficiently energy is transferred to the water when the burner is firing. *RE* covers steady-state energy efficiency only. It accounts for the amount of energy lost through the flue and fittings while the burner is firing.

- ***Rated Input Power (P_{ON})***. Rated input power is the nominal power rating the manufacturer assigns to a particular design expressed in Btu/h.

- ***Set Point of Thermostat (T_{tank})***. The thermostat set point is the desired delivery temperature of the hot water.

- ***Inlet Water Temperature (T_{in})***. The inlet water temperature is the temperature of the water supplied to the water heater.

- ***Volume of Hot Water Drawn in 24-Hour Period (vol).*** The estimated daily household use of hot water.

- ***Density of Water (den)***. The density of hot water at the average of the set point and inlet temperatures (8.24 lb/gal). The density is mass per unit volume, expressed as lb/gal (kg/l).

- ***Specific Heat of Water (C_p)***. The specific heat of water at the average of the set point and inlet temperatures (1.000743 Btu/lb-°F). The specific heat is the amount of heat needed to increase or decrease the temperature of 1 pound mass of water by 1 °F (1 kJ/kg – Kelvin).

7.3.3 Derivation of Hot Water Use

Hot water use differs widely among households, because it depends on characteristics of the household and the water heater, such as the number and ages of the people who live in the household, the way they consume hot water, the presence of hot-water-using appliances, and thermostat set point of the water heater. DOE used RECS 2020 and CBECS 2018 water heating energy use estimates per sampled home or building to estimate the annual hot water use volume. The annual hot water use equation, derived from WHAM equations, is expressed as follows.

$$vol_{annual} = \frac{Q_{in,existing} - 24 \times UA \times (T_{tank} - T_{amb})}{\left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon, existing}\right)} \times \frac{RE_{existing}}{den \times C_P \times (T_{tank} - T_{in})}$$

Eq. 7.4

Where:

vol_{annual} =	annual hot water use volume, gal/year,
$Q_{in,existing}$ =	total water heater energy consumption in RECS 2020 or CBECS 2018, Btu/year,
UA =	set as 0 for GIWHs,
den =	density of water, lb/gal,
C_p =	specific heat of water, Btu/lb-°F,
T_{tank} =	set point of thermostat, °F,
T_{in} =	inlet water temperature, °F,
$RE_{existing}$ =	recovery efficiency of the existing equipment, %, and
$P_{ON,existing}$ =	rated input power of the existing equipment, Btu/h.

Figure 7.3.1 shows the range in hot water use among sample households. DOE calculated average daily hot water use to be 71 gallons for households having gas-fired instantaneous water heaters. These results are similar to recent field data and hot water draw models. [5,6,7,8,9,10,11]

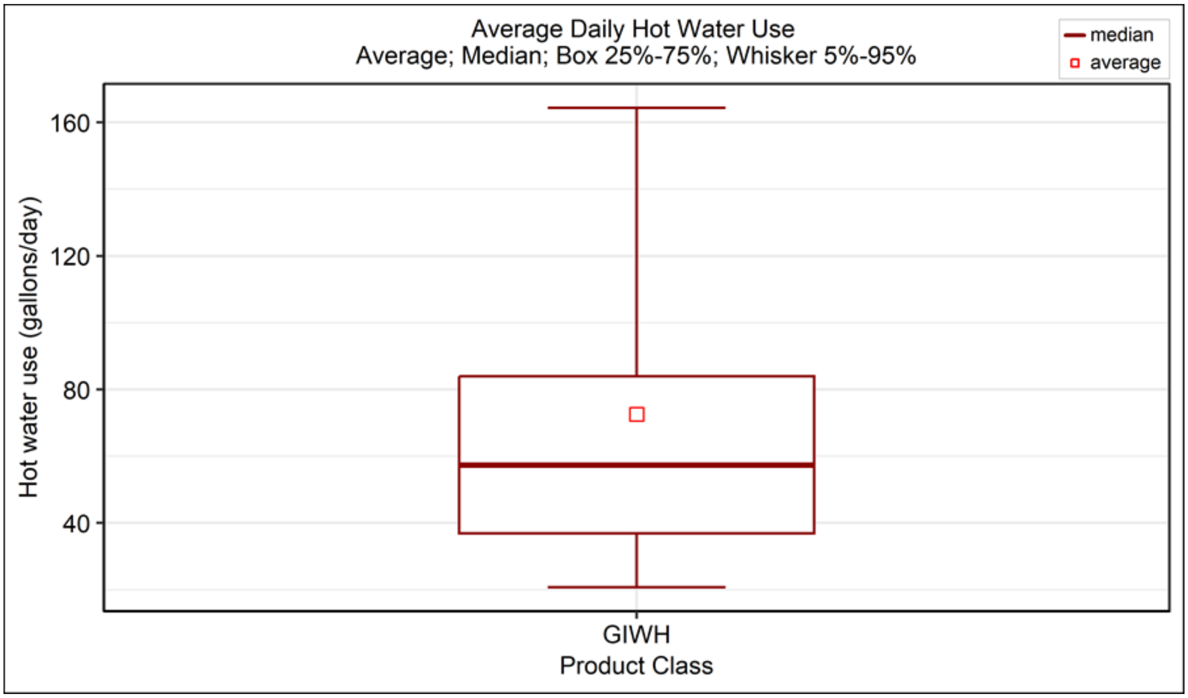

Figure 7.3.1 Range of Daily Hot Water Use in Sample Households for Gas-Fired Instantaneous Water Heaters

7.3.4 Assignment of Draw Patterns

In the LCC analysis, DOE accounted for different draw patterns. DOE gathered data from a variety of sources including:

1) AHRI certification directory[12] and DOE's public Certification Compliance Database (CCD)[13] with other publicly available data from manufacturers' catalogs of gas-fired instantaneous water heaters,
2) Combination of confidential data provided by AHRI from 2004-2007,[14]
3) Disaggregated shipments data from BRG Building Solutions 2023 report with shipment data from 2007 to 2022[15]

Table 7.3.1 shows the percentages of GIWH samples that were assigned to each draw pattern for the LCC analysis.

Table 7.3.1 Assignment of Draw Patterns to Sampled GIWH

Product Class	Draw Pattern		
	Low	Medium	High
Gas-fired Instantaneous Water Heaters	-	15%	85%

7.3.5 Derivation of Other Energy Parameters

Key parameters in DOE's calculation of water heater energy consumption are the recovery efficiency (*RE*) and the rated input power (P_{on}). DOE's test procedure for water heaters provided the definitions for these parameters.[28] DOE developed the parameters for selected energy efficiency level as described below. (See chapter 5 for a discussion of DOE's selection of energy efficiency levels.)

Determining RE. Table 7.3.2 shows the most common assignment of *RE* values for gas-fired instantaneous water heaters by efficiency level based on the distribution of models at each efficiency level.

Table 7.3.2 Assignment of *RE* for Gas-Fired Instantaneous Water Heaters

Efficiency Level	UEF		RE
	Med Draw	Large Draw	
0	0.81	0.81	82%
1	0.87	0.89	88%/90%
2	0.91	0.93	92%/94%
3	0.92	0.95	93%/96%
4	0.93	0.96	94%/97%

Determining $\boldsymbol{P_{ON}}$. DOE determined appropriate bins for rated input power (P_{ON}) based on the models listed in the AHRI Directory.[12] The most common assignment of the input capacity is shown in Table 7.3.3.

Table 7.3.3 Assignment of Input Capacity

Product Class	Input Capacity *(P_{ON})* *(kBtu/h)*
Gas-fired Instantaneous Water Heaters	120/199

7.3.6 Derivation of Temperatures

The temperatures for thermostat set point and inlet water temperature are derived from the average annual outdoor air temperature for each sample household.

7.3.6.1 Outdoor Air Temperature.

RECS 2020 provides data on heating and cooling degree-days, but not outdoor air temperatures for each household in the sample. To each RECS 2020 household DOE assigned a physical location from which outdoor air temperatures could be derived as follows:

- DOE assembled weather data from 282 weather stations that provide 30-year averages for annual average outdoor air temperatures.[16,17] DOE also gathered the heating and cooling degree-days at a base temperature of 65 ºF for 2020 for those weather stations.[18] The 2020 heating and cooling degree-days match the period used to determine the degree-days in RECS 2020.

- RECS 2020 reports both heating and cooling degree-days to base temperature 65 °F for each housing record. DOE assigned each RECS 2020 household to one of the 282 weather stations by calculating which station (within the appropriate census region or large state) gave the best fit of RECS 2020 data to weather data.

Details about the derivation of the annual average outdoor air temperatures for the RECS 2020 and CBECS 2018 water heater sample are provided in appendix 7C, Weather Data and Temperature Parameters for LCC Analysis. Figure 7.3.2 shows the range of average annual outdoor air temperatures among sample households.

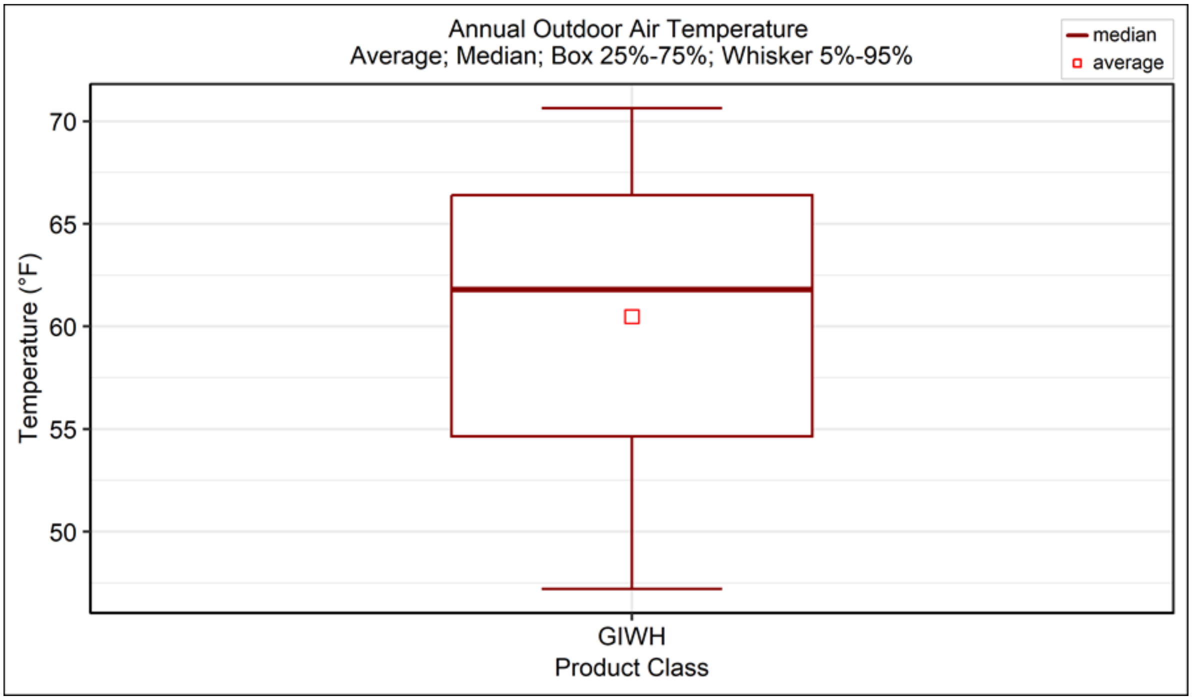

Figure 7.3.2 Range of Annual Outdoor Air Temperature for Sample Households for Gas-fired Instantaneous Water Heaters

7.3.6.2 Inlet Water Temperature

The inlet water comes to the water heater either from a municipal treatment plant or from ground well sources. RECS 2020 provides ground water temperature data for each household.

DOE then derived inlet water temperature using an approach developed by the National Renewable Energy Laboratory.[19,20] This approach accounts for seasonal variations in inlet water temperature as a function of annual average outdoor air temperature. The monthly average inlet water temperature varies directly with the average annual outdoor air temperature corrected by an offset term. The equation for inlet water temperature has the following form:

$$T_{IN} = T_{air,avg} + offset + lag$$

Eq. 7.5

The calculation details and the parameter definitions are described in appendix 7B. DOE calculated the offset using data from cold water inlet temperatures for select U.S. locations available in the HOTCALC Commercial Water Heating Performance Simulation Tool.[21] shows the range of inlet water temperatures among sample households.

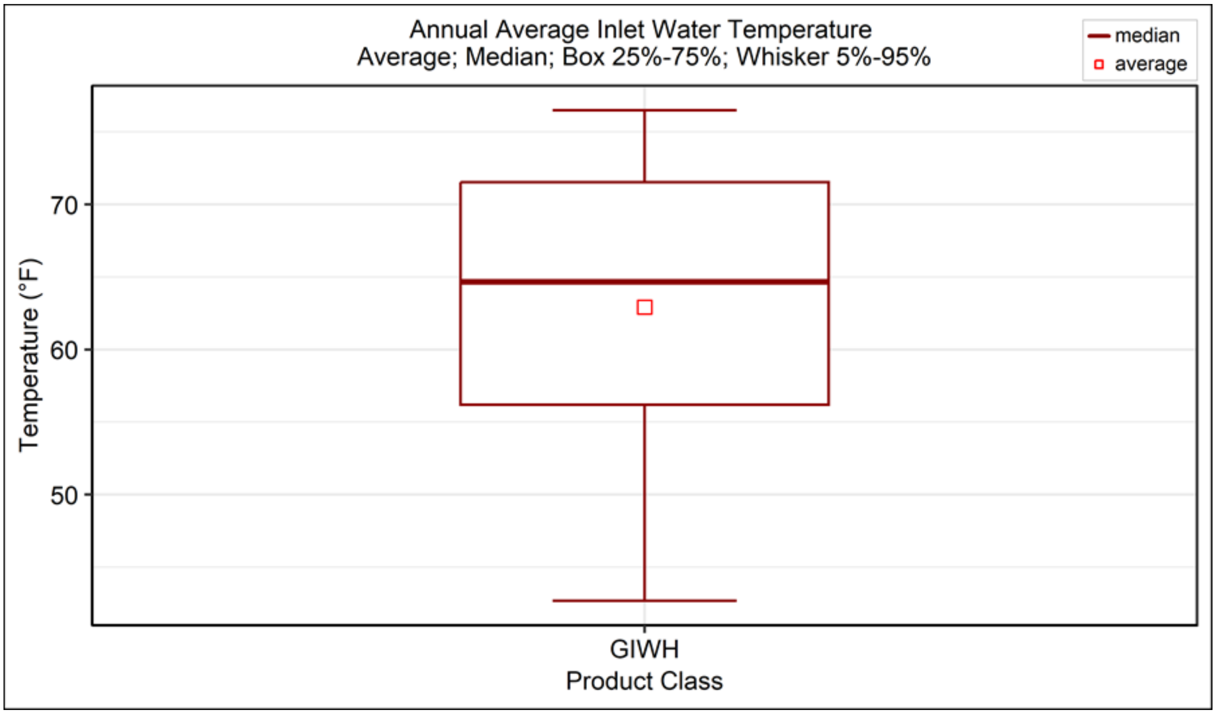

Figure 7.3.3 Range of Daily Average Annual Inlet Water Temperature for Sample Households for Gas-fired Instantaneous Water Heaters

7.3.6.3 Water Heater Thermostat Settings

DOE assigned water heater thermostat settings to the RECS 2020 households based on a 2006-2017 contractor survey from ClearSeas.[22,23] The information about thermostat settings reflects the results from a survey of more than 300 plumbing/hydronic heating contractor firms per survey year that install water heaters throughout the United States in new and replacement markets.

The survey indicated that 31 percent of responding contractors always install a water heater with a set point temperature of 120 °F; 45 percent usually install the water heater with a thermostat at 120 °F. In total, over 75 percent usually or always set the setpoint temperature to 120 °F. Based on this information, DOE estimated that a total of 70 percent of water heaters set to 120 °F, with 30 percent uniformly distributed between 121 °F and 140 °F.[c] This approach resulted in a mean temperature set point of 123 °F for the RECS water heater household sample. This aligns with available field data.[9]

[c] 140 °F is the maximum allowed to avoid scalding.

Although many water heaters are shipped having the thermostat set to 120 °F, several factors may cause contractors and/or household occupants to increase the set-point temperature, such as:

- High hot water draws: Increasing the set point temperature decreases the likelihood of running out of hot water.
- Cold inlet water: Increasing the set point temperature can help compensate for the mixture produced by very cold water and hot water.

7.4 SUMMARY OF ENERGY USE RESULTS

This section presents the average annual energy use for each considered energy efficiency level compared to the baseline energy. For its LCC and PBP analyses, DOE used the full distribution of energy use values calculated for the sample households.

Table 7.4.1 lists the average annual energy use for gas-fired instantaneous water heaters by efficiency levels and draw patterns.

Table 7.4.1 Annual Energy Consumption for Gas-fired Instantaneous Water Heaters

EL	Low			Medium			High		
	UEF	Annual Fuel Use (MMBtu/yr)	Annual Elec Use (kWh/yr)	UEF	Annual Fuel Use (MMBtu/yr)	Annual Elec Use (kWh/yr)	UEF	Annual Fuel Use (MMBtu/yr)	Annual Elec Use (kWh/yr)
Instantaneous Gas-Fired Water Heaters, <2 gal and >50,000 Btu/h									
0				0.81	16.8	33.7	0.81	15.6	32.0
1				0.87	15.7	39.4	0.89	14.2	37.2
2				0.91	15.0	39.0	0.93	13.6	36.9
3				0.92	14.8	38.9	0.95	13.3	36.8
4				0.93	14.7	27.3	0.96	13.2	24.8

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CHAPTER 8. LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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CHPATER 8. LIFE-CYCLE COST AND PAYPACK PERIOD ANALYSIS

8.1 INTRODUCTION

This chapter describes the U.S. Department of Energy (DOE)'s method for analyzing the economic impacts on individual consumers from potential energy efficiency standards for gas-fired instantaneous water heaters. The effects of standards on individual consumers include a change in purchase price (usually an increase) and a change in operating costs (usually a decrease). This chapter describes three metrics DOE used to determine the impact of standards on individual consumers:

- **Life-cycle cost** (LCC) is the total consumer expense during the lifetime of an appliance (or other equipment), including total installed cost (manufacturer selling price, distribution chain markups, sales tax, and installation costs) and operating costs (expenses for energy use, maintenance, and repair). DOE discounts future operating costs to the year of purchase and sums them over the lifetime of the product.
- **Payback period** (PBP) measures the amount of time it takes a consumer to recover the higher purchase cost (including installation) of a more energy efficient product through lower operating costs. DOE calculates a simple payback period which does not discount operating costs.
- **Rebuttable payback period** is a special case of the PBP. Whereas the LCC is estimated for a range of inputs that reflect real-world conditions, the rebuttable payback period energy use estimates are based on laboratory conditions as specified in the DOE test procedure.

Inputs to the LCC and PBP analysis are discussed in sections 8.2, 8.3, and 8.4. Results for each metric are presented in section 8.5.

DOE performed the calculations discussed herein using a Microsoft Excel® spreadsheet that is accessible at https://www.energy.gov/eere/buildings/consumer-water-heaters. The LCC spreadsheet model generates a Monte Carlo simulation using Crystal Ball (a commercially available software program) to perform the analysis by incorporating uncertainty and variability considerations in certain of the key parameters as discussed further in section 8.1.1. Details and instructions for using the spreadsheet are provided in appendix 8A of this technical support document (TSD).

8.1.1 General Analysis Approach

Life-cycle cost is calculated using the following equation:

$$LCC = TIC + \sum_{t=1}^{N} \frac{OC_t}{(1+r)^t}$$

Eq. 8.1

Where:

LCC =	life-cycle cost (in dollars),
TIC =	total installed cost in dollars,
$\sum$ =	sum over the appliance lifetime, from year 1 to year N,
N =	lifetime of the appliance in years,
OC =	operating cost in dollars,
r =	discount rate, and
t =	year to which operating cost is discounted.

The payback period is the ratio of the increase in total installed cost (i.e., from a less energy efficient design to a more efficient design) to the decrease in annual operating expenditures. This type of calculation results in what is termed a simple payback period, because it does not take into account changes in energy expenses over time or the time value of money. That is, the calculation is done at an effective discount rate of zero percent. The equation for PBP is:

$$PBP = \frac{\Delta TIC}{\Delta OC}$$

Eq. 8.2

Where:

PBP =	payback period (in years),
ΔTIC =	difference in total installed cost between a more energy efficient design and the baseline design, and
ΔOC =	difference in first year annual operating cost.

Payback periods are expressed in years. Payback periods greater than the life of the product indicate that the increased total installed cost is not recovered through reduced operating expenses.

Recognizing that inputs to the determination of consumer LCC and PBP may be either variable or uncertain, DOE conducts the LCC and PBP analysis by modeling both the uncertainty and variability of certain key inputs using Monte Carlo simulation and probability distributions for the inputs rather than single-point values. Therefore, the outcomes of the Monte Carlo analysis can also be expressed as probability distributions. As a result, the Monte Carlo analysis produces a range of LCC results. A distinct advantage of this type of approach is that DOE can identify the percentage of consumers achieving LCC savings due to an increased efficiency level, in addition to the average LCC savings. The LCC and PBP Monte Carlo model was developed using Microsoft Excel spreadsheets combined with Crystal Ball. Appendix 8B provides a detailed explanation of Monte Carlo simulation and the use of probability distributions and discusses the tool used to incorporate these methods. Details and instructions for using the spreadsheet are provided in appendix 8A.

DOE calculates LCC impacts relative to a case without amended or new energy conservation standards (referred to as the "no-new-standards case"). In the no-new-standards case, some consumers may purchase products with energy efficiency higher than a baseline model. For any given standard level under consideration, consumers expected to purchase a product with efficiency equal to or greater than the considered level in the no-new-standards case would be unaffected by that standard. See section 8.4 and appendix 8I for more details about the derivation of the no-new-standards case efficiency distributions. The PBP results are displayed compared to the baseline efficiency level.

DOE expresses all costs in 2023$. DOE calculates the LCC and PBP as if all consumers purchase the product in the expected initial year of compliance with a new or amended standard. At this time, the expected compliance date of potential energy conservation standards for gas-fired instantaneous water heaters manufactured in, or imported into, the United States is in 2030.[a] Therefore, DOE conducted the LCC and PBP analysis assuming purchases take place in 2030.

8.1.2 Overview of Analysis Inputs

The LCC analysis uses inputs for establishing (1) the purchase expense, otherwise known as the total installed cost, and (2) the operating costs over the product lifetime. Future operating costs are discounted to the time of purchase and summed over the lifetime of the product.

The primary inputs for establishing the total installed cost are:

- *Baseline manufacturer cost*: The costs incurred by the manufacturer to produce products that meet current minimum efficiency standards, or another efficiency level designated as the baseline for analysis.

- *Standard-level manufacturer cost*: The manufacturer cost (or cost increase) associated with producing products that meet particular efficiency levels above the baseline.

- *Markups and sales tax*: The markups and sales tax associated with converting the manufacturer cost to a consumer product cost.

- *Installation cost*: Installation cost is the cost to the consumer of installing the product. The installation cost represents all costs required to install the product but does not include the marked-up consumer product price. The installation cost includes labor, overhead, and any miscellaneous materials and parts.

The primary inputs for calculating the operating cost are:

- *Product energy consumption*: The product energy consumption is the site energy use associated with operating the product.

[a] Pursuant to 42 U.S.C. 6295(m), the compliance date of any new energy efficiency standard for consumer water heaters is 5 years after the final rule is published. Consistent with its published regulatory agenda, DOE assumed that the final rule would be issued by the end of 2024 and that, therefore, the new standards would require compliance beginning in 2030.

- *Energy prices*: The prices consumers pay for energy (*e.g.*, electricity and natural gas).

- *Energy price trends*: The annual rates of change projected for energy prices during the study period.

- *Maintenance costs*: The labor and material costs associated with maintaining the operation of the product.

- *Repair costs*: The labor and material costs associated with repairing or replacing components that have failed.

- *Lifetime*: The age at which the product is retired from service.

- *Discount rates*: The rates at which DOE discounts future expenditures to establish their present value.

The inputs for calculating the PBP are the total installed cost and the first-year operating costs. The inputs to operating costs are the first-year energy cost and the annualized repair cost and the annualized maintenance cost. The PBP uses the same inputs as the LCC analysis, except the PBP does not require energy price trends or discount rates.

The PBP is the increase in purchase cost of a higher efficiency product divided by the change in annual operating cost of the product. It represents the number of years that it will take the consumer to recover the increased purchase cost through decreased operating costs. In the PBP calculation, future costs are not discounted.

Figure 8.1.1 depicts the relationships among the inputs to installed cost and operating cost for calculating a product's LCC and PBP. In the figure, the tan boxes indicate inputs, the green boxes indicate intermediate outputs, and the blue boxes indicate final outputs.

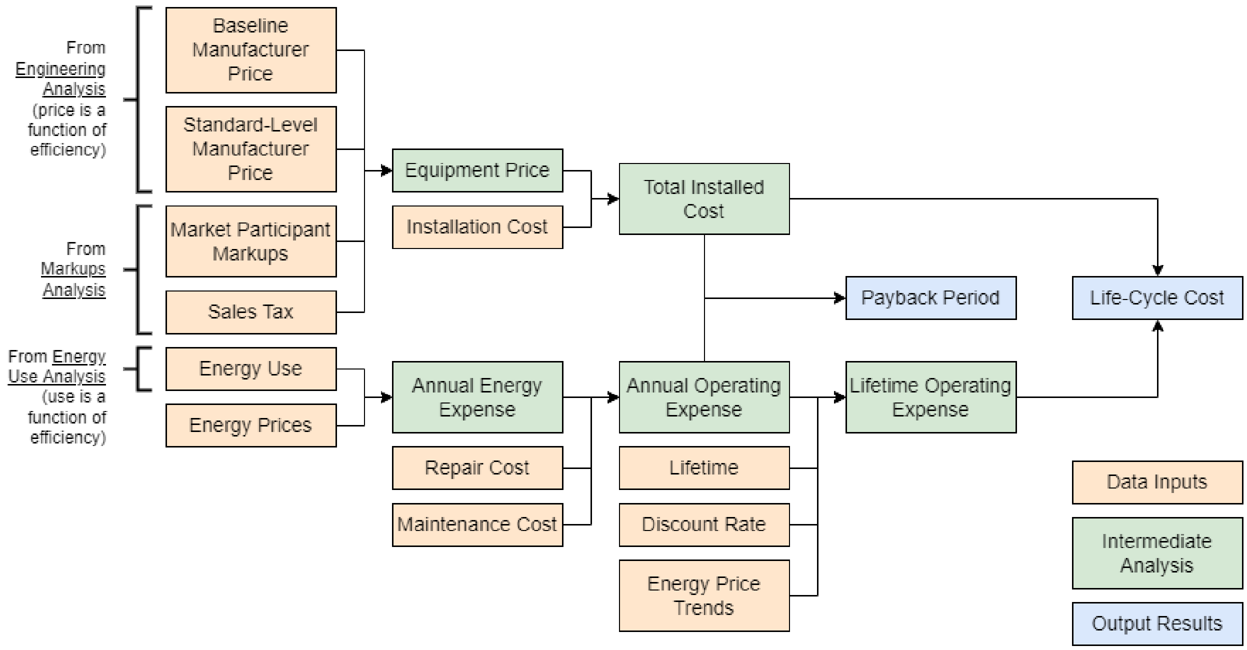

Figure 8.1.1 Flow Diagram of Inputs for the Determination of LCC and PBP

Table 8.1.1 provides a summary of inputs, with a greater degree of detail, used in the analysis. As noted earlier, most of the inputs are characterized by probability distributions that capture variability in the input variables.

Table 8.1.1 Summary of Inputs and Key Assumptions Used in the LCC and PBP Analysis

Inputs	Description
Affecting Total Installed Costs	
Product Price	Derived from the manufacturer production cost (MPC) for gas-fired instantaneous water heater units at different draw patterns. The MPCs and the shipping costs are then multiplied by the various market participant markups (*e.g.*, manufacturer, wholesaler, and plumbing contractor) for each distribution channel and sales taxes derived for each state and the District of Columbia (see chapter 6).
Installation Cost	Varies by efficiency level and individual house/building characteristic. Material and labor costs are derived for each state and the District of Columbia mainly using *RSMeans Residential Cost Data 2023*.[1] Overhead and profits are included in the RSMeans data. Probability distributions are derived for various installation cost input parameters (see appendix 8D).
Affecting Operating Costs	
Annual Energy Use	Derived mainly by using the heating energy use data for each housing unit and building from Energy Information Administration (EIA)'s 2020 *Residential Energy Consumption Survey* (*RECS* 2020) and EIA's 2018 *Commercial Buildings Energy Consumption Survey* (*CBECS* 2018) together with gas-fired instantaneous water heater test procedure calculation methodologies used to determine the annual energy consumption associated with the considered standard levels.[2,3] Probability distributions are derived for various input parameters (see chapter 7).
Energy Prices	Calculated monthly marginal average electricity and natural gas in each of the 50 U.S. states and District of Colombia using EIA historical data and billing data for each RECS 2020 housing unit and CBECS 2018 building. Residential and commercial prices were projected by using EIA's 2023 *Annual Energy Outlook* (*AEO 2023*) forecasts to estimate future energy prices. Projections performed at the Census division level (see appendix 8E).[4]
Maintenance and Repair Costs	Estimated the costs associated with preventive maintenance (e.g., checking burner and controls) and repair (e.g., replacing burner or fan) based on data from a variety of published sources including *RSMeans 2023 Facilities Maintenance and Repair Data*.[5] It is assumed that maintenance and repair costs vary by efficiency level and probability distributions are derived for various input parameters (see appendix 8F).
Affecting Present Value of Annual Operating Cost Savings	
Product Lifetime	Used Weibull probability distribution of lifetimes developed for gas-fired instantaneous water heaters based on various survey and shipments data (see appendix 8G).
Discount Rate	Probability distributions by income bins are derived for residential discount rates based on multiple Federal Reserve Board's *Survey of Consumer Finances* from 1995-2019 and various interest rate sources.[6] Probability distributions for commercial discount rates for various building activities (e.g., office) are derived using multiple interest rate sources. See section 8.3.5 and appendix 8H.
Compliance Date	2030 (5 years after publication of the final rule)

All of the inputs depicted in Figure 8.1.1 and summarized in Table 8.1.1 are discussed in sections 8.2 and 8.3.

8.1.3 Sample of Gas-fired Instantaneous Water Heater Users

The LCC and PBP calculations detailed here are for a representative sample of individual gas-fired instantaneous water heater users. By developing gas-fired instantaneous water heater samples, DOE accounts for the variability in energy consumption and energy price associated with a range of consumers. Gas-fired instantaneous water heaters are assumed to be installed both in residential and commercial buildings.

As described in chapter 7 of this TSD, DOE used the DOE Energy Information Administration (EIA)'s 2020 *Residential Energy Consumption Survey* (RECS 2020) to develop household samples for applications with gas-fired instantaneous water heaters based on households that use gas water heaters.[2] The RECS 2020 consists of nearly 18,500 housing units and is representative of the estimated 123.5 million occupied, primary household population of the United States in 2020.[b] DOE also used the EIA's 2018 *Commercial Buildings Energy Consumption Survey* (*CBECS* 2018) to develop a sample of commercial buildings that use water heaters.[3] The CBECS 2018 consists of 6,436 commercial buildings and is representative of 5.9 million commercial buildings throughout the United States in 2018.

Both RECS and CBECS collect energy-related and housing unit and building characteristic data for occupied primary housing units and commercial buildings in the United States. Appendix 7A presents the variables used and their definitions, as well as further information about the derivation of the household and building samples. For example, DOE used the RECS and CBECS data to assign a unique monthly energy use, energy price, and total installed cost to each household or commercial building in the sample. The large sample of households and commercial buildings considered in the analysis provides wide ranges of energy use, energy prices, and total installed costs.

8.2 TOTAL INSTALLED COST INPUTS

DOE uses the following equation to define the total installed cost.

$$TIC = CPC + IC$$

Eq. 8.3

Where:

TIC = total installed cost,
CPC = consumer purchase cost ($) (i.e., consumer price for the product only), and
IC = installation cost ($) (i.e., the cost for labor and materials).

The consumer purchase cost is equal to the manufacturer cost multiplied by markups, and where applicable, sales tax. The cost varies based on the distribution channel through which the consumer purchases the product. The installation cost represents all costs to the consumer for

[b] RECS 2020 excludes vacant, seasonal or vacation homes, and group quarters such as prisons, military barracks, dormitories, and nursing homes. CBECS 2018 specifically excludes buildings on military bases that are closed to the public or have restricted public access, foreign embassies, monuments, structures that people do not usually enter, such as oil storage tanks, the cooling towers of a nuclear power plant, and pumping stations, enclosed parking garages, and commercial buildings on manufacturing sites.

installing the product, including labor, overhead, and any miscellaneous materials and parts. The installation cost may vary by efficiency level.

The rest of this section provides information about each of the inputs that DOE used to calculate the total installed cost of gas-fired instantaneous water heater products.

8.2.1 Consumer Purchase Cost

DOE derived the consumer product cost (*CPC*) by taking the product manufacturer selling price (*MSP*), cost of shipping, the overall markup (including the sales tax, if applicable) as well as the learning rate in 2030. DOE uses the following equation to define the consumer purchase cost:

$$CPC = (MSP + SC) \times OMU \times LR$$

Eq. 8.4

Where:

CPC =	consumer purchase cost ($),
MSP =	manufacturer selling price ($), derived by multiplying the manufacturer product cost and manufacturer markup,
SC =	shipping costs ($),
OMU =	overall markup (not including manufacturer markup) and including sales taxes, if applicable, and
LR =	learning rate in 2030.

8.2.1.1 Manufacturer Selling Price

To obtain the manufacturer selling price (*MSP*), DOE multiplies the manufacturer production cost *(MPC*) by the manufacturer markup, as follows:

$$MSP = MPC \times MMU$$

Eq. 8.5

Where:

MSP =	manufacturer selling price ($),
MPC =	manufacturer production cost ($), and
MMU =	manufacturer markup.

The resulting MSP is the price that DOE's engineering research suggests the manufacturer can sell a given unit into the marketplace under a standards scenario, and is typically high enough so that the manufacturer can recover the full cost of the product (i.e., full production and non-production costs) and yield a profit. The output of the cost estimation portion of the engineering analysis is the MPC, which comprises all production-related costs including labor, materials, depreciation, and overhead. The manufacturer markup is a multiplier that scales MPC to the MSP (without the shipping costs, which are added in after applying the markup) and covers all non-production cost elements including sales, general and administrative, research and development, and other corporate expenses, as well as the manufacturer's profit margin. The manufacturer markup is 1.45 for gas-fired instantaneous water heaters (GIWHs). See chapter 5 for more details.

8.2.1.2 Manufacturer Production Costs

DOE developed MPCs for gas-fired instantaneous water heaters by draw pattern for each efficiency level as described in chapter 5, Engineering Analysis, and as shown in Table 8.2.1. To assign sampled households and buildings into the different draw patterns to match the MPC data, DOE used DOE's gas-fired instantaneous water heater sizing methodology, RECS 2020 and CBECS 2018 data, historical shipments data by rated volume, and available model data by rated volume and draw pattern (see chapter 7 for more details). The derived the fraction of shipments by draw pattern bins as shown in Table 8.2.2.

Chapter 5 contains additional details about DOE's cost assumptions and estimates.

Table 8.2.1 Manufacturer Production Cost for Gas-fired Instantaneous Water Heaters by Efficiency Level and Draw Pattern

EL	Technology Option	Draw Pattern					
		Low		Medium		High	
		UEF	MPC *2023$*	UEF	MPC *2023$*	UEF	MPC *2023$*
0	Step modulating burner Non-condensing tube-and-fin heat exchanger			0.81	$310.51	0.81	$327.89
1	Condensing tube heat exchanger			0.87	$441.74	0.89	$461.02
2	Larger condensing heat exchanger			0.91	$445.63	0.93	$466.00
3	Larger condensing heat exchanger			0.92	$451.39	0.95	$473.22
4	Fully modulating burner Larger condensing heat exchanger			0.93	$490.04	0.96	$514.99

Note: See chapter 5 for more details about the technology options.

Table 8.2.2 Fraction of Gas-fired Instantaneous Water Heaters by Draw Pattern

Product Class	Draw Pattern			Total Fraction
	Low	Medium	High	
GIWH	-	15%	85%	100%

8.2.1.3 Shipping Costs

The MPC of gas-fired instantaneous water heater products derived above does not include the cost of shipping the product to the distributor/wholesaler or other market participant (such as retailer or mobile home manufacturer for mobile home gas-fired instantaneous water heaters in the new construction distribution channel). Shipping costs were determined based on the area of floor space occupied by the unit. DOE research suggests that gas-fired instantaneous water heaters are usually shipped together in fully loaded trailers, rather than in less than truckload (LTL) configurations, where the gas-fired instantaneous water heaters only occupy a portion of the trailer volume. Therefore, shipping costs were calculated based on a full trailer.

To calculate these shipping costs, DOE calculated the cost per area of a trailer, based on the standard dimensions of a 40-foot trailer and an estimated 5-year average cost per shipping load that approximates the cost of shipping the products from the coast to coast. Next, DOE examined the sizes of products at each efficiency level and determined the number of units that would fit in a trailer. DOE then calculated the average shipping cost per unit using the cost per trailer load. DOE modeled that gas-fired instantaneous water heaters could be stacked, due to the smaller size and weight of units. Chapter 5 contains additional details about DOE's shipping cost assumptions and estimates.

Table 8.2.3 shows the estimated shipping costs of standard-compliant products for gas-fired instantaneous water heaters by efficiency level.

Table 8.2.3 Shipping Costs for Gas-fired Instantaneous Water Heaters by Efficiency Level and Draw Pattern

EL	Technology Option	Draw Pattern					
		Low		Medium		High	
		UEF	Shipping *2023$*	UEF	Shipping *2023$*	UEF	Shipping *2023$*
0	Step modulating burner Non-condensing tube-and-fin heat exchanger			0.81	$4.52	0.81	$7.63
1	Condensing tube heat exchanger			0.87	$7.07	0.89	$9.49
2	Larger condensing heat exchanger			0.91	$10.17	0.93	$11.45
3	Larger condensing heat exchanger			0.92	$10.17	0.95	$11.45
4	Fully modulating burner Larger condensing heat exchanger			0.93	$10.17	0.96	$11.45

8.2.1.4 Overall Markup

For a given distribution channel, the overall markup is the value determined by multiplying all the associated markups and the applicable sales tax together to arrive at a single overall distribution chain markup value. The overall markup is multiplied by the baseline or standard-compliant manufacturer cost to arrive at the price paid by the consumer. Because there are baseline and incremental markups associated with several wholesaler and mechanical contractor, the overall markup is also divided into a baseline markup (i.e., a markup used to convert the baseline manufacturer price into a consumer price) and an incremental markup (i.e., a markup used to convert a standard-compliant manufacturer cost increase due to an efficiency increase into an incremental consumer price). Markups can differ depending on whether the product is being purchased for a new construction installation or is being purchased to replace an existing product. DOE developed the overall baseline markups and incremental markups by market segment (e.g., new construction, replacement, residential, and commercial) as a part of the markups analysis (chapter 6). Based on the percentages of the market attributed to each distribution channel by market segment, Table 8.2.4 displays the weighted-average baseline and incremental markups for gas-fired instantaneous water heaters. The values in the table do not include the manufacturing markup, which are shown in section 8.2.1.1.

Table 8.2.4 Summary of Overall Markup (Not Including Manufacturing Markup) for Gas-Fired Instantaneous Water Heaters

Product Class	Distinguishing Characteristics (Rated Storage Volume and Input Rating)	Baseline Markup	Incremental Markup
GIWH	<2 gal and >50 kBtu/h	2.06	1.51

8.2.1.5 Future Product Prices

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices may, in many cases, overestimate long-term trends in appliance and equipment prices. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves. Desroches *et al.* (2013) summarizes the data and literature that is relevant to price projections for selected appliances and equipment.[7] The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[8]

In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a manufactured product. This experience is usually measured in terms of cumulative production. A common functional relationship used to model the evolution of production costs in this case is:

$$Y = a\, X^{(-b)} \qquad \textbf{Eq. 8.6}$$

Where:

a =	an initial price (or cost),
b =	a positive constant known as the learning rate parameter,
X =	cumulative production, and
Y =	the price as a function of cumulative production.

As experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (*LR*), and is given by:

$$LR = 1 - 2^{(-b)} \qquad \textbf{Eq. 8.7}$$

In typical experience curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost).

DOE obtained historical PPI data for water heating equipment from 1967-1973 and 1977-2022 for non-electric water heaters from the Bureau of Labor Statistics' (BLS).[c] The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for heating equipment manufacturing was calculated by dividing the PPI series by the implicit price deflator for Gross Domestic Product Chained Price Index.

[c] Series ID PCU33522833522083; www.bls.gov/ppi/

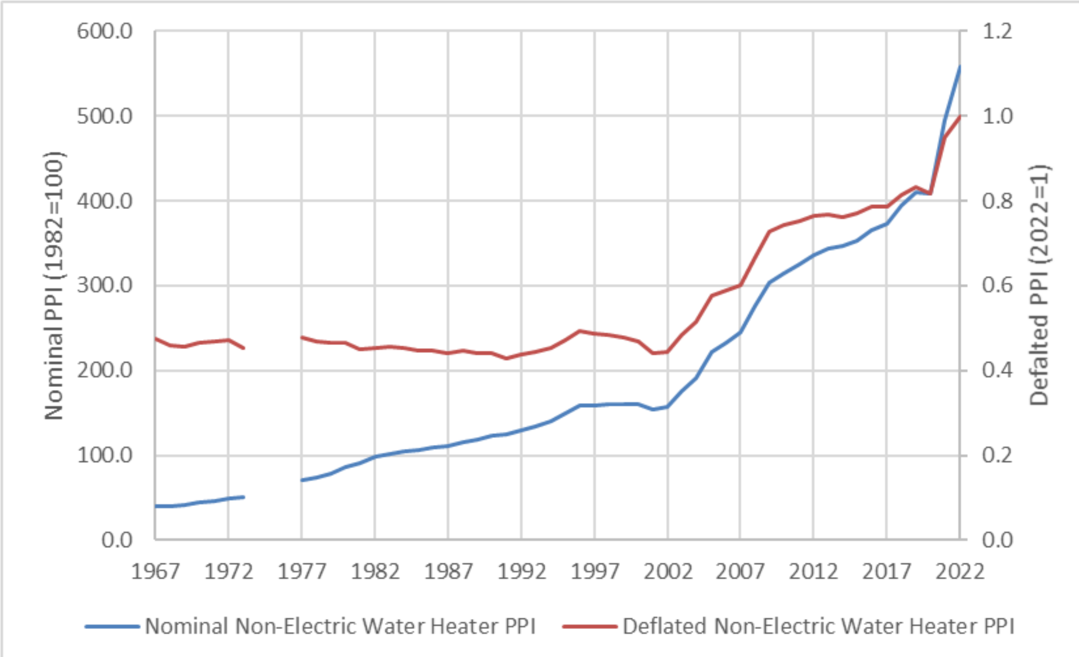

Figure 8.2.2 Historical Nominal and Deflated Producer Price Indexes for non-Electric Consumer Water Heaters

From 1950 to 2006, the deflated price index for non-electric consumer water heaters was mostly decreasing, or staying flat. Since then, the index has risen, primarily due to rising prices of copper, aluminum, and steel products which are the major raw material used in water heating equipment (as shown in Figure 8.2.2).[d] The rising prices for copper and steel products were attributed to a series of global events, from strong demand from China and other emerging economies to the recent severe delay in commdotiy shipping due to the covid pandemic. Given the slowdown in global economic activity in recent years and the lingering impact from the global pandemic, DOE believes that the extent to which the trends of the past five years will continue is very uncertain. Therefore, DOE decided to use constant prices as the default price assumption to project future gas-fired instantaneous water heater prices. Thus, projected prices for the LCC and PBP analysis are equal to the 2023 values for each efficiency level. See appendix 8C for more details and sensitivity analysis.

[d] Series ID WPU10260314, WPU101, and WPU10250105; www.bls.gov/ppi/

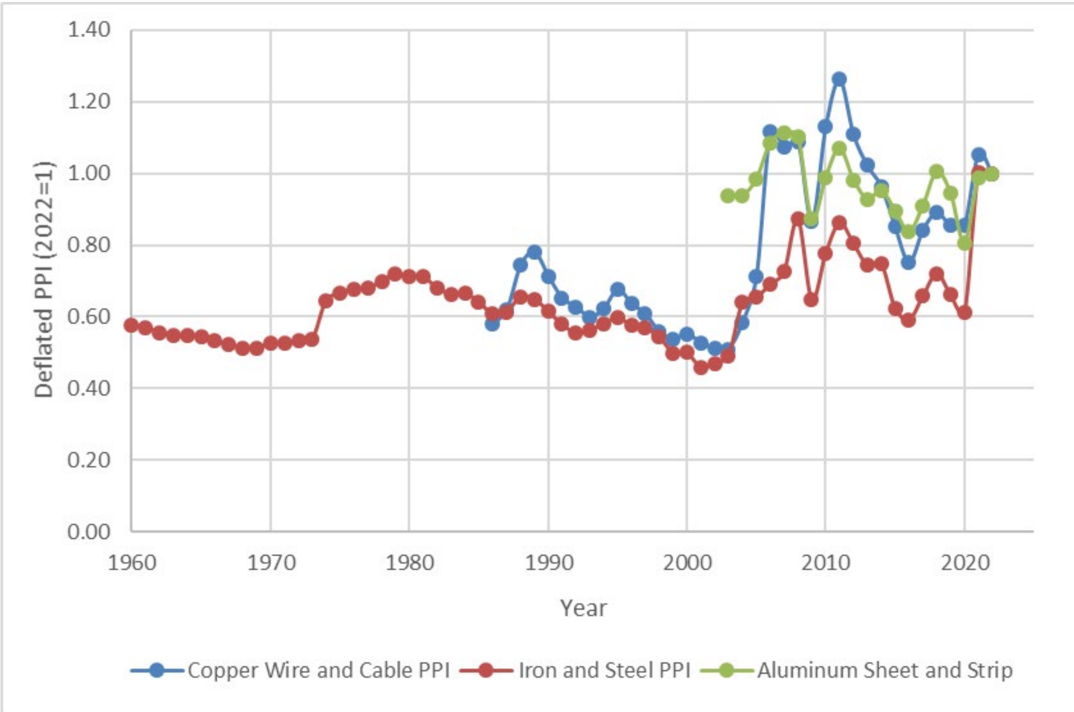

Figure 8.2.3 Historical Deflated Copper, Iron and Aluminum Sheet PPI

8.2.1.6 Average Consumer Purchase Cost

DOE derived the consumer product cost for the baseline product (EL 0) by taking the product of the baseline manufacturer selling price and the baseline overall markup (including the sales tax, not including manufacturer markup) as well as the learning rate in 2030 (as shown in equation 8.8). For each efficiency level above the baseline, DOE derived the consumer product price by taking baseline product consumer price and adding to it the product of the incremental manufacturer selling price and the incremental overall markup (including the sales tax, not including manufacturer markup) as well as the learning rate (as shown in equation 8.9). Markups and sales tax can all take on a variety of values depending on location, so the resulting consumer purchase cost for a particular efficiency level is represented by a distribution of values.

$$CPC_{Baseline} = (MSP + SC)_{Baseline} \times OMU_{Baseline} \times LR$$

Eq. 8.8

Where:

$CPC_{Baseline}$ =	baseline (EL 0) consumer purchase cost ($),
$MSP_{Baseline}$ =	baseline manufacturer selling price ($),
$SC_{Baseline}$ =	baseline shipping costs ($),
$OMU_{Baseline}$ =	overall baseline markup (not including manufacturer markup) and, if applicable, including sales tax, and
LR =	learning rate in 2030.

$$CPC_{Higher\ efficiency} = CPC_{Baseline} + (MSP + SC)_{Incremental} \times OMU_{Incremental} \times LR$$

Eq. 8.9

Where:

$CPC_{Higher\ efficiency}$ = above baseline product consumer purchase cost ($),
$CPC_{Baseline}$ = baseline (EL 0) consumer purchase cost ($),
$MSP_{Incremental}$ = incremental manufacturer selling price ($),
$SC_{Incremental}$ = incremental shipping costs ($),
$OMU_{Incremental}$ = incremental markup (not including manufacturer markup) and, if applicable, including sales tax, and
LR = learning rate in 2030.

Table 8.2.5 presents the average consumer product price at each efficiency level examined in 2030.

Table 8.2.5 Average Consumer Price for Gas-fired Instantaneous Water Heaters and Draw Pattern in 2030

EL	Low			Medium			High		
	UEF	Average Consumer Price	Incr. Cost 2023$	UEF	Average Consumer Price	Incr. Cost 2023$	UEF	Average Consumer Price	Incr. Cost 2023$
0				0.81	937	-	0.81	994	-
1				0.87	1,230	292	0.89	1,289	295
2				0.91	1,243	305	0.93	1,303	309
3				0.92	1,255	318	0.95	1,318	325
4				0.93	1,340	403	0.96	1,410	416

8.2.2 Installation Cost

The installation cost is the cost to the consumer of installing the water heaters. The cost of installation covers all labor and material costs associated with the replacement of an existing gas-fired instantaneous water heater or the installation of a new gas-fired instantaneous water heater in a new or existing home or commercial building, as well as removal of the existing gas-fired instantaneous water heater, and any applicable permit fees. Higher-efficiency gas-fired instantaneous water heaters may require higher installation cost. DOE's analysis of installation costs estimated specific installation costs for each sample household based on building characteristics given in RECS 2020 and CBECS 2018. DOE also accounted for differences in installation costs and practices in different buildings types (such as single-family detached, single family attached, multi-family, mobile homes, commercial buildings) and market segments (replacements, new owners, and new construction). DOE estimated the installation costs at each considered efficiency level using a variety of sources, including RSMeans data,[1] manufacturer literature, and information from expert consultant report. DOE's analysis of installation costs also accounted for regional differences in labor costs.

First, DOE estimated basic installation costs that are applicable to all gas-fired instantaneous water heaters, in replacement, new owner, and new home or building installations.[e] These costs include putting in place and setting up the gas-fired instantaneous water heater, gas piping and/or electrical hookup, permits, water piping, removal of the existing gas-fired instantaneous water heater, and removal or disposal fees.

Then, DOE estimated the venting cost. For non-condensing GIWHs, DOE estimated the cost of installing a stainless steel vent, while for condensing gas instantaneous water heaters DOE calculated the cost of installing a plastic vent material. DOE calculated the possible vent length for both vertical and horizontal vent configurations and assumed that the vent run depends on whichever is shorter. There are two types of vent materials that DOE took into account, single-wall pipe and concentric pipe. DOE applied the use of concentric pipe to a fraction of installation given the advantage of only needing to drill one wall penetration. DOE also took into account a fraction of installations that are outdoor and therefore do not require venting. Besides flue vent piping, DOE also estimated the cost for installing combustion air vent for direct vent installations as well as concealing vent pipes for indoor installations.

For condensing GIWHs, DOE estimated the cost for condensate withdraw. Freeze protection is accounted for in the cost of condensate removal for a fraction of condensing gas-fired instantaneous water heaters installed in non-conditioned spaces. Additionally, DOE also accounted for the extra labor hour that might be needed for installing a water heater of higher complexity.

Table 8.2.6 presents the average installation cost by efficiency level. For a detailed discussion of the development of installation costs as well as the full consultant report, see appendix 8D.

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[e] DOE estimated replacements, new owners, and new construction shipments fractions in 2030 based on DOE's shipments analysis, which is further described in chapter 9.

Table 8.2.6 Average Installation Cost for Gas-fired Instantaneous Water Heaters

EL	Low			Medium			High		
	UEF	Average Installation Cost	Incr. Cost 2023$	UEF	Average Installation Cost	Incr. Cost 2023$	UEF	Average Installation Cost	Incr. Cost 2023$
0				0.81	1,096	-	0.81	1,103	-
1				0.87	1,020	(76)	0.89	1,025	(78)
2				0.91	1,020	(76)	0.93	1,025	(78)
3				0.92	1,020	(76)	0.95	1,025	(78)
4				0.93	1,020	(76)	0.96	1,025	(78)

8.2.3 Total Installed Cost

The total installed cost is the sum of the product price and the installation cost. Total manufacturer prices, markups, and sales taxes all can take on a variety of values, depending on location, so the resulting total installed cost for a particular efficiency level will not be a single-point value, but rather a distribution of values. Table 8.2.7 presents the average total installed cost for gas-fired instantaneous water heaters at each efficiency level and draw pattern examined.

Table 8.2.7 Average Total Installed Cost for Gas-fired Instantaneous Water Heaters

EL	Low			Medium			High		
	UEF	Total Installed Cost	Incr. Cost 2023$	UEF	Total Installed Cost	Incr. Cost 2023$	UEF	Total Installed Cost	Incr. Cost 2023$
0				0.81	2,033	-	0.81	2,097	-
1				0.87	2,249	216	0.89	2,314	217
2				0.91	2,263	229	0.93	2,328	231
3				0.92	2,275	242	0.95	2,344	247
4				0.93	2,360	327	0.96	2,435	339

8.3 OPERATING COST INPUTS

DOE defined the operating cost by the following equation:

$$OC = EC + RC + MC$$

Eq. 8.10

Where:

OC = operating cost ($),
EC = energy cost associated with operating the product ($),
RC = repair cost associated with component failure ($), and
MC = maintenance cost for maintaining product operation ($).

The following equation summarizes DOE's approach of calculating the energy cost per year using monthly average and marginal energy prices together with monthly energy consumption for each sampled gas-fired instantaneous water heater:

$$EC_t = \left[\sum_m MEC_{BASE,t,m} \times MEP_{AVG,t,m} + \sum_m \Delta MEC_{t,m} \times MEP_{MAR,t,m} \times MEPF_{MAR,t,m}\right] \times EPT_t$$

Eq. 8.11

Where:

$MEC_{BASE,t,m}$ = monthly energy consumption at the site for baseline design in the month m of year t,
$MEP_{AVG,t,m}$ = monthly average energy price in the month m of year t,
$\Delta MEC_{t,m}$ = change in monthly energy consumption from higher efficiency design in the month m of year t,
$MEP_{MAR,t,m}$ = monthly average marginal energy price in the month m of year t,
$MEPF_{MAR,t,m}$ = monthly marginal energy price factor for the month m of year t, and
EPT_t = energy price trend in year t.

The remainder of this section provides information about the variables that DOE used to calculate the operating cost for gas-fired instantaneous water heaters. The monthly energy costs of the product are computed from energy consumption per unit for the baseline (efficiency level 0) and standard-compliant cases (efficiency level 1, 2, 3, and so on), combined with the monthly energy prices. Product lifetime, discount rate, and compliance date of the standard are required for determining the operating cost and for establishing the operating cost present value.

8.3.1 Energy Consumption

DOE calculated the monthly energy use for each sample product user at each efficiency level, as described in chapter 7 of this TSD. Tables in chapter 7 provide the average annual energy consumption by efficiency level for gas-fired instantaneous water heaters.

DOE considered the possibility that some consumers may use a higher-efficiency gas-fired instantaneous water heater more than a baseline one, thereby negating some or all of the energy savings from the more-efficient product. Such change in behavior when operating costs decline is known as a (direct) rebound effect. However, the increased gas-fired instantaneous water heater usage associated with the rebound effect provides consumers with increased value (e.g., more available hot water). DOE believes that, if it were able to monetize the increased value to consumers of the rebound effect, this value would be similar in monetary value to the foregone energy savings. Therefore, the economic impacts on consumers, with or without including the rebound effect in the analysis, are the same.

8.3.2 Energy Prices

Because marginal electricity price more accurately captures the incremental savings associated with a change in energy use from higher efficiency, it provides a better representation of incremental change in consumer costs than average electricity prices. Therefore, DOE applied average electricity prices for the energy use of the product purchased in the no-new-standards case, and marginal electricity prices for the incremental change in energy use associated with the other efficiency levels considered.

DOE derived average monthly energy prices for each state in the United States using the latest data from EIA and monthly energy price factors that it developed. The process then assigns an appropriate energy price to each household and commercial building in the sample, depending on its type (residential or commercial) and its location. The following sections describe the derivation of base year (2022) average and marginal energy prices for each month, as well as the future price trends used to derive energy prices in future years

8.3.2.1 Base Year (2023) Energy Prices

DOE first derived average annual energy prices for 2022 by State. Then DOE multiplied the average 2022 annual prices by the monthly price factors derived by State for each fuel to derive prices for each month. Finally, DOE multiplied the calculated average monthly energy prices by seasonal marginal price factors to derive marginal prices for electricity and natural gas. DOE used the consumer price index (CPI) to convert energy prices from 2022$ to 2023$.[9]

EIA Data – Derivation of Average Annual Energy Prices. DOE derived 2022 annual residential and commercial electricity prices by State from EIA Form 826 data.[10] DOE obtained 2022 annual residential and commercial electricity natural gas prices by State from EIA's Natural Gas Navigator.[11] Energy prices were scaled to 2023 prices using AEO 2023 price trends and consumer price index (CPI).[12,4,9] See appendix 8E for more details.

EIA Data – Derivation of Average Monthly Energy Factors. To determine monthly prices for use in the analysis, DOE developed monthly energy price factors for each fuel based on long-term monthly price data. See appendix 8E for a description of the method.

EIA Data – Seasonal Electricity and Natural Gas Marginal Price Factors. Monthly electricity and natural gas prices were adjusted using seasonal marginal price factors to determine monthly marginal electricity and natural gas prices. These marginal energy prices were used to determine the cost to the consumer of the change in energy consumed. Because marginal price data is only available for residential electricity and natural gas, DOE only developed marginal monthly prices for these fuels. For a detailed discussion of the development of marginal energy price factors and for a comparison to other data and methods, see appendix 8E.

Table 8.3.1 and Table 8.3.2 show residential marginal monthly natural gas and electricity prices. Average commercial prices are shown in appendix 8E.

Table 8.3.1 Residential Marginal Monthly Natural Gas Prices for 2022 (2023$/MMBtu)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	13.71	13.58	14.11	11.73	13.33	14.79	15.45	15.60	15.55	14.96	16.92	14.72
Alaska	10.33	10.47	10.31	9.06	9.68	10.62	11.14	10.92	9.93	9.21	10.38	10.75
Arizona	11.55	12.26	13.10	11.43	12.78	14.21	15.47	15.84	15.40	13.66	14.33	12.35
Arkansas	12.03	11.95	12.55	8.92	10.54	12.49	13.65	14.25	13.82	12.44	14.76	12.91
California	22.41	22.02	21.27	17.48	18.43	18.82	19.08	19.08	18.83	18.78	21.98	22.66
Colorado	9.65	9.76	10.24	7.53	8.74	11.01	12.37	12.47	11.07	8.44	10.64	10.08
Connecticut	14.62	14.78	15.12	12.46	14.01	16.17	17.64	18.47	17.90	15.23	16.37	15.37
Delaware	11.42	11.68	12.26	8.86	10.29	12.49	13.95	14.70	14.18	12.38	13.58	12.14
Dist. of Columbia	13.80	13.69	14.19	11.53	13.30	14.84	16.26	16.08	15.64	13.84	15.62	14.24
Florida	14.68	14.69	15.69	14.29	15.56	16.90	17.90	18.41	18.00	17.65	18.43	16.16
Georgia	12.59	13.29	14.15	11.71	14.53	17.36	18.41	18.56	18.58	14.95	15.36	13.62
Hawaii	33.34	34.59	35.53	72.24	74.23	74.71	75.20	75.13	75.18	76.08	36.20	35.46
Idaho	7.40	7.43	7.65	6.71	7.02	7.57	8.03	8.19	7.72	6.98	7.55	7.49
Illinois	11.29	11.32	12.21	7.62	9.39	11.52	13.41	13.61	12.56	8.93	12.83	11.75
Indiana	8.34	8.50	9.52	6.46	7.51	9.79	10.33	10.20	9.16	6.12	8.55	8.36
Iowa	9.49	9.73	10.76	7.27	8.67	11.13	12.71	13.28	12.65	9.27	10.97	9.69
Kansas	11.81	12.11	12.85	8.20	9.88	12.42	13.38	14.23	13.23	10.09	13.48	12.33
Kentucky	11.33	11.36	12.09	6.91	9.17	11.22	12.09	12.50	11.86	8.61	13.04	12.14
Louisiana	10.91	10.98	11.76	9.40	10.81	11.99	12.44	12.72	12.29	11.87	13.93	11.95
Maine	22.95	23.66	23.45	17.11	17.23	19.74	22.14	22.97	22.13	18.01	23.22	23.64
Maryland	12.81	12.77	13.23	10.60	12.63	14.91	15.95	16.29	15.71	12.56	14.27	13.64
Massachusetts	21.38	21.35	21.39	20.87	21.10	20.83	22.82	23.69	22.92	19.76	21.54	22.26
Michigan	9.43	9.53	9.82	8.19	9.48	11.15	12.07	12.48	11.37	9.00	10.24	9.89
Minnesota	12.57	12.65	12.95	8.46	9.85	11.78	12.58	12.46	11.66	9.11	13.18	12.83
Mississippi	11.07	11.20	12.07	8.77	10.14	11.40	11.32	11.66	11.64	10.88	13.33	11.86
Missouri	8.39	8.37	8.88	6.70	8.20	10.93	12.76	13.37	12.51	10.24	11.10	9.26
Montana	9.42	9.54	9.64	8.24	8.71	9.88	11.43	12.26	11.14	9.09	10.05	9.70
Nebraska	10.23	10.43	10.67	6.77	7.76	9.89	11.46	12.07	11.71	9.68	12.53	11.12
Nevada	8.56	8.84	9.28	7.91	8.62	9.27	10.15	10.58	10.15	9.21	10.26	9.02
New Hampshire	20.05	19.77	19.89	15.26	15.92	17.18	20.43	21.70	21.25	18.11	21.62	21.69
New Jersey	11.83	11.78	11.82	8.93	9.86	10.85	11.47	11.80	11.48	10.49	12.95	12.28
New Mexico	10.41	10.40	10.75	6.59	7.52	9.34	10.40	10.62	10.58	9.39	12.55	11.02
New York	12.39	12.23	12.57	9.58	10.91	13.12	14.22	14.47	14.16	12.39	14.30	13.02
North Carolina	12.37	12.51	13.18	11.25	13.95	16.26	17.35	16.93	16.80	13.90	14.18	13.52
North Dakota	9.79	9.88	10.32	5.59	6.79	9.72	11.98	12.03	10.19	6.41	10.67	10.08
Ohio	9.19	9.33	9.63	4.90	6.23	8.78	9.95	10.39	9.67	6.61	10.80	9.82
Oklahoma	9.22	9.40	9.97	7.88	10.08	12.79	14.91	16.28	15.58	13.79	14.17	9.97
Oregon	11.30	11.23	11.55	9.91	10.69	11.46	12.50	13.29	12.33	10.62	11.91	11.42
Pennsylvania	11.72	11.80	12.10	9.10	10.42	12.79	14.33	14.90	14.06	11.11	13.01	12.19
Rhode Island	13.66	13.78	14.07	13.52	14.65	16.13	17.60	18.30	17.99	16.28	15.51	14.49
South Carolina	10.27	10.60	11.25	8.75	11.24	12.78	13.63	13.52	13.31	10.66	11.75	11.04
South Dakota	8.83	9.00	9.59	6.98	7.57	9.54	11.28	11.72	10.99	8.01	9.61	8.85
Tennessee	9.78	9.73	10.04	6.65	7.97	9.59	10.57	11.08	10.43	9.22	11.78	10.33
Texas	10.14	10.10	11.02	7.62	9.15	10.34	11.12	11.89	11.57	10.37	14.00	11.56
Utah	10.30	10.51	10.59	8.58	8.41	9.27	10.17	10.63	10.39	9.38	10.64	10.79
Vermont	12.31	12.07	12.34	9.45	10.44	12.57	14.42	15.21	14.67	12.38	14.07	13.07
Virginia	11.89	11.98	12.16	9.40	11.39	13.49	14.81	14.87	14.47	11.84	13.54	12.72
Washington	11.72	11.76	11.91	9.79	10.64	11.65	12.67	13.12	12.13	10.35	12.30	12.00
West Virginia	10.40	10.48	10.62	8.34	9.82	12.36	13.65	13.87	12.31	9.42	11.20	10.83
Wisconsin	11.34	11.36	11.89	7.65	8.60	10.58	11.36	11.67	10.60	7.60	11.96	11.64
Wyoming	9.67	9.80	10.02	8.32	8.98	10.96	14.48	15.43	14.03	10.56	10.93	10.18
United States	11.95	12.02	12.48	8.79	10.10	11.84	12.88	13.23	12.60	10.23	13.27	12.53

Table 8.3.2 Residential Marginal Monthly Electricity Prices for 2022 (2023$/kWh)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.111	0.115	0.118	0.151	0.148	0.152	0.151	0.153	0.153	0.152	0.120	0.113
Alaska	0.206	0.207	0.211	0.192	0.198	0.200	0.204	0.201	0.197	0.198	0.218	0.215
Arizona	0.107	0.110	0.112	0.135	0.145	0.143	0.143	0.142	0.142	0.140	0.113	0.111
Arkansas	0.086	0.089	0.091	0.129	0.131	0.135	0.134	0.135	0.135	0.130	0.097	0.091
California	0.245	0.244	0.240	0.310	0.341	0.355	0.357	0.359	0.351	0.309	0.250	0.249
Colorado	0.126	0.129	0.129	0.166	0.167	0.174	0.175	0.174	0.176	0.169	0.133	0.130
Connecticut	0.214	0.222	0.222	0.229	0.230	0.227	0.219	0.223	0.227	0.227	0.221	0.215
Delaware	0.103	0.104	0.107	0.116	0.123	0.121	0.117	0.118	0.120	0.125	0.118	0.110
Dist. of Columbia	0.110	0.111	0.112	0.126	0.131	0.134	0.133	0.134	0.133	0.134	0.116	0.115
Florida	0.164	0.167	0.166	0.151	0.148	0.151	0.151	0.152	0.154	0.153	0.171	0.168
Georgia	0.110	0.112	0.116	0.168	0.174	0.184	0.187	0.188	0.181	0.171	0.115	0.109
Hawaii	0.379	0.382	0.384	0.414	0.417	0.422	0.424	0.425	0.426	0.427	0.400	0.399
Idaho	0.106	0.106	0.107	0.117	0.122	0.128	0.129	0.128	0.122	0.125	0.109	0.109
Illinois	0.102	0.106	0.110	0.148	0.152	0.147	0.143	0.145	0.146	0.151	0.114	0.105
Indiana	0.109	0.111	0.115	0.148	0.149	0.143	0.141	0.143	0.146	0.152	0.124	0.115
Iowa	0.096	0.098	0.102	0.177	0.186	0.193	0.199	0.201	0.190	0.180	0.104	0.099
Kansas	0.098	0.103	0.107	0.148	0.150	0.151	0.152	0.153	0.150	0.147	0.108	0.102
Kentucky	0.101	0.102	0.104	0.128	0.129	0.128	0.127	0.127	0.128	0.132	0.112	0.108
Louisiana	0.091	0.094	0.097	0.132	0.136	0.134	0.137	0.138	0.138	0.139	0.099	0.096
Maine	0.216	0.220	0.219	0.224	0.226	0.226	0.223	0.223	0.226	0.225	0.223	0.218
Maryland	0.130	0.131	0.133	0.136	0.140	0.146	0.143	0.143	0.144	0.145	0.137	0.136
Massachusetts	0.278	0.281	0.281	0.252	0.250	0.248	0.242	0.248	0.255	0.248	0.277	0.288
Michigan	0.159	0.161	0.161	0.190	0.194	0.200	0.200	0.202	0.197	0.195	0.165	0.165
Minnesota	0.117	0.119	0.120	0.160	0.166	0.174	0.175	0.173	0.172	0.167	0.124	0.121
Mississippi	0.093	0.095	0.099	0.121	0.122	0.120	0.118	0.118	0.117	0.118	0.102	0.098
Missouri	0.078	0.079	0.084	0.157	0.177	0.188	0.188	0.187	0.170	0.161	0.088	0.082
Montana	0.099	0.099	0.101	0.104	0.107	0.111	0.112	0.111	0.112	0.110	0.105	0.102
Nebraska	0.068	0.071	0.074	0.130	0.135	0.148	0.150	0.151	0.152	0.136	0.078	0.073
Nevada	0.116	0.119	0.120	0.136	0.134	0.129	0.128	0.128	0.131	0.137	0.124	0.119
New Hampshire	0.234	0.239	0.241	0.227	0.229	0.226	0.220	0.223	0.231	0.233	0.248	0.246
New Jersey	0.167	0.169	0.169	0.178	0.180	0.189	0.193	0.194	0.189	0.178	0.170	0.171
New Mexico	0.122	0.125	0.126	0.163	0.164	0.175	0.178	0.180	0.175	0.174	0.127	0.124
New York	0.202	0.207	0.203	0.233	0.241	0.249	0.250	0.248	0.251	0.247	0.213	0.207
North Carolina	0.096	0.100	0.101	0.120	0.119	0.116	0.118	0.119	0.122	0.125	0.104	0.098
North Dakota	0.069	0.072	0.074	0.088	0.095	0.104	0.102	0.102	0.104	0.095	0.079	0.074
Ohio	0.110	0.112	0.115	0.153	0.158	0.160	0.160	0.159	0.156	0.156	0.120	0.115
Oklahoma	0.069	0.076	0.078	0.127	0.124	0.126	0.125	0.127	0.134	0.132	0.080	0.071
Oregon	0.107	0.109	0.109	0.114	0.116	0.117	0.118	0.117	0.118	0.118	0.112	0.110
Pennsylvania	0.136	0.139	0.140	0.164	0.169	0.171	0.170	0.170	0.170	0.170	0.146	0.143
Rhode Island	0.232	0.239	0.234	0.202	0.201	0.198	0.193	0.203	0.212	0.205	0.238	0.245
South Carolina	0.115	0.118	0.119	0.144	0.143	0.143	0.142	0.142	0.144	0.145	0.124	0.119
South Dakota	0.091	0.093	0.094	0.124	0.131	0.136	0.135	0.134	0.136	0.134	0.101	0.096
Tennessee	0.104	0.103	0.106	0.129	0.130	0.129	0.128	0.128	0.127	0.132	0.113	0.109
Texas	0.115	0.117	0.120	0.138	0.138	0.140	0.139	0.139	0.140	0.139	0.123	0.120
Utah	0.103	0.104	0.104	0.125	0.130	0.135	0.138	0.138	0.134	0.127	0.106	0.105
Vermont	0.170	0.173	0.174	0.191	0.192	0.193	0.189	0.189	0.192	0.196	0.182	0.176
Virginia	0.108	0.110	0.113	0.148	0.151	0.154	0.155	0.155	0.154	0.151	0.117	0.112
Washington	0.098	0.099	0.099	0.093	0.093	0.095	0.095	0.095	0.096	0.095	0.102	0.101
West Virginia	0.105	0.106	0.110	0.129	0.132	0.131	0.128	0.129	0.131	0.135	0.115	0.109
Wisconsin	0.132	0.134	0.135	0.154	0.158	0.158	0.156	0.156	0.159	0.157	0.138	0.134
Wyoming	0.092	0.094	0.095	0.097	0.101	0.104	0.105	0.104	0.105	0.104	0.100	0.096
United States	0.119	0.121	0.124	0.163	0.166	0.168	0.169	0.170	0.170	0.166	0.128	0.124

8.3.2.2 Future Energy Price Trends

To arrive at prices in future years, DOE multiplied the prices described in the preceding section by annual energy price factors derived from the forecasts of annual average price changes in EIA's *AEO 2023*. DOE applied the projected energy price trends from 2023 to 2050 for each of the nine census divisions to each building in the sample based on the building's location. DOE converted the forecasted energy prices into energy price factors, with 2023 as the base year. Figure 8.3.1 shows the national residential and commercial energy price factors. To estimate the trend after 2050, DOE used the average rate of change during 2046–2050 based on the methods used in the 2022 Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP).[13] For more details, see appendix 8E. For sensitivity analysis on AEO 2023 high and low economic scenarios see appendix 8J.

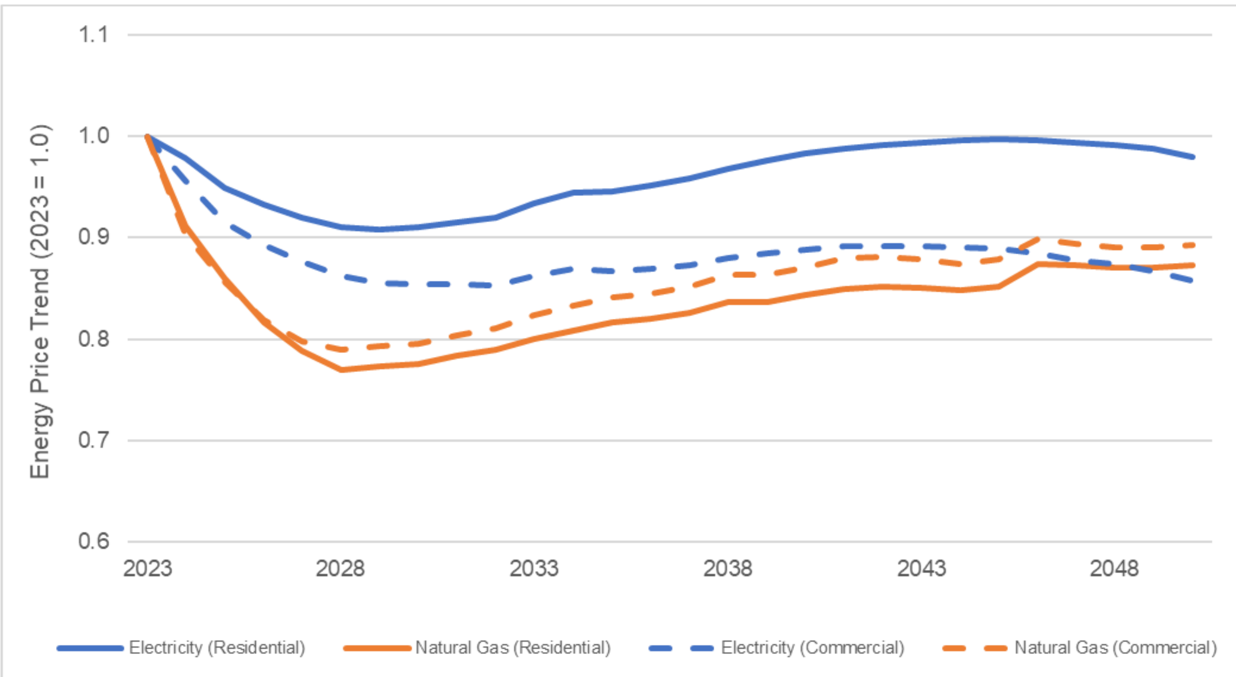

Figure 8.3.1 Projected National Residential and Commercial Energy Price Factors

8.3.2.3 Average and Marginal Energy Price Results in 2030

Table 8.3.3 presents the resulting average and marginal energy prices in 2030. The average price is applied to the no-new-standards case energy use. The marginal price is applied to the energy savings when comparing each efficiency level to the no-new-standards case.

Table 8.3.3 Summary of Gas-fired Instantaneous Water Heater Average and Marginal Energy Prices in 2030

Fuel Type	Unit	Energy Prices (2023$)		Fraction of Affected Shipments
		Average	Marginal	
Natural Gas	$/MMbtu	17.08	12.94	74%
Electricity	$/kWh	0.165	0.165	100%

8.3.3 Maintenance and Repair Cost

The maintenance cost is the routine cost to the consumer of maintaining product operation. The repair cost is the cost to the consumer for replacing or repairing components in the gas-fired instantaneous water heater that have failed (such as the burner, blower, heating element). DOE assumes that some higher efficiency gas-fired instantaneous water heaters have a higher maintenance and repair cost than baseline gas-fired instantaneous water heater. The maintenance and repair costs (including labor hours, component costs, and frequency) at each considered efficiency level are derived based on RSMeans data,[5] manufacturer literature, and a consultant reports. DOE accounted for regional differences in labor costs. For a detailed discussion of the development of maintenance and repair costs, see appendix 8F (including the full consultant report).

Table 8.3.4 shows the annualized maintenance and repair cost estimates for gas-fired instantaneous water heaters.

Table 8.3.4 Annualized Maintenance and Repair Cost for Gas-fired Instantaneous Water Heaters

EL	Maintenance Cost 2023$		Repair Cost 2023$	
	Average	Incr. Cost	Average	Incr. Cost
0	50.2	-	7.9	-
1	52.7	2.5	9.1	1.2
2	52.7	2.5	9.1	1.2
3	52.7	2.5	9.1	1.2
4	52.7	2.5	9.1	1.2

8.3.4 Lifetime

The product lifetime is the age at which a product is retired from service. Because product lifetime varies, DOE uses a lifetime distribution to characterize the probability a product will be retired from service at a given age. DOE conducted an extensive literature review and took into account published studies. Because the basis for the estimates in the literature was uncertain, DOE developed a method using national survey data, along with shipment data, to estimate the distribution of gas-fired instantaneous water heaters lifetimes in the field.

DOE assumed that the probability function for the annual survival of gas-fired instantaneous water heaters would take the form of a Weibull distribution. A Weibull distribution is a probability distribution commonly used to measure failure rates.[f] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a specific fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}}, for\ x > \theta, \text{ and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Eq. 8.12

Where:

P(x) =	probability that the appliance is still in use at age *x*,
x =	age of appliance in years,
θ =	delay parameter, which allows for a delay before any failures occur,
α =	scale parameter, which would be the decay length in an exponential distribution, and
β =	shape parameter, which determines the way in which the failure rate changes through time.

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age. DOE estimated a delay parameter of $\theta = 1$ year, based on the minimum manufacturer warranty period for gas-fired instantaneous water heater. DOE then derived the Weibull distribution parameters for gas-fired instantaneous water heater lifetimes by using water heater stock and age data from U.S. Census's biennial *American Housing Survey* (AHS) from 1974-2021[14] and EIA's RECS from 1987-2020,[15] as well as historical shipments data (detailed in chapter 9). For a detailed discussion of the development of gas-fired instantaneous water heater lifetime, see appendix 8G. This appendix also includes a literature search of gas-fired instantaneous water heater lifetime information.

Table 8.3.5 shows the Weibull distribution parameters alpha, beta and the location and Figure 8.3.2 displays the Weibull probability distribution. DOE assumed that the lifetime of a gas-instantaneous water heater is the same across the different draw patterns and efficiency levels. The resulting average and median appliance lifetime from the derived Weibull distributions are also provided in the table and are within the range of the values found in DOE's literature review (which can be found in appendix 8G). Gas-fired instantaneous water heaters have limited data so DOE assumed 20 year average lifetime with same shape as gas-fired storage water heaters based from the June 2024 Consumer Water Heater Final Rule[16].

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[f] For reference on the Weibull distribution, see sections 1.3.6.6.8 and 8.4.1.3 of the *NIST/SEMATECH e-Handbook of Statistical Methods*. www.itl.nist.gov/div898/handbook/.

Table 8.3.5 Lifetime Parameters for Gas-fired Instantaneous Water Heaters

Product Class	Weibull Parameters			Distribution Statistics	
	Alpha (scale)	Beta (shape)	Location (delay)	Mean	Median
Gas-fired Instantaneous Water Heater	21.3	1.76	1.0	20.0	18.3

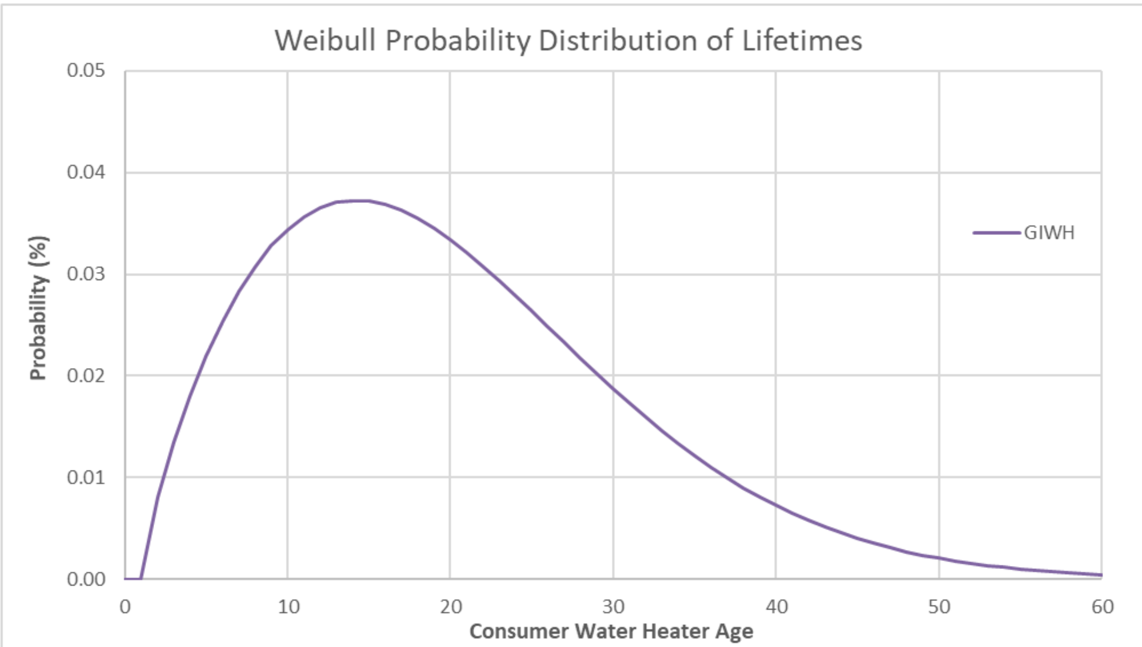

Figure 8.3.2 Weibull Probability Distribution for the Gas-fired Instantaneous Water Heater Lifetimes

Additionally, DOE performed a sensitivity analysis for lifetime to evaluate the impact of lifetime on the consumer economics. See appendix 8G for the descriptions and comparison of the results.

8.3.5 Discount Rates

The discount rate is the rate at which future expenditures and savings are discounted to establish their present value. DOE estimates discount rates separately for residential and commercial end users. For residential end users, DOE calculates discount rates as the weighted average real interest rate across consumer debt and equity holdings. For commercial end users, DOE calculates commercial discount rates as the weighted average cost of capital (WACC), using the Capital Asset Pricing Model (CAPM).

8.3.5.1 Discount Rates for Residential Applications

The consumer discount rate is the rate at which future operating costs of residential products are discounted to establish their present value in the LCC analysis. The discount rate value is applied in the LCC to future year energy costs and non-energy operations and maintenance costs in order to calculate the estimated net life-cycle cost of products of various efficiency levels and the life-cycle cost savings of higher-efficiency models as compared to the baseline for a representative sample of consumers.

DOE calculates the consumer discount rate using publicly available data (the Federal Reserve Board's *Survey of Consumer Finance*s (SCF)) to estimate a consumer's required rate of return or opportunity cost of funds related to appliances.[6] In the economics literature, opportunity cost reflects potential foregone benefit resulting from choosing one option over another. Opportunity cost of capital refers to the rate of return that one could earn by investing in an alternate project with similar risk; similarly, opportunity cost may be defined as the cost associated with opportunities that are foregone when resources are not put to their highest-value use.[17]

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. The stream of savings is discounted at a rate reflecting (1) the rates of return associated with other investments available to the consumer, and (2) the observed costs of credit options available to the consumer to reflect the value of avoided debt. DOE notes that the LCC does not analyze the appliance purchase decision, so the implicit discount rate is not relevant in this model. The LCC estimates net present value over the lifetime of the product, so the appropriate discount rate will reflect the general opportunity cost of household funds, taking this time scale into account.

Given the long time horizon modeled in the LCC, the application of a marginal interest rate associated with an initial source of funds is inaccurate. Regardless of the method of purchase, consumers are expected to continue to rebalance their debt and asset holdings over the LCC analysis period, based on the restrictions consumers face in their debt payment requirements and the relative size of the interest rates available on debts and assets. DOE estimates the aggregate impact of this rebalancing using the historical distribution of debts and assets. The discount rate is the rate at which future savings and expenditures are discounted to establish their present value.

DOE estimates separate discount rate distributions for six income groups, divided based on income percentile as reported in the SCF. These income groups are listed in Table 8.3.6. This disaggregation reflects the fact that low and high income consumers tend to have substantially different shares of debt and asset types, as well as facing different rates on debts and assets. Summaries of shares and rates presented in this chapter are averages across the entire population.

Table 8.3.6 Definitions of Income Groups

Income Group	Percentile of Income
1	0 – 19.9
2	20 – 39.9
3	40 – 59.9
4	60 – 79.9
5	80 – 89.9
6	90 - 100

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Shares of Debt and Asset Classes

DOE's approach involved identifying all household debt or equity classes in order to approximate a consumer's opportunity cost of funds over the product's lifetime. This approach assumes that in the long term, consumers are likely to draw from or add to their collection of debt and asset holdings approximately in proportion to their current holdings when future expenditures are required or future savings accumulate. DOE now includes several previously excluded debt types (i.e., vehicle and education loans, mortgages, all forms of home equity loan) in order to better account for all of the options available to consumers.

The average share of total debt plus equity and the associated rate of each asset and debt type are used to calculate a weighted average discount rate for each SCF household (Table 8.3.7). The household-level discount rates are then aggregated to form discount rate distributions for each of the six income groups.[g]

DOE estimated the average percentage shares of the various types of debt and equity using data from the SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[h] DOE derived the household-weighted mean percentages of each source of across the twenty-one years covered by the eight survey versions. DOE posits that these long-term averages are most appropriate to use in its analysis.

[g] Note that previously DOE performed aggregation of asset and debt types over households by summing the dollar value across all households and then calculating shares. Weighting by dollar value gave disproportionate influence to the asset and debt shares and rates of higher income consumers. DOE has shifted to a household-level weighting to more accurately reflect the average consumer in each income group.

[h] Note that two older versions of the SCF are also available (1989 and 1992); these surveys are not used in this analysis because they do not provide all of the necessary types of data (e.g., credit card interest rates, etc.). DOE feels that the time span covered by the eight surveys included is sufficiently representative of recent debt and equity shares and interest rates.

Table 8.3.7 Average Shares of Household Debt and Asset Types by Income Group

Type of Debt or Equity	Income Group, %						
	1	2	3	4	5	6	All
Debt:							
Mortgage	14.3	22.2	33.1	43.3	47.5	37.0	31.0
Home equity loan	1.5	1.8	2.4	3.5	4.6	7.7	3.1
Credit card	15.8	12.2	9.4	6.1	4.0	1.9	9.3
Other installment loan	31.9	28.0	23.9	16.9	11.5	5.9	21.9
Other line of credit	1.4	1.8	1.5	2.0	2.5	2.3	1.8
Other residential loan	0.7	0.4	0.5	0.4	0.3	0.2	0.5
Equity:							
Savings account	19.1	15.0	11.6	9.0	8.2	7.5	12.5
Money market account	3.5	4.3	3.8	3.6	4.4	6.7	4.1
Certificate of deposit	6.0	6.4	4.6	3.8	3.1	3.3	4.8
Savings bond	1.5	1.6	1.4	1.6	1.4	1.2	1.5
State & Local bonds	0.0	0.1	0.2	0.2	0.4	1.3	0.3
Corporate bonds	0.1	0.1	0.1	0.2	0.1	0.4	0.1
Stocks	2.3	3.2	3.8	4.8	6.0	12.2	4.6
Mutual funds	1.8	3.0	3.7	4.8	6.1	12.5	4.5
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Rates for Types of Debt

DOE estimated interest rates associated with each type of debt. The source for interest rates for mortgages, loans, credit cards, and lines of credit was the SCF for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019, which associates an interest rate with each type of debt for each household in the survey.

DOE adjusted the nominal rates to real rates for each type of debt by using the annual inflation rate for each year (using the Fisher formula).[i] In calculating effective interest rates for home equity loans and mortgages, DOE also accounted for the fact that interest on both such loans is tax deductible. This rate corresponds to the interest rate after deduction of mortgage interest for income tax purposes and after adjusting for inflation. The specific inflation rates vary by SCF year, while the marginal tax rates vary by SCF year and income bin as shown in Table 8.3.8. For example, a 6 percent nominal mortgage rate has an effective nominal rate of 5.5 percent for a household at the 25 percent marginal tax rate. When adjusted for an inflation rate of 2 percent, the effective real rate becomes 2.45 percent.

[i] Fisher formula is given by: Real Interest Rate = [(1 + Nominal Interest Rate) / (1 + Inflation Rate)] – 1. Note that for this analysis DOE used a minimum real effective debt interest rate of 0 percent.

Table 8.3.8 Data Used to Calculate Real Effective Household Debt Rates

Year	Inflation Rate (%)	Applicable Marginal Tax Rate by Income Group (%)					
		1	2	3	4	5	6
1995	2.81	15.0	15.0	15.0	28.0	28.0	39.6
1998	1.55	15.0	15.0	15.0	28.0	28.0	39.6
2001	2.83	10.0	15.0	15.0	27.5	27.5	39.1
2004	2.68	10.0	15.0	15.0	25.0	25.0	35.0
2007	2.85	10.0	15.0	15.0	25.0	25.0	35.0
2010	1.64	10.0	15.0	15.0	25.0	25.0	35.0
2013	1.46	10.0	15.0	15.0	25.0	25.0	37.3
2016	1.26	10.0	15.0	15.0	25.0	25.0	37.3
2019	1.81	10.0	12.0	12.0	22.0	22.0	36.0

Table 8.3.9 shows the household-weighted average effective real rates in each year and the mean rate across years. Because the interest rates for each type of household debt reflect economic conditions throughout numerous years and various phases of economic growth and recession, they are expected to be representative of rates in effect in 2030.

Table 8.3.9 Average Real Effective Interest Rates for Household Debt (%)

Type of Debt	Income Group						
	1	2	3	4	5	6	All
Mortgage	4.09	3.74	3.60	2.92	2.79	2.19	3.18
Home equity loan	4.29	4.34	3.86	3.24	3.11	2.45	3.35
Credit card	9.80	11.02	11.15	11.26	10.90	10.11	10.64
Other installment loan	6.14	7.09	5.98	5.33	4.54	4.42	6.10
Other line of credit	3.73	3.67	6.23	5.47	4.89	5.33	4.97
Other residential loan	6.53	6.41	5.22	4.96	4.33	3.99	5.32

Sources: Federal Reserve Board. *Survey of Consumer Finances (SCF)* for 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.

Rates for Types of Assets

No similar rate data are available from the SCF for classes of assets, so DOE derived asset interest rates from various sources of national historical data (1993-2022). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1993–2022.[18] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1993–2022.[19] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index

(COSI) data covering 1993–2022.[20,j] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1993-2016, Bartel Associates for 2017-2021, and WM Financial Strategies for 2022.[26,27,28,k] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1993–2022.[29] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1993–2022.[30] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[l] DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see appendix 8H). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in Table 8.3.10.

Table 8.3.10 Average Capital Gains Marginal Tax Rate by Income Group (%)

Year	Income Group					
	1	2	3	4	5	6
1995	12.5	12.5	12.5	28.0	28.0	33.8
1998	12.5	12.5	12.5	24.0	24.0	29.8
2001	7.5	10.0	15.0	21.3	21.3	27.1
2004	7.5	10.0	15.0	21.3	21.3	27.1
2007	7.5	10.0	15.0	20.0	20.0	25.0
2010	5.0	7.5	15.0	20.0	20.0	25.0
2013	5.0	7.5	15.0	20.0	20.0	27.4
2016	5.0	7.5	15.0	20.0	20.0	27.4
2019	5.0	6.0	6.0	18.5	18.5	26.8

Average real effective interest rates for the classes of household assets are listed in Table 8.3.11. Because the interest and return rates for each type of asset reflect economic conditions throughout numerous years, they are expected to be representative of rates that may be in effect in the compliance year. The average nominal interest rates and the distribution of real interest rates by year are shown in appendix 8H.

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[j] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[21,22] From July 2007 to October 2009 the index was known as Wachovia COSI[23] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[24,25]

[k] This Federal Reserve Board index was discontinued in 2016. To calculate the 2017 and after values, DOE used data collected by Bartel Associates and WM Financial Strategies.

[l] SCF reports what type of mutual funds the household has (e.g., stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8.3.11 Average Real Interest Rates for Household Assets (%)

Equity Type	Income Group						
	1	**2**	**3**	**4**	**5**	**6**	**All**
Savings accounts	0.06	0.05	0.05	0.05	0.05	0.04	0.05
Money market accounts	0.11	0.11	0.10	0.09	0.09	0.09	0.10
Certificate of deposit	0.26	0.25	0.24	0.22	0.22	0.20	0.24
Treasury Bills (T-bills)	1.79	1.75	1.68	1.53	1.53	1.41	1.65
State/Local bonds	1.60	1.76	1.68	1.53	1.53	1.40	1.51
AAA Corporate Bonds	1.96	1.98	2.30	2.20	2.12	2.03	2.12
Stocks (S&P 500)	7.89	7.74	7.39	6.70	6.70	6.17	6.93
Mutual funds	6.49	6.55	6.34	5.67	5.75	5.04	5.80

Discount Rate Calculation and Summary

Using the asset and debt data discussed above, DOE calculated discount rate distributions for each income group as follows. First, DOE calculated the discount rate for each consumer in each of the versions of the *SCF*, using the following formula:

$$DR_i = \sum_j Share_{i,j} \times Rate_{i,j}$$

Eq. 8.13

Where:

DR_i = discount rate for consumer i,
$Share_{i,j}$ = share of asset or debt type j for consumer i, and
$Rate_{i,j}$ = real interest rate or rate of return of asset or debt type j for consumer i.

The rate for each debt type is drawn from the SCF data for each household. The rate for each asset type is drawn from the distributions described above.

Once the real discount rate was estimated for each consumer, DOE compiled the distribution of discount rates in each survey by income group by calculating the proportion of consumers with discount rates in bins of 1 percent increments, ranging from 0-1 percent at the low end to 30 percent and greater at the high end. Giving equal weight to each survey, DOE compiled the overall distribution of discount rates.

Table 8.3.12 presents the average real effective discount rate and its standard deviation for each of the six income groups. To account for variation among households, DOE sampled a rate for each RECS household from the distributions for the appropriate income group. (RECS provides household income data.) Appendix 8H presents the full probability distributions for each income group that DOE used in the LCC and PBP analysis.

Table 8.3.12 Average Real Effective Discount Rates

Income Group	Discount Rate (%)
1	4.63
2	4.86
3	4.41
4	3.71
5	3.34
6	3.01
Overall Average	4.16

Source: Board of Governors of the Federal Reserve System, Survey of Consumer Finances (1995 – 2019)

8.3.5.2 Discount Rates for Commercial Applications

DOE's method views the purchase of a higher efficiency appliance as an investment that yields a stream of energy cost savings. DOE derived the discount rates for the LCC analysis by estimating the cost of capital for companies or public entities that purchase gas-fired instantaneous water heaters. For private firms, the weighted average cost of capital (WACC) is commonly used to estimate the present value of cash flows to be derived from a typical company project or investment.[31] Most companies use both debt and equity capital to fund investments, so their cost of capital is the weighted average of the cost to the firm of equity and debt financing, as estimated from financial data for publicly traded firms in the sectors that purchase gas-fired instantaneous water heaters.[32] As discount rates can differ across industries, DOE estimates separate discount rate distributions for a number of aggregate sectors with which elements of the LCC building sample can be associated.

Damodaran Online, the primary source of data for this analysis, is a widely used source of information about debt and equity financing for most types of firms.[33] The approximately 200 detailed industries included in the Damodaran Online data (shown in a table in Appendix 8H) were assigned to the aggregate sectors shown in Table 8.3.13, which also shows the mapping between the aggregate sectors and CBECS Principal Building Activities (PBAs).[m] Damodaran Online data for manufacturing and other similar industries were assigned to the aggregate Industrial sector, while data for farming and agriculture were assigned to the Agriculture sector. Public entities are included in the sectors Federal Government and State/Local Government, but Damodaran data are not used for these sectors.

[m] Previously, Damodaran Online provided firm-level data, but now only industry-level data is available, as compiled from individual firm data, for the period of 1998-2018. The data sets note the number of firms included in the industry average for each year.

Table 8.3.13 Mapping of Aggregate Sectors to CBECS Categories

Sector in DOE Analysis	Applied to CBECS PBAs (Name and PBA number)
Education[n]	Education (14)
Food Sales	Food sales (6)
Food Service	Food service (15)
Health Care	Outpatient health care (8); Inpatient health care (16); Nursing (17); Laboratory (4)
Lodging	Lodging (18)
Mercantile	Enclosed mall (24); Strip shopping mall (23); Retail other than mall (25)
Office	Office (2)
Public Assembly	Public assembly (13)
Service	Service (26)
All Commercial	All CBECS PBAs, including those specified above
Industrial	Not in CBECS
Agriculture	Not in CBECS
Federal Government	Not in CBECS
State/Local Government	Not in CBECS

Note: CBECS only includes buildings used by firms in "commercial" sectors, so Industrial and Agriculture have no associated PBA identifier. However, discount rate distributions are required for these sectors because they are significant consumers of some types of appliances and energy-consuming equipment.

For private firms, DOE estimated the cost of equity using the capital asset pricing model (CAPM).[34] CAPM assumes that the cost of equity (k_e) for a particular company is proportional to the systematic risk faced by that company, where high risk is associated with a high cost of equity and low risk is associated with a low cost of equity. In CAPM, the systematic risk facing a firm is determined by several variables: the risk coefficient of the firm (β), the expected return on risk-free assets (R_f), and the equity risk premium (*ERP*). The cost of equity can be estimated at the industry level by averaging across constituent firms. The risk coefficient of the firm indicates the risk associated with that firm relative to the price variability in the stock market. The expected return on risk-free assets is defined by the yield on long-term government bonds. The *ERP* represents the difference between the expected stock market return and the risk-free rate. The cost of equity financing is estimated using the following equation, where the variables are defined as above:

$$k_{ei} = R_f + \beta_i \times ERP$$

Eq. 8.14

[n] This sector applies to private education, while public education is covered under the later discussion of buildings operated by state and local government entities.

Where:

k_{ei} = cost of equity for industry i,
R_f = expected return on risk-free assets,
β_i = risk coefficient of industry i, and
ERP = equity risk premium.

Several parameters of the cost of capital equations can vary substantially over time, and therefore the estimates can vary with the time period over which data is selected and the technical details of the data averaging method. For guidance on the time period for selecting and averaging data for key parameters and the averaging method, DOE used Federal Reserve methodologies for calculating these parameters. In its use of the CAPM, the Federal Reserve uses a forty-year period for calculating discount rate averages, utilizes the gross domestic product price deflator for estimating inflation, and considers the best method for determining the risk free rate as one where "the time horizon of the investor is matched with the term of the risk-free security."[35]

By taking a forty-year geometric average of Federal Reserve data on annual nominal returns for 10-year Treasury bonds, as provided by Damodaran Online, DOE estimated annual risk free rates back to 1998. DOE estimated the ERP by calculating the difference between risk free rate and stock market return for the same time period, as estimated using Damodaran Online data on the historical return to stocks.

The cost of debt financing (k_d) is the interest rate paid on money borrowed by a company. The cost of debt is estimated by adding a risk adjustment factor (R_a) to the risk-free rate. This risk adjustment factor depends on the variability of stock returns represented by standard deviations in stock prices. This same calculation can alternatively be performed with industry-level data. Tax rates also impact the cost of debt financing. Using industry average tax rates provided by Damodaran Online, DOE incorporates the after-tax cost of debt.

For industry i, the cost of debt financing is:

$$k_{di} = \left(R_f + R_{ai}\right) \times (1 - tax_i)$$

Eq. 8.15

Where:

k_{di} = (after-tax) cost of debt financing for industry, i,
R_f = expected return on risk-free assets,
R_{ai} = risk adjustment factor to risk-free rate for industry, i, and
tax_i = tax rate of industry, i.

DOE estimates the weighted average cost of capital using the following equation:

$$WACC = k_{ei} + W_{e,i} + k_{di} + w_{d,i}$$

Eq. 8.16

Where:

$WACC_i$ = weighted average cost of capital for industry i,
k_{ei} = cost of equity for industry i,
k_{di} = cost of debt financing for industry, i,
w_e = proportion of equity financing for industry i, and
w_d = proportion of debt financing for industry i.

OE accounts for inflation using the all items Gross Domestic Product deflator, as published by the Bureau of Economic Analysis.[36] Table 8.3.14 shows the real average WACC values for the major sectors that purchase gas-fired instantaneous water heaters. Tables providing full discount rate distributions by sector are included in appendix 8H. While WACC values for any sector may trend higher or lower over substantial periods of time, these values represent a cost of capital that is averaged over major business cycles.

For each entity in the consumer sample for gas-fired instantaneous water heaters, a discount rate is drawn from the distribution calculated for the appropriate sector.

Table 8.3.14 Weighted Average Cost of Capital for Commercial/Industrial Sectors

Sector	Observations	Total Firms	Mean WACC (%)
Education	25	869	7.21
Food Sales	46	923	5.68
Food Service	25	1,980	6.58
Health Care	60	6,023	6.99
Lodging	25	1,754	6.57
Mercantile	109	5,925	7.03
Office	493	50,170	6.87
Public Assembly	50	4,033	7.31
Service	166	16,530	6.23
All Commercial	1013	88,365	6.76
Industrial	1,403	84,723	7.29
Agriculture	10	345	7.16
Utilities	109	2,193	4.20
R.E.I.T/Property	61	4,944	6.56

Note: "Observations" reflect the number of Damodaran Online detailed industries included in DOE's aggregate sector calculation, while "Total Firms" presents a sum of the number of individual companies represented by those detailed industries. These are two measures of the comprehensiveness of the data used in the WACC calculation.

For publicly owned and operated buildings, the cost of capital can be derived using state and local bond rates and U.S. Treasury bond rates.[18,26,37] State and local bond rates are used for buildings identified as owned and/or occupied by state or local government entities, such as public schools or local government administrative buildings. Treasury bond rates are used for buildings identified as occupied by federal government entities. Table 8.3.15 presents the average values of discount rates used for public sectors.

Table 8.3.15 Discount Rates for Public Sectors that Purchase Gas-Fired Instantaneous Water Heaters

Sector	Observations	Mean Discount Rate (%)
State/Local Govt	30	3.21
Federal Govt	30	2.90

8.4 ENERGY EFFICIENCY DISTRIBUTIONS

To estimate the percentage of consumers who would be affected by a potential standard at any of the considered efficiency levels, DOE first develops a distribution of efficiencies for products that consumers purchase under the no-new-standards case.

For gas-fired instantaneous water heaters, DOE estimated the no-new standards case efficiency distribution based on available shipments data by efficiency including in previous Air-conditioning, Heating, and Refrigeration Institute (AHRI) submitted historical shipment data,[38] ENERGY STAR unit shipments data,[39] and data from a 2023 BRG Building Solutions report.[40] To cover gaps in the available shipments data, DOE used the AHRI certification directory[41] and DOE's public Certification Compliance Database (CCD)[42] with other publicly available data from manufacturers' catalogs of gas-fired instantaneous water heaters to develop efficiency distribution based on available models. DOE considered incentives and other market forces that have increased the sales of high-efficiency gas-fired instantaneous water heaters to estimate future no-new-standards case efficiency distributions for the considered products.

Using the projected distribution of efficiencies for gas-fired instantaneous water heaters, DOE randomly assigned a product efficiency to each household and commercial user drawn from the consumer samples. DOE also accounted for some consumer subgroups that could select higher efficiency gas-fired instantaneous water heaters more often, by using data derived from Decision Analyst's 2022 American Home Comfort Study[43] showing a relationship between square footage[o] and higher efficiency consumer space heating and cooling equipment. If a consumer is assigned a product efficiency that is greater than or equal to the efficiency under consideration, the consumer would not be affected by a standard at that efficiency level.

[o] DOE found that square footage seems to be a good indicator of both higher income and increased energy use HVAC. The lower third of the square footage bin was 5% less likely to install higher efficiency compared to the middle third of the square footage bin, while the upper third square footage bin was 5 percent more likely than the middle square footage bin. At this time, DOE does not have similar data for water heating equipment, but believes a similar relationship could be applicable.

Table 8.4.1 shows the no-new-standards case efficiency distribution in the compliance year. For a detailed discussion of the development of no-new-standards case distributions, see appendix 8I.

Table 8.4.1 No-New-Standards Case Energy Efficiency Distributions in 2030 for Gas-fired Instantaneous Water Heaters

EL	Low		Medium		High		All Draw Patterns
	UEF*	Market Share	UEF*	Market Share	UEF*	Market Share	
0			0.81	30%	0.81	30%	30%
1			0.87	8%	0.89	8%	8%
2			0.91	47%	0.93	47%	47%
3			0.92	6%	0.95	7%	7%
4			0.93	8%	0.96	8%	8%

* UEF values based on representative effective volume (see Chapter 5).

8.5 LIFE-CYCLE COST AND PAYBACK PERIOD RESULTS

The LCC calculations were performed for each of the 10,000 consumers in the sample of consumers established for gas-fired instantaneous water heaters. Each LCC calculation sampled inputs from the probability distributions that DOE developed to characterize many of the inputs to the analysis.[p,q]

For the set of the sample consumers for each gas-fired instantaneous water heaters, DOE calculated the average installed cost, first year's operating cost, lifetime operating cost, and LCC for each EL. These averages are calculated assuming that all of the sample purchasers purchase a product at each EL. This allows the installation costs, operating costs, and LCCs for each EL to be compared under the same conditions, across a variety of sample purchasers. DOE used these average values to calculate the PBP for each EL, relative to the baseline EL.

DOE first assigned gas-fired instantaneous water heaters to consumers using the efficiency distribution in the no-new-standards case. DOE calculated the LCC and PBP for all consumers as if each was to purchase a new gas-fired instantaneous water heater in the expected year of compliance with amended standards. For any given efficiency level, DOE measures the change in LCC relative to the LCC in the no-new-standards case, which reflects the estimated efficiency distribution of gas-fired instantaneous water heaters in the absence of new or amended energy conservation standards.

The following sections present the key LCC and PBP findings, as well as figures that illustrate the range of LCC and PBP effects among a sample of consumers. A consumer is

[p] The difference in the LCC and PBP results using a higher number of simulations (e.g., 20,000) is not statistically significant.
[q] To ensure the consistency of the analysis, for the draw patterns within gas-instantaneous water heaters, the number of households sampled is extracted from the 10,000 simulation results for all households. Performing the analysis for the sample that only includes households that draw pattern could produce slightly different results because of the use of a smaller set of the simulation results.

considered to have received a net LCC cost if the purchaser had negative LCC savings at the EL being analyzed. DOE presents the average LCC savings for affected consumers, which includes only consumers with non-zero LCC savings due to the standard.

8.5.1 Summary of Results

Table 8.5.1 and Table 8.5.2 show the LCC and PBP results for gas-fired instantaneous water heaters by EL and draw pattern.

Table 8.5.1 Average LCC and PBP Results by Draw Pattern and Efficiency Level for Gas-Fired Instantaneous Water Heaters with a Rated Storage Volume Less than 2 Gallons and an Input Rating Greater than 50,000 Btu/h

Efficiency Level	Average Costs (*2023$*)				Simple PBP (*Years*)	Average Lifetime (*Years*)
	Installed Cost	First-Year's Operating Cost	Lifetime Operating Cost	LCC		
Medium Draw Pattern						
Baseline	$2,033	$316	$4,646	$6,679	-	19.7
1	$2,249	$303	$4,478	$6,728	15.7	19.7
2	$2,263	$293	$4,343	$6,606	9.9	19.7
3	$2,275	$291	$4,311	$6,586	9.5	19.7
4	$2,360	$288	$4,265	$6,625	11.4	19.7
High Draw Pattern						
Baseline	$2,097	$300	$4,558	$6,655	-	20.0
1	$2,314	$282	$4,315	$6,629	12.1	20.0
2	$2,328	$274	$4,186	$6,514	8.7	20.0
3	$2,344	$270	$4,126	$6,470	8.1	20.0
4	$2,435	$267	$4,079	$6,515	10.1	20.0
Weighted Average Over All Draw Patterns						
Baseline	$2,087	$303	$4,571	$6,659	-	20.0
1	$2,304	$285	$4,339	$6,644	12.6	20.0
2	$2,318	$277	$4,210	$6,528	8.9	20.0
3	$2,334	$273	$4,154	$6,487	8.3	20.0
4	$2,424	$270	$4,107	$6,531	10.3	20.0

Note: The results for each EL represent the average value if all purchasers in the sample use products with that efficiency level. The PBP is measured relative to the baseline product.

Table 8.5.2 LCC Results Relative to the No-New-Standards Case Efficiency Distribution by Draw Pattern and Efficiency Level for Gas-Fired Instantaneous Water Heaters with a Rated Storage Volume Less Than 2 Gallons and an Input Rating Greater Than 50,000 Btu/h

Efficiency Level	Average LCC Savings* (*2023$*)	% of Consumers that Experience Net Cost
Medium Draw Pattern		
1	($42)	19%
2	$83	17%
3	$56	30%
4	$13	59%
High Draw Pattern		
1	$6	17%
2	$117	15%
3	$96	24%
4	$43	56%
Average Over All Draw Patterns		
1	($1)	17%
2	$112	15%
3	$90	25%
4	$39	56%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings.

8.5.2 Distribution of Impacts

Figure 8.5.1 through Figure 8.5.5 show the no-new-standards case LCC distributions for gas-fired instantaneous water heaters. In the figure, a text box next to a vertical line at a given value on the x-axis shows the mean savings.

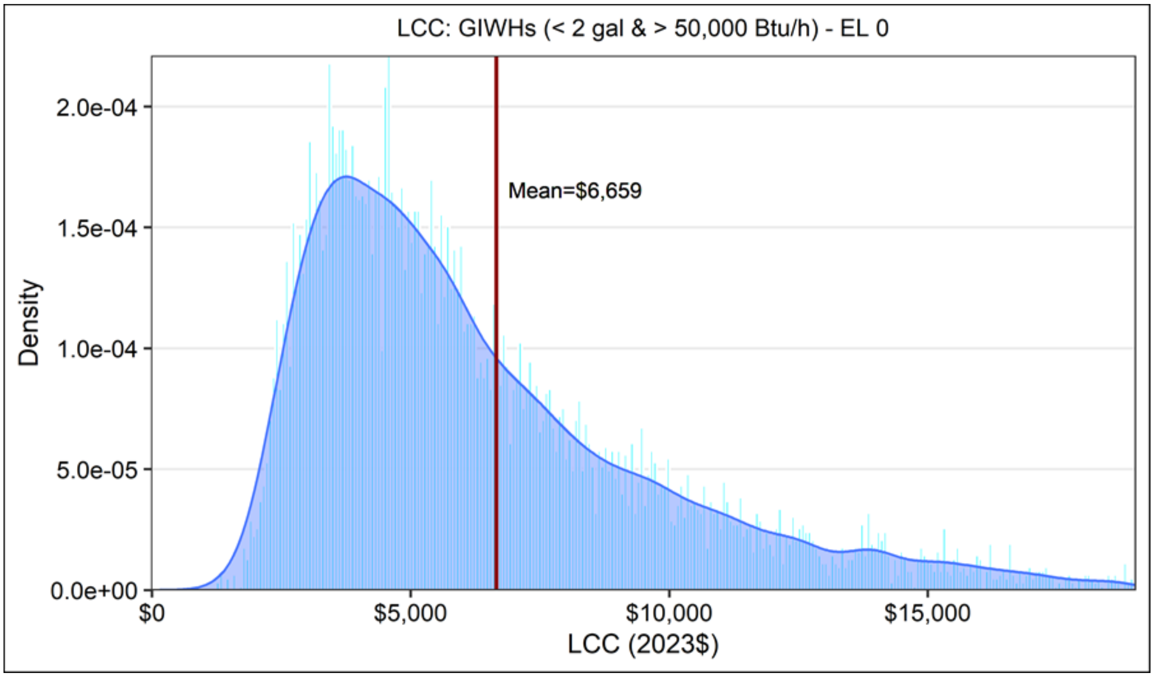

Figure 8.5.1 LCC Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 0

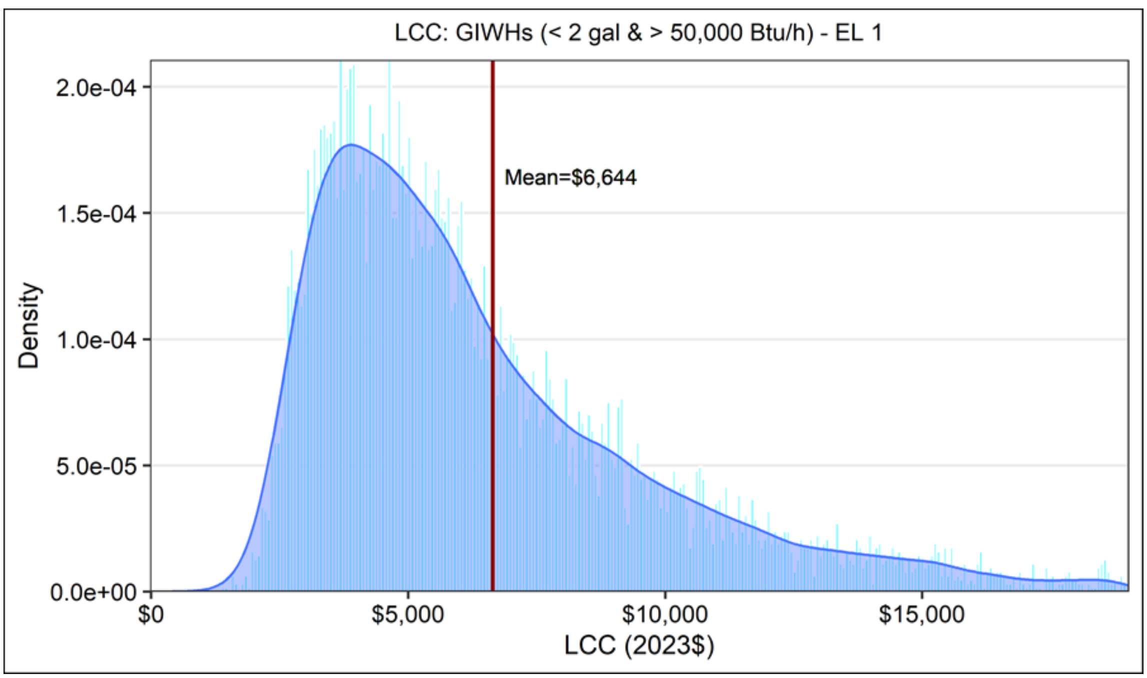

Figure 8.5.2 LCC Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 1

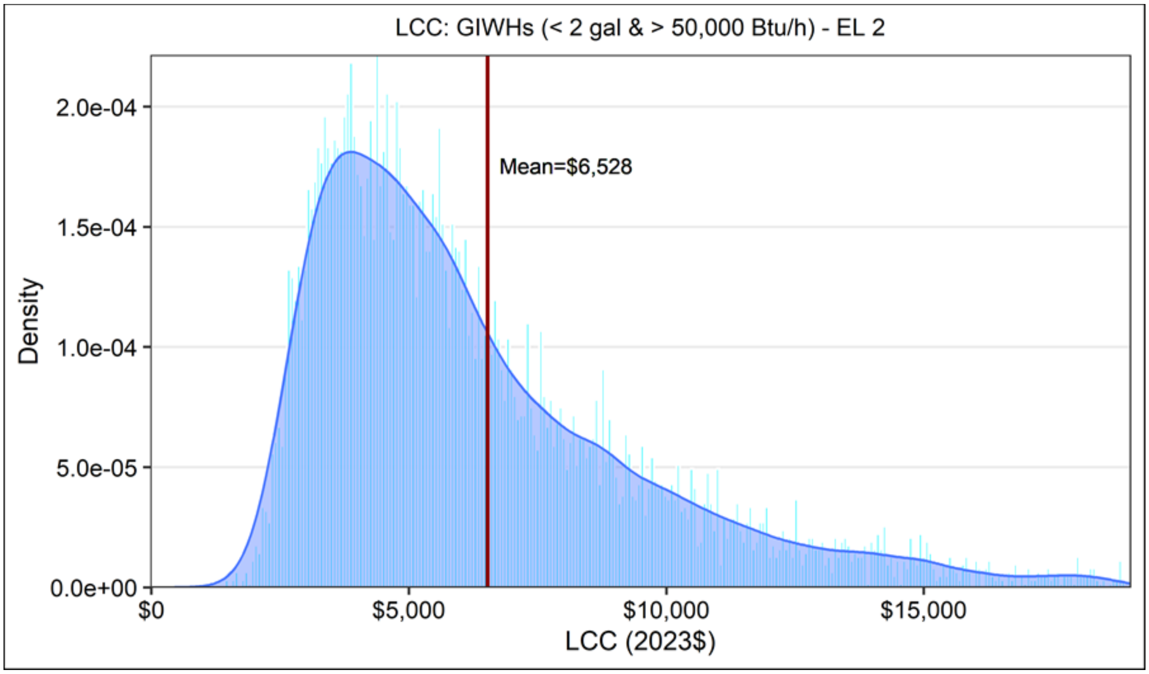

Figure 8.5.3 LCC Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 2

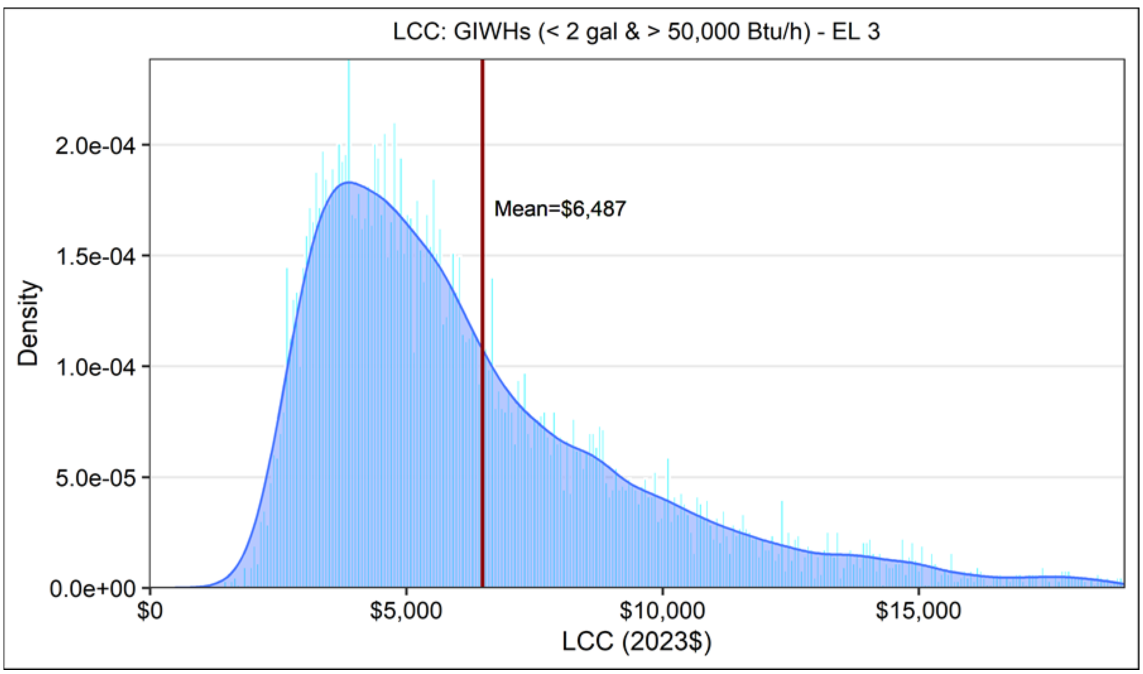

Figure 8.5.4 LCC Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 3

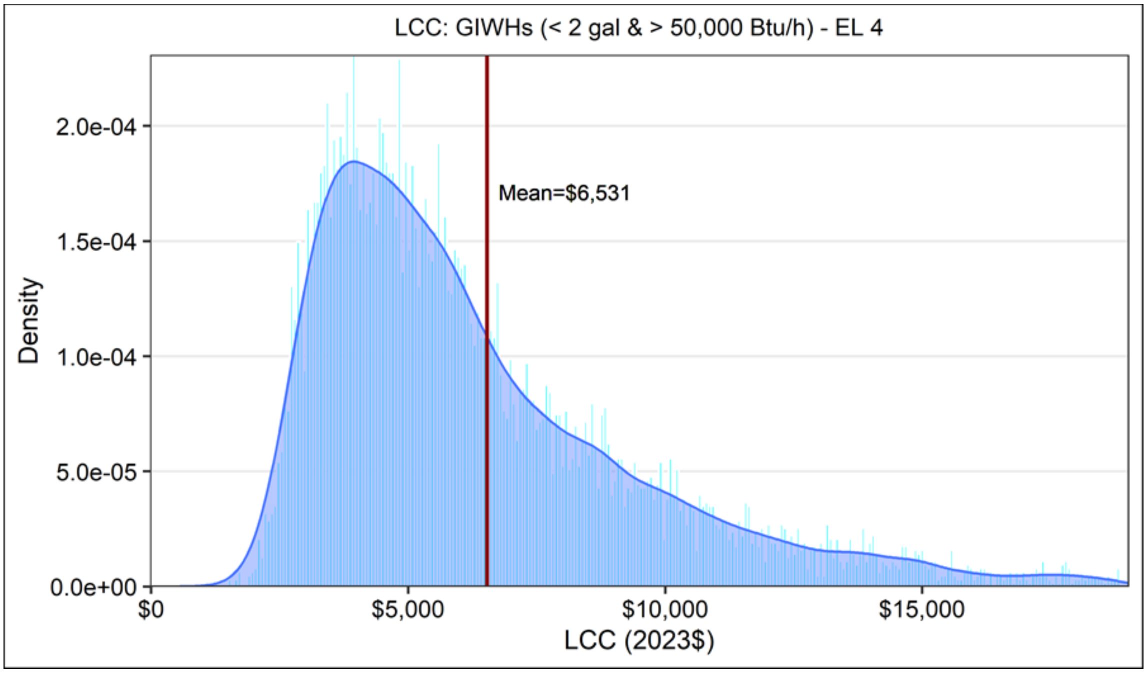

Figure 8.5.5 LCC Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 4

8.5.3 Range of LCC Impacts

Figure 8.5.6 through Figure 8.5.9 the distribution of LCC impacts by efficiency levels of gas-fired instantaneous water heaters.

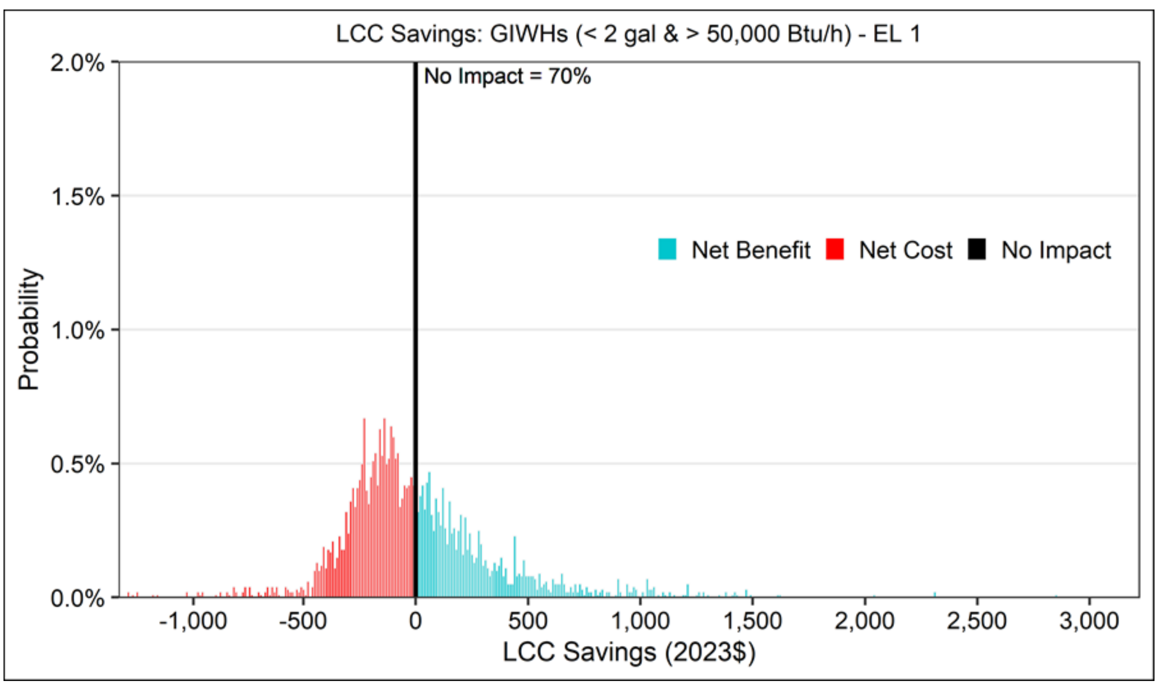

Figure 8.5.6 LCC Savings Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 1

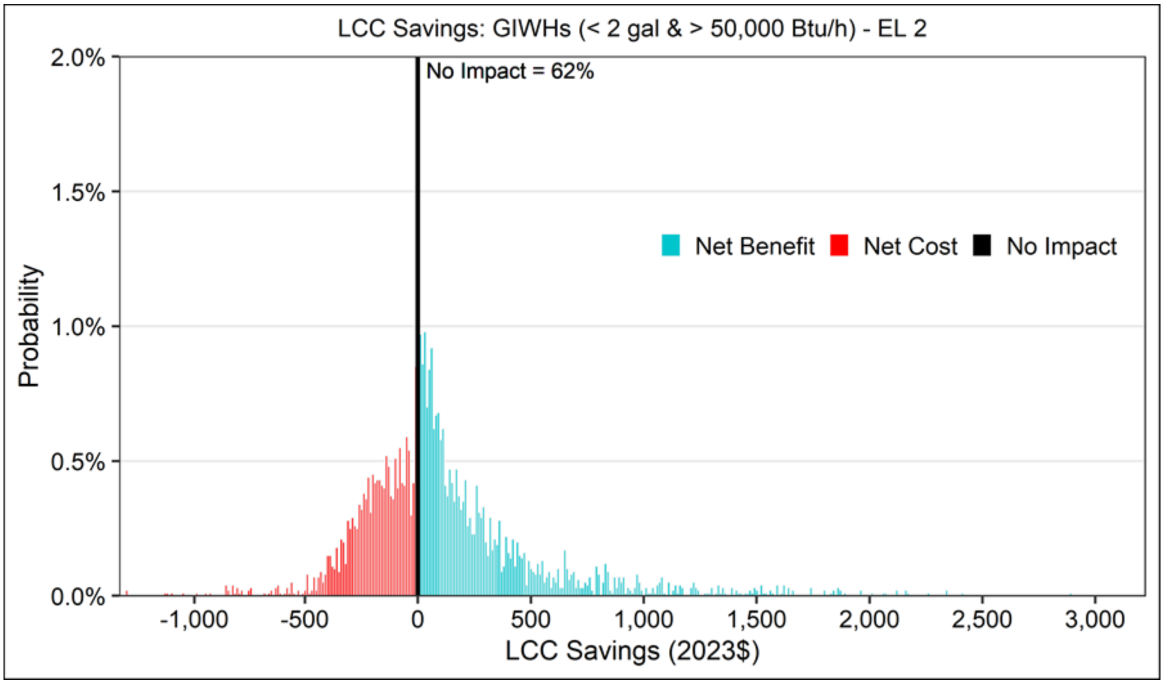

Figure 8.5.7 LCC Savings Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 2

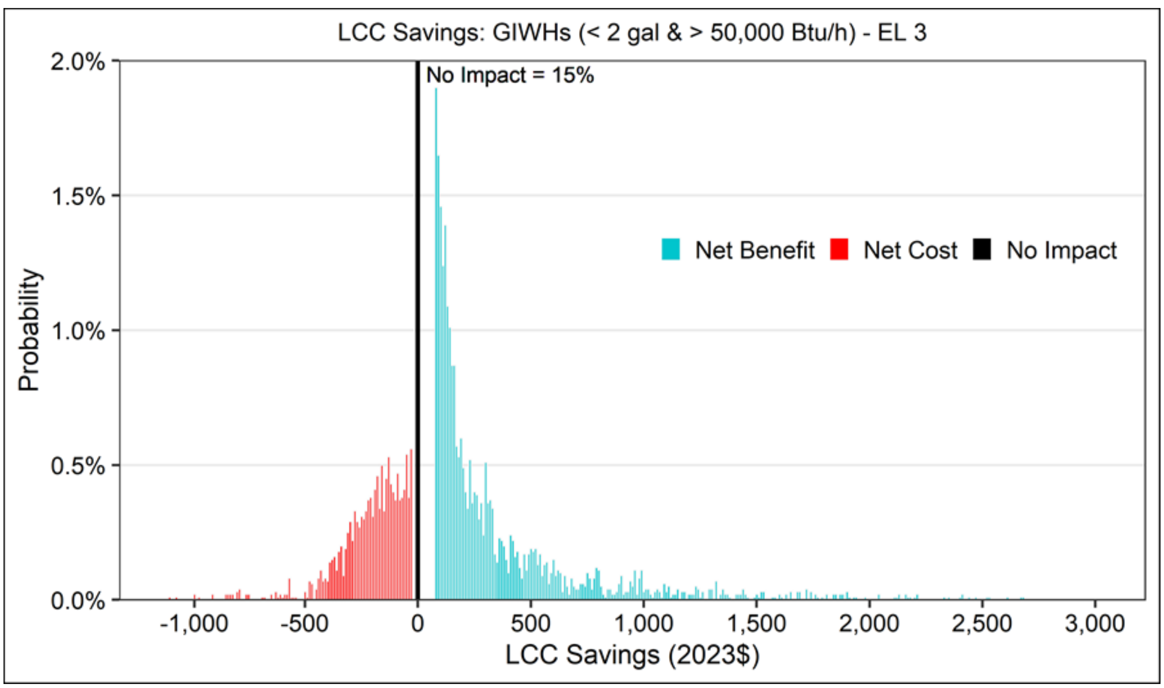

Figure 8.5.8 LCC Savings Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 3

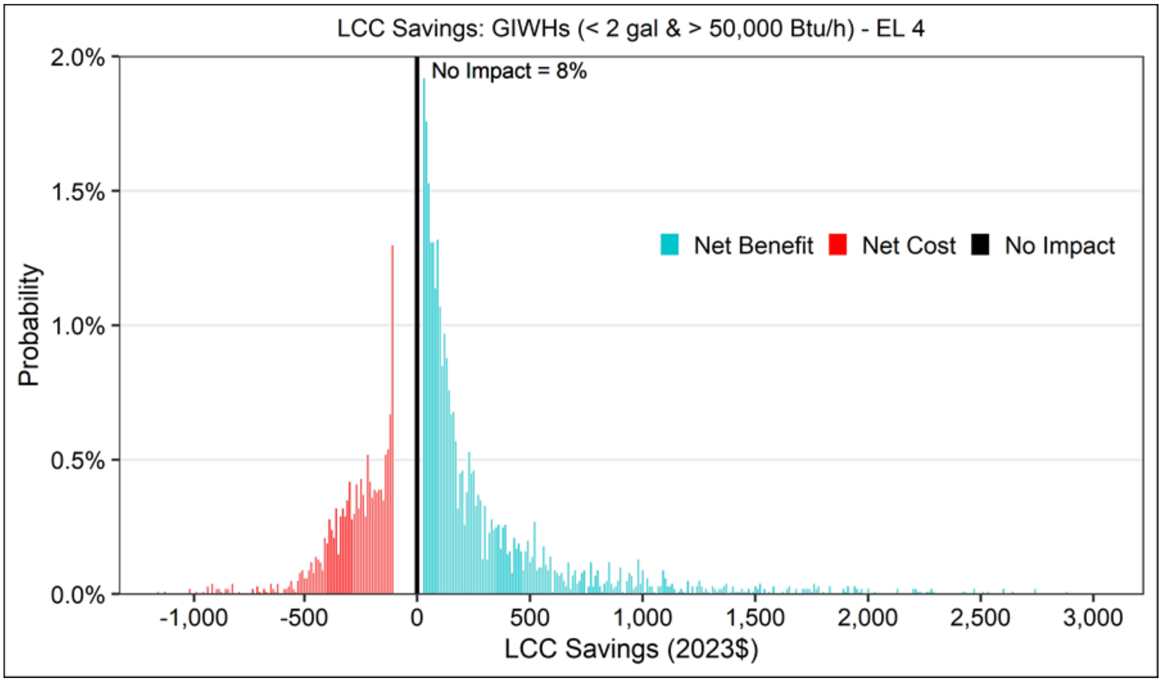

Figure 8.5.9 LCC Savings Distribution: GIWHs (< 2 gal & > 50,000 Btu/h) - EL 4

Figure 8.5.10 shows the range of LCC savings for all efficiency levels considered. For each efficiency level, the top and the bottom of the box indicate the 75th and 25th percentiles, respectively. The bar at the middle of the box indicates the median: 50 percent of the households have LCC savings in excess of that value. The "whiskers" at the bottom and the top of the box indicate the 5th and 95th percentiles. The small box shows the average LCC savings for each efficiency level.

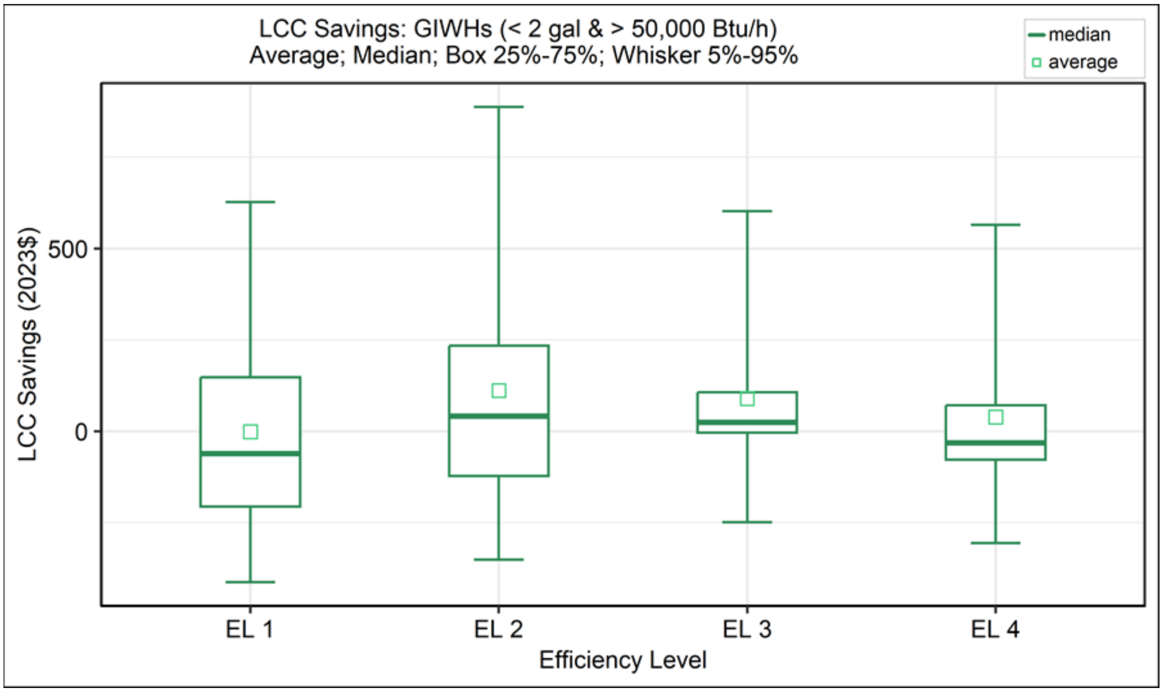

Figure 8.5.10 Distribution of LCC Savings for GIWHs (< 2 gal & > 50,000 Btu/h)

8.5.4 Rebuttable Payback Period

DOE calculates so-called rebuttable PBPs to test the legally established rebuttable presumption that an energy efficiency standard is economically justified if the additional product costs attributed to the standard are less than three times the value of the first-year energy cost savings. (42 U.S.C. §6295 (o)(2)(B)(iii))

The basic equation for rebuttable PBP is the same as that used for PBP. However, the rebuttable PBP is not based on the use of household samples and probability distributions. Instead, the rebuttable PBP is based on discrete single-point values. For example, whereas DOE uses a probability distribution of energy prices in the main PBP analysis, it uses only the national average energy price to determine the rebuttable PBP. In addition, the rebuttable PBP relies on the DOE test procedure to determine a product's annual energy consumption. The rebuttable PBP also excludes any maintenance and repair costs.

The following summarizes the single-point values that DOE used in determining the rebuttable PBP:

- Manufacturing costs, markups, sales taxes, and installation costs were all based on the single-point values used in the distributional LCC and PBP analysis.
- Energy prices were based on national average values for the year that new standards will take effect.
- An average discount rate or lifetime is not required in the rebuttable PBP calculation.
- The effective date of the standard is assumed to be 2030.

Table 8.5.3 presents the rebuttable payback periods by draw pattern and considered EL.

Table 8.5.3 Rebuttable Payback Periods for Gas-fired Instantaneous Water Heaters

Product Class	**Rated Storage Volume and Input Rating (if applicable)**	**Draw Pattern**	**Rebuttable Payback Period, *years***			
			Efficiency Level			
			1	**2**	**3**	**4**
GIWH	<2 gal and >50 kBtu/h	Medium	19.1	12.5	12.1	14.6
		High	9.6	7.1	6.6	8.3

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CHAPTER 9. SHIPMENTS ANALYSIS

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CHAPTER 9. SHIPMENTS ANALYSIS

9.1 INTRODUCTION

Projections of product shipments are a necessary input for calculating national energy savings (NES) and net present value (NPV) of potential new or amended energy efficiency standards. Shipments also are necessary to the manufacturer impact analysis (MIA). This chapter describes the U.S. Department of Energy (DOE)'s method and results of projecting annual shipments for consumer gas-fired instantaneous water heaters (GIWHs).

The shipments model developed by DOE takes an accounting approach, tracking the entry and exit of products in the stock, resulting in an age distribution of in-service product stock for each year in the analysis period. Rather than simply extrapolating a current shipments trend, the analysis uses key drivers of shipments, including construction forecasts and product retirement functions, to project sales in each market segment. For GIWHs, DOE accounted for three market segments: (1) shipments to new construction; (2) shipments to replace retired units in existing buildings; and (3) shipments to new owners. DOE also accounts for GIWH shipments to residential and commercial applications. To estimate the effect of potential standard levels on product shipments, the shipments model accounts for the effects of changes in purchase price and energy efficiency on the consumer purchase decision.

The shipments model was developed as a part of the Microsoft Excel® spreadsheet for the national impact analysis (NIA) that is accessible on DOE's Appliance and Equipment Standards Rulemakings and Notices website (https://www.energy.gov/eere/buildings/consumer-water-heaters). Appendix 10A of this technical support document (TSD) describes how to access the NIA workbook and provides basic instructions for its use.

The rest of this chapter explains the shipments model in more detail. Section 9.2 presents an overview of the shipments model; section 9.3 describes the data inputs and analysis of market segments; section 9.4 defines the decision models used in the no-new-standards case and standards cases; and section 9.5 presents the projection of shipments in the no-new-standards and standards cases.

9.2 SHIPMENTS MODEL OVERVIEW

The shipments model disaggregates the total stock of GIWHs according to the following characteristics:

1. Product class: GIWHs with a rated storage volume less than 2 gallons and an input rating greater than 50 kBtu/h,

2. Draw pattern: medium draw and high draw patterns were analyzed as part of this analysis and incorporated into the life-cycle cost (LCC) consumer sample (see Chapter 8 of this TSD), and

3. Application market sector: Two market sectors were considered in this analysis: residential sector and commercial sector.

The GIWH shipments model considers three product market segments (hereafter referred to as "market segments") as follows:

1. *Existing owners (replacement shipments)*: these are defined as existing buildings with GIWHs installed. This category receives new shipments when existing products are replaced.

2. *New construction (shipments to new construction)*: a certain fraction of new buildings acquire GIWHs in each future year. This fraction is defined as the new construction saturation, which varies by year.

3. *New owners (shipments to new owners)*: these are defined as existing buildings that acquire GIWHs for the first time during the analysis period. The new owners primarily consist of households or buildings that previously did not have a GIWH and install a new GIWH.

9.2.1 Fundamental Model Equations

The fundamental dependent variable in the shipments model is the product stock, which is represented as a function of the analysis year (indexed by *j)*, and product vintage or age (the product age is noted as *a*, and is equal to the analysis year minus the vintage). The stock function is adjusted in each year of the analysis period by new shipments coming in and broken or demolished product being taken out.

For existing stock:

$$Stock_p(j,a) = Stock_p(j-1,a-1) - Rem_p(j,a) + Ship(j-1,a-1)$$

Eq. 9.1

and for new shipments:

$$Stock_p(j,a=1) = Ship_p(j-1)$$

Eq. 9.2

Where:

$Stock_p(j, a)$ = number of units of product class *p* and age *a* in analysis year *j*,
$Rem_p(j, a)$ = number of units of product class *p* and age *a* removed in analysis year *j*, and
$Ship_p(j)$ = number of units of product class *p* shipped in year *j*.

Removals due to product failure contain a survival function $f_p(a)$ that is used to represent the probability that a unit of age *a* will survive in a given year; equivalently, the probability that this unit will fail is 1- $f_p(a)$.

Total removals in the no-new-standards case are then:

$$Rem_p(j,a) = [1 - f_p(a)] \times Stock_p(j,a)$$

Eq. 9.3

The total number of shipments for each product class is the sum of the shipments to each of the three market segments:

$$Ship_p(j) = Rpl_p(j) + NC_p(j) + NO_p(j)$$

Eq. 9.4

Where:

$Rpl_p(j)$ = number of units of product *p* replaced in year *j*, which depends on removed units and units in demolished buildings,
$NC_p(j)$ = number of units installed in new construction of product *p* in year *j*, and
$NO_p(j)$ = number of units shipped to "new owners" of product *p* in year *j*.

9.2.2 Replacement Shipments

The shipments model assumes that units that are taken from demolished buildings, $Dem(j)$, are included in the mix of broken units $Rem_p(j)$. As the demolished units do not need to be replaced, they are deducted from $Rem_p(j)$ when calculating the required replacements, as represented by the following expression:

$$Rpl_p(j) = Rem_p(j) - Dem(j)$$

Eq. 9.5

When a GIWH fails, it is removed from the stock or is repaired for extended use. The following retirement function $r_p(a)$ is used to represent the probability that a unit will fail at age a.

$$Rem_p(j) = \sum_a r_p(a) \times Stock_p(j,a)$$

Eq. 9.6

Retirement functions and product lifetimes are discussed in more detail in chapter 8.

In each year, products are removed from demolished buildings. As represented by the following expression, the shipments model assumes that the saturation of the product in the demolished buildings is the same as that of the overall building population.

$$Dem(j) = D(j) \times sat(p, j-1)$$

Eq. 9.7

The number of demolished buildings is calculated by:

$$D(j) = H\_Stock(j-1) + H\_Starts(j) - H\_Stock(j)$$

Eq. 9.8

Where:

$H\_Stock(j)$ = number of building units in analysis year j,
$H\_Starts(j)$ = number of new building units in year j,
$D(j)$ = number of demolished buildings,
$Dem(j)$ = number of products demolished in analysis year j, and
$sat(p,j)$ = saturation of products of product class p for all buildings in year j.

9.2.3 Shipments to New Constructions

DOE multiplied new construction market saturations by projections of new housing units to estimate shipments to the new construction segment. The determination of shipments to new construction is represented by the following expression:

$$NC_p(j) = NC\_Starts\_res(j) \times NC\_Sat\_res_p(j) + NC\_Starts\_com(j) \times NC\_Sat\_com_p(j)$$

Eq. 9.9

Where:

$NC\_Starts\_res(j)$ = number of new residential housing starts in year j,
$NC\_Sat\_res_p(j)$ = new residential housing saturation for product class p and year j,
$NC\_Starts\_com(j)$ = number of new commercial building starts in year j, and
$NC\_Sat\_com_p(j)$ = new commercial building saturation for product class p and year j.

9.2.4 Shipments to New Owners

The third market segment consists of new owners of GIWHs. Because there are no data on the extent of these phenomena, DOE estimated historical shipments to this market segment as a residual, using the following equation:

$$NO(j) = Shipment(j) - (RU(j) + NU(j))$$

Eq. 9.10

Where:

j = year where historical shipment data is available,
$NO(j)$ = new owners (if positive) or adjustment for switching (if negative) for year j,
$Shipment(j)$ = historical shipment in year j,
$RU(j)$ = estimated replacement units in year j, and
$NU(j)$ = new units for new homes in year j.

The shipments model begins with an estimate of the building stock and product stock in the base year, and adds shipments and removes retirements each year. In principle, only building and market saturation data are needed to allow the shipments model to estimate shipments to new construction and replacements. The third product segment, new owners, is more difficult to describe based on existing data.

9.3 DATA INPUTS AND MARKET SEGMENTS

9.3.1 Historical Shipments

DOE used historical GIWH shipments data (i.e., domestic shipments and imports) to populate its shipments model. As shown in Table 9.3.1, the sources of annual historical shipments are: (1) AHRI data submittals;[1] (2) BRG Building Solutions 2023 report;[2] (3) ENERGY STAR unit shipments data;[3] and 2010 Heating Products Final Rule.[4]

Table 9.3.1 Sources for Gas-fired Instantaneous Water Heater Historical Shipments

Product Class	Annual Shipments Data Sources
Gas-fired Instantaneous Water Heaters	1954-2003 – No data available (used backcasted shipments)* 2004-2007 – AHRI data provided to LBNL;[1] 2007-2022 – BRG 2023 report[2,]** and ENERGY STAR.[3]

* Due to the lack of historical shipments data, DOE “backcasted” the shipments model (i.e., applied the shipments model to years prior to 2003) to estimate historical shipments.
** BRG 2023 report provides estimated shipments for 2023.

The shipments data include units for the residential and commercial sectors (see Figure 9.3.1).

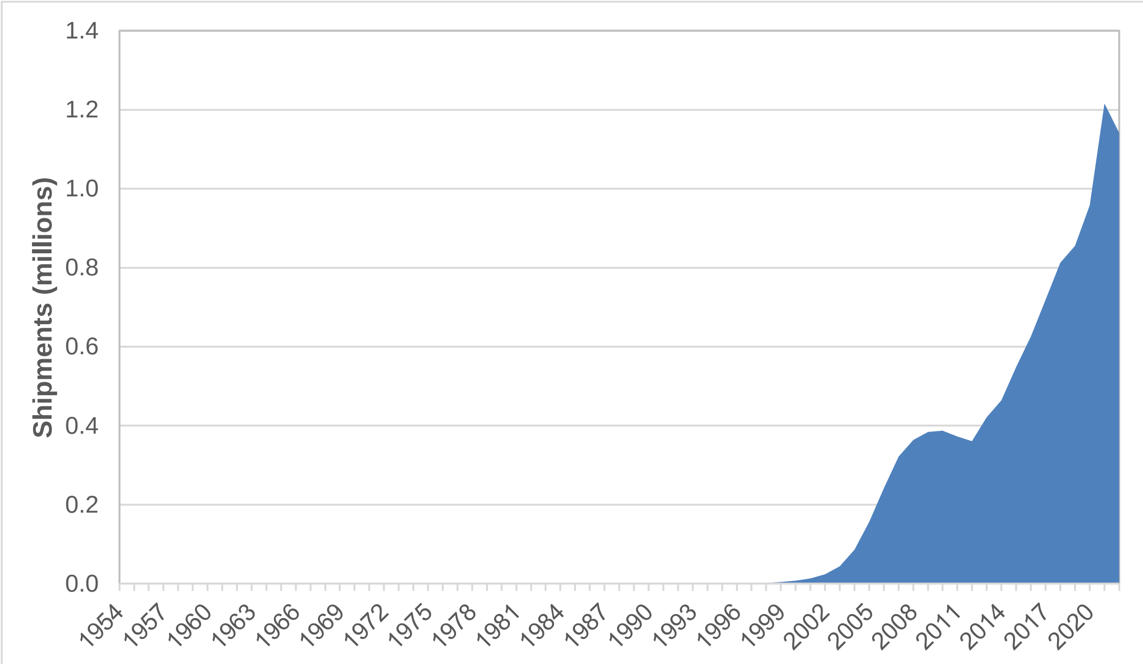

Figure 9.3.1 Historical Shipments of Gas-fired Instantaneous Water Heaters, 1954-2022

Limited information and data are available to estimate shipments by draw patterns, market sectors, and market segments. DOE mostly relied on BRG report,[2] model data, as well as DOE "backcasted" shipments model. Based on this information and data, DOE made the following assumption: GIWH shipments data includes units outside of the <2 gal and >50 kBtu/h and > 200 kBtu/h – about 1% of shipments in 2022.

In addition, DOE disaggregated GIWH shipments into residential and commercial applications based on Energy Information Administration (EIA)'s 1990–2020 Residential Energy Consumption Survey (RECS),[5] EIA's 2018 Commercial Building Energy Consumption Survey (CBECS)[6] and BRG 2023 report[2]. Table 9.3.2 shows the resulting fractions used in 2022.

Table 9.3.2 Estimated Fraction of Gas-fired Instantaneous Water Heaters Historical Shipments

Product Class	Residential	Commercial
Gas-fired Instantaneous Water Heaters, <2 gal and >50 kBtu/h	91%	9%

DOE disaggregated GIWH by draw patterns in 2022 (using BRG report data, model data, and consultant input), as shown in Table 9.3.3.

Table 9.3.3 Estimated Fraction of Gas-fired Instantaneous Water Heaters by Draw Pattern

Product Class	Draw Pattern	Fraction
Gas-fired Instantaneous Water Heaters, <2 gal and >50 kBtu/h	Medium	15%
	High	85%

9.3.2 Projecting Shipments by Market Segment

The market for GIWHs primarily consists of replacement units for equipment that has been retired and units that are installed in new homes. The sum of modeled replacements and new home installations may not fully account for all shipments as given by historical data, so DOE used an additional market segment to calibrate the shipments model. For GIWHs, the shipments model includes a market segment ("new owners") consisting of purchases by existing households without GIWH. DOE also accounted for non-replacement demolitions. Overtime a certain fraction of the housing stock gets demolished resulting in the GIWH be removed from the stock and not replaced. DOE subtracted demolitions from the overall replacements.

9.3.2.1 Replacements

To determine shipments for the replacement market, DOE used an accounting method that tracks the total stock of units by vintage. DOE estimated a stock of GIWHs by vintage by integrating historical shipments starting from 1954. Over time, some units are retired and removed from the stock, triggering the shipment of a replacement unit. Depending on the vintage, a certain percentage of units will fail and need to be replaced. To estimate how long a unit will function before failing, DOE used a survival function based on the distribution of product lifetime (see chapter 8 and appendix 8G).[a] The survival function is applied to both historical shipments and projected shipments from all of the market segments. Figure 9.3.2 shows the survival function for GIWHs that DOE used to estimate replacement shipments.

[a] DOE defined lifetime as the age when a product is retired from service and uses survival function to model the probability distribution of retirements of the product. The survival function, which is assumed to have the form of a cumulative Weibull distribution, was developed based on a method using shipments and survey data to estimate the distribution of GIWH lifetimes in the field.

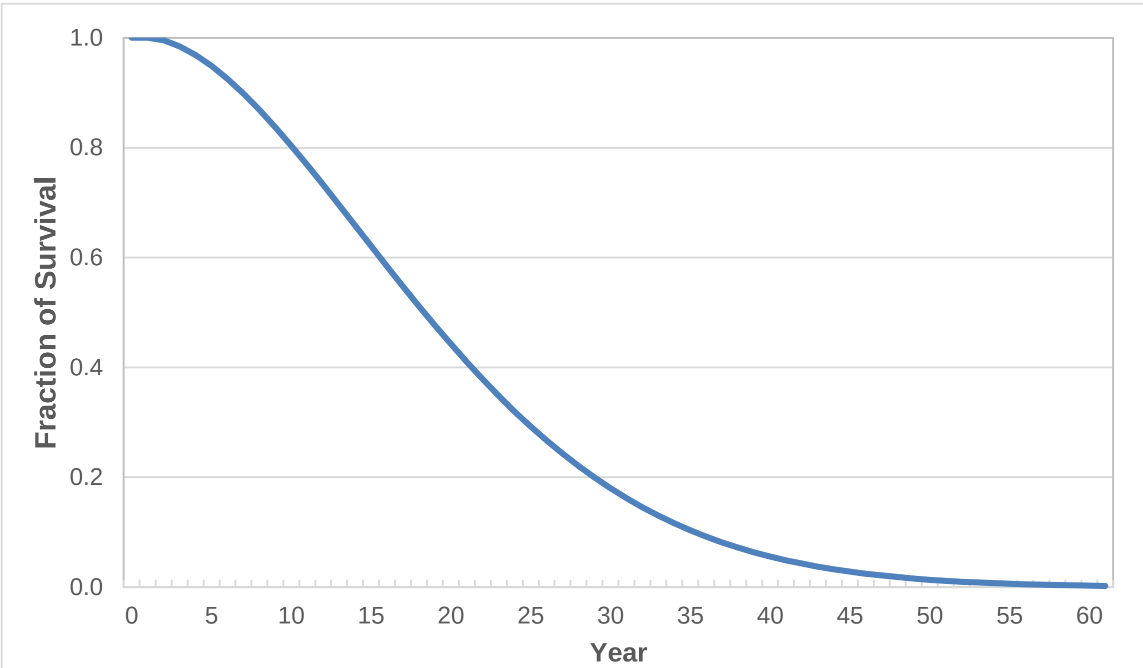

Figure 9.3.2 Survival Function for Gas-fired Instantaneous Water Heaters

Housing demolitions are calculated using the differential between the housing stock and housing start projects and then multiplying by the GIWH stock saturations. The resulting value is subtracted from replacement shipments.

9.3.2.2 Installations in New Construction

To forecast the shipments of GIWHs to new homes and buildings for any given year, DOE multiplied the forecasted new housing starts and new commercial floor space by the forecasted saturation of GIWHs in new housing and buildings. The development of saturation estimates (including saturation projections) of consumer water heaters in homes and commercial buildings is described in more detail in appendix 9A. By multiplying these saturations by forecasted new housing starts and new commercial floor space, the analysis excludes any new housing starts or new commercial floor space that does not utilize a consumer water heater.

For new housing starts and commercial floor space, DOE used reference case projections from EIA's *Annual Energy Outlook 2023* (*AEO2023*) through 2050.[7] For years after 2050, DOE froze new housing starts and new additions to commercial floor space at the level in 2050. Figure 9.3.3 shows the projected new housing starts disaggregated into single-family, multi-family, and mobile home units, while Figure 9.3.4 shows the projected new additions into the commercial building floor space.

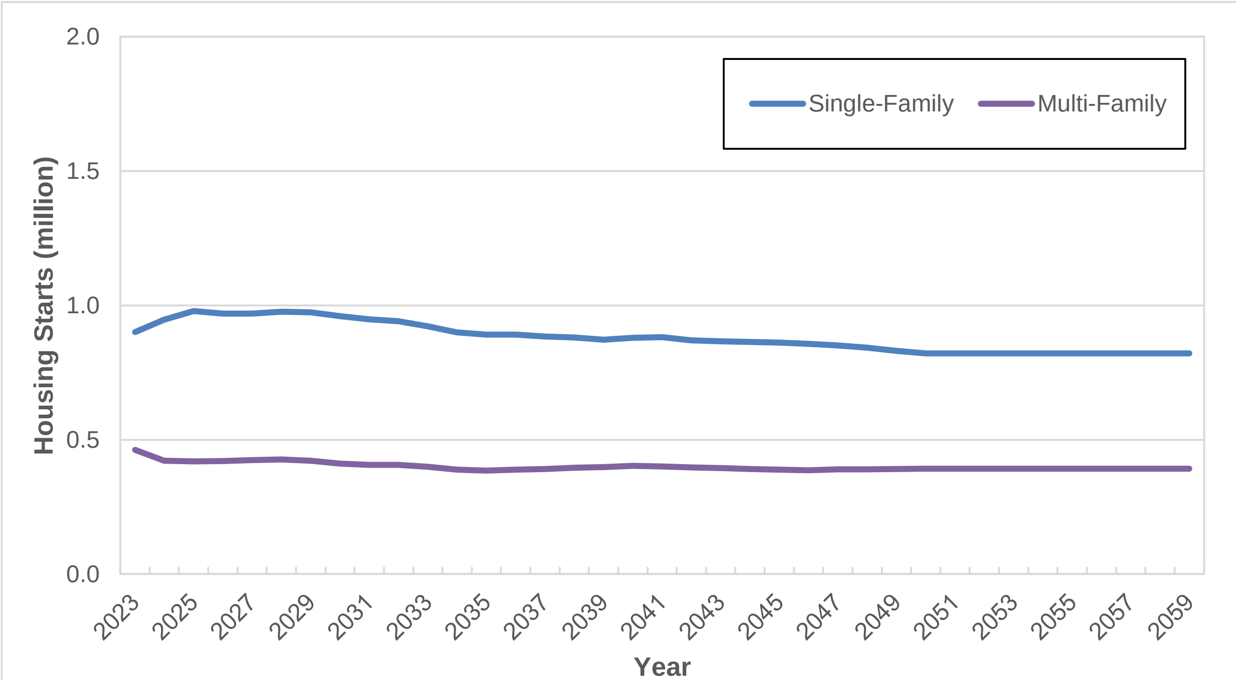

Figure 9.3.3 Housing Starts Projections, 2023-2059

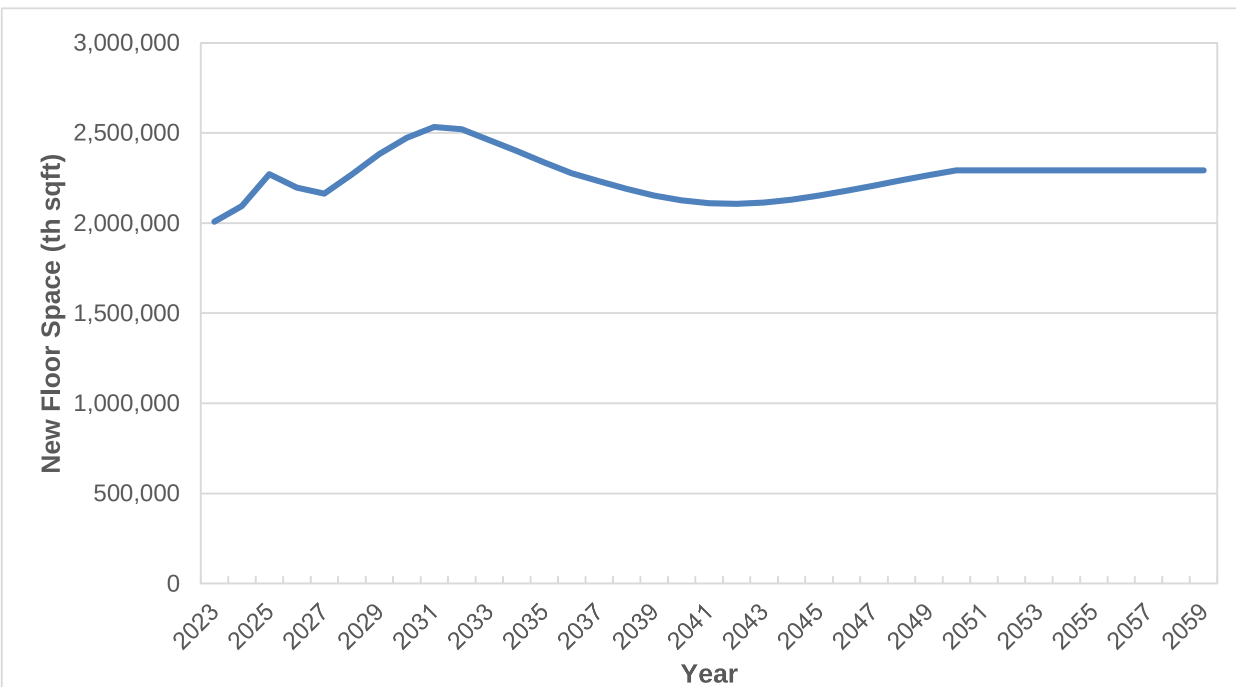

Figure 9.3.4 New Additions to Commercial Floor Space Projections from 2023-2059

The historical data on the market saturation of GIWHs based on Energy Information Administration (EIA)'s 1990–2020 Residential Energy Consumption Survey (RECS),[5] EIA's 2018 Commercial Building Energy Consumption Survey (CBECS),[6] U.S. Census American

Housing Survey,[8] U.S. Census Characteristics of New Housing,[9] Decision Analyst's American Home Comfort Study,[10] and Home Innovations Research Labs Annual Builder Practices Survey.[11] To project the saturation in future years, DOE used a 10-year historical average from 2013-2022 to estimate saturations in 2023. For GIWHs fractions after 2023, DOE estimated a negative 1 percent decreasing growth rate for shipments of gas-fired storage water heaters (GSWHs) that goes towards GIWHs saturations. For commercial applications, DOE assumed that a GIWH was installed on average every 15,800 sq.ft. of the new additions to commercial floor space. Figure 9.3.5 through Figure 9.3.7 present the saturations for each market segment.

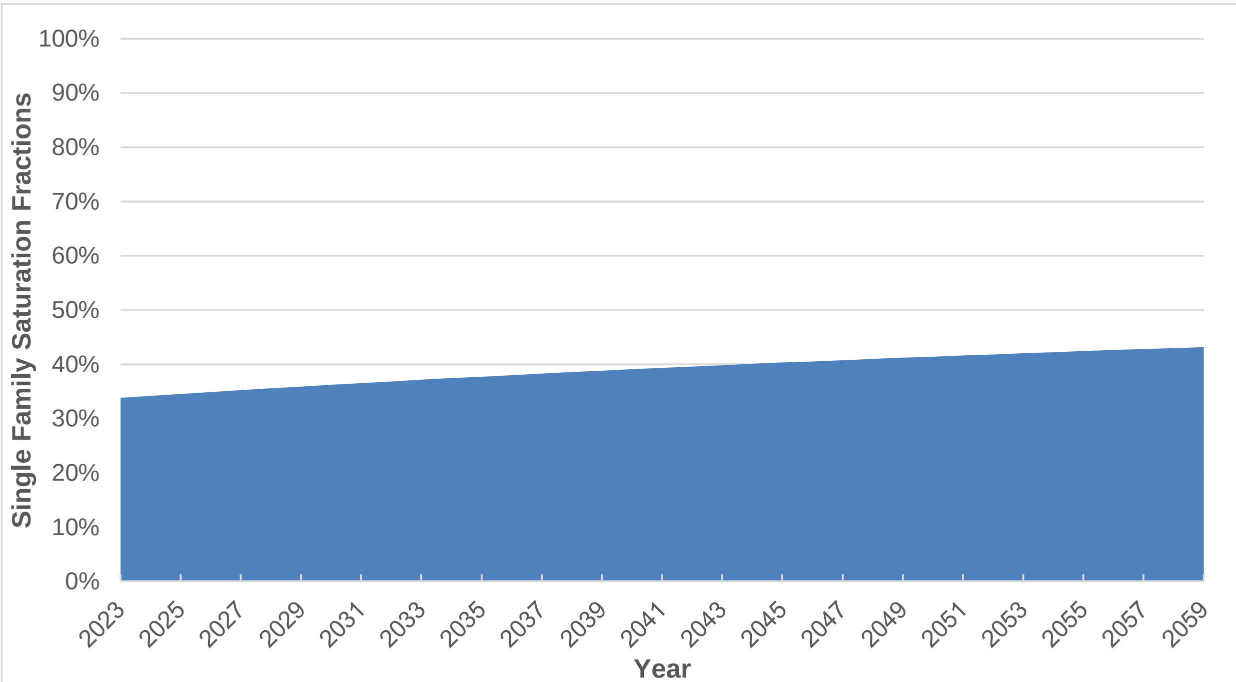

Figure 9.3.5 Gas-fired Instantaneous Water Heaters Saturations for Single-Family Housing Starts, 2023-2059

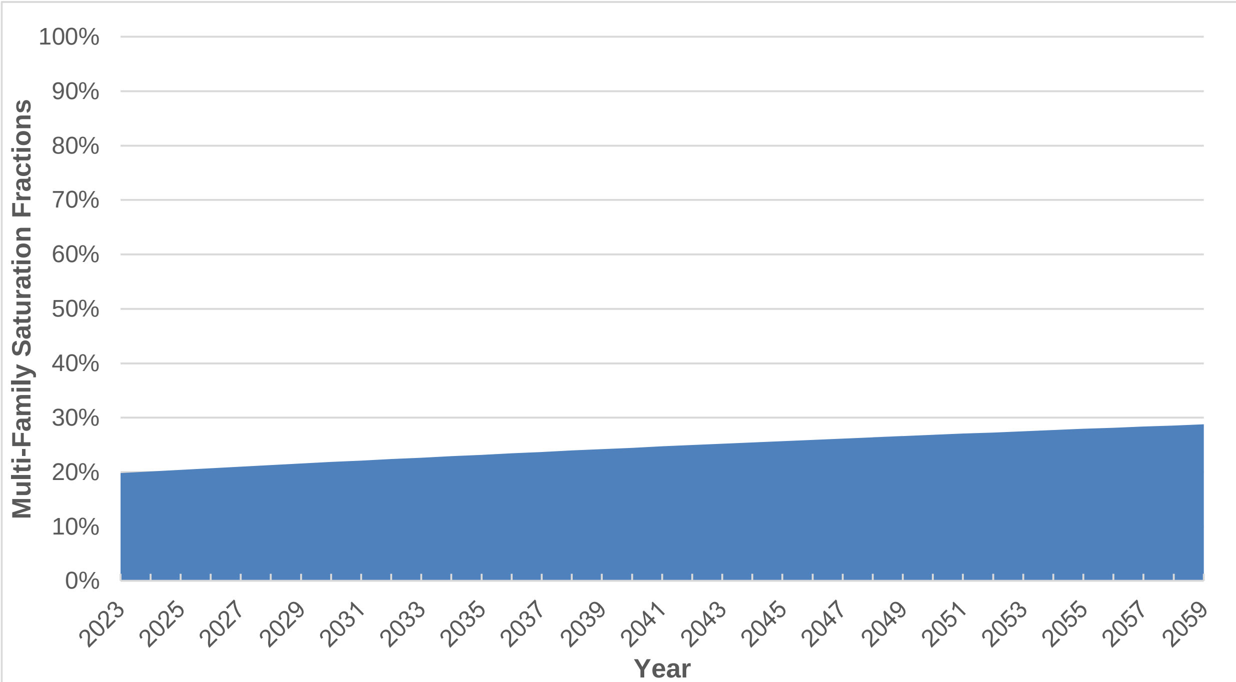

Figure 9.3.6 Gas-fired Instantaneous Water Heaters Saturations for Multi-Family Housing Starts, 2023-2059

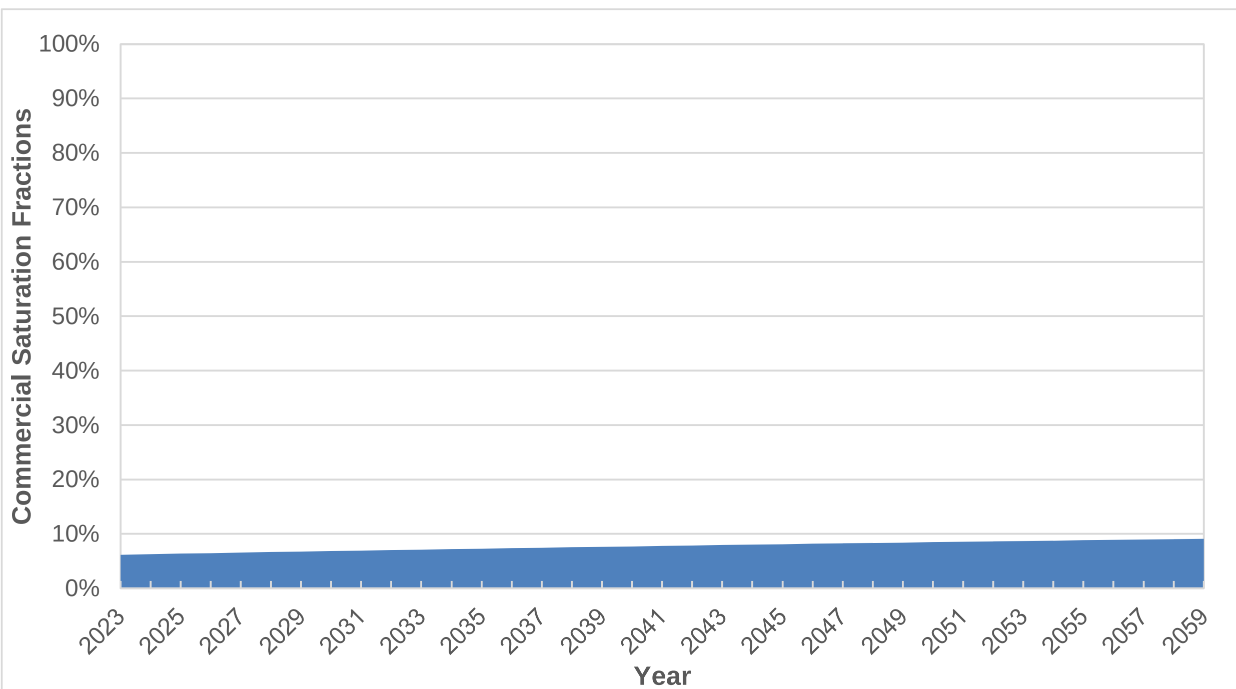

Figure 9.3.7 Gas-fired Instantaneous Water Heaters Saturations for New Additions to the Commercial Floor Space, 2023-2059

9.3.2.3 New Owner

New purchases of GIWHs include purchases of additional GIWH units by households, as well as purchases by households without existing GIWHs. DOE used this market segment to calibrate the modeled shipments with the historical data. DOE used the last 10 years of modeled new owner data to project trend into future years from 2023-2059. These trends tend to show increasing GIWHs new owners that offset decreases in the GSWH shipments.

9.4 IMPACT OF ENERGY CONSVERATION STANDARDS ON SHIPMENTS

9.4.1 Potential Product Switching as a Result of a Standard

DOE evaluated the potential for consumers to switch from GIWH to a different type of water heater as a result of a standard. When faced with the need to replace a GIWH, a consumer can either install a standards-compliant product of the same product class as they originally had, or potentially spend even more to switch to an alternative type of water heater. Because of the high cost to switch, DOE concludes it is extremely unlikely that consumers would choose to spend more to switch product classes specifically in response to amended standards.

As discussed in the specific examples in the following paragraphs, the costs to switch to another product class can be higher than simply purchasing a standards-compliant product in the same product class. When faced with the need to replace a gas-fired instantaneous water heater, a consumer can either install a standards-compliant product of the same product class as they originally had, or consider a switch to a standards-compliant product of an alternative product class. Similarly, when faced with the need to install a consumer water heater in new construction, the consumer can choose from available standards-compliant products across various product classes. As part of considering which water heater to purchase, consumers look at the first cost, the installation cost, expected energy savings, and the amenities provided by the water heaters such as the location within the residence and the amount of hot water the water heater could deliver.

In consumer hot water heater replacement scenarios, shipments data demonstrate purchasers mostly replace their existing water heater with the same product class when purchase price is similar (*see* section 9.3.1 for details). In the case of gas-fired instantaneous water heaters, other product classes often cost more to switch to and install than a standards-compliant gas-fired instantaneous water heater (as discussed below). Even if, for a given household, another product class costs less, DOE expects other factors (including logistical barriers, lower LCC savings, shorter product lifetimes, and other attributes consumers value in instantaneous water heaters) to limit product-switching. Because of the higher cost in some scenarios, consumer preferences, and other limitations on product-switching, DOE concludes it is extremely unlikely that consumers would choose to switch product classes specifically in response to these amended standards. In the absence of amended standards, some consumers choose to switch for reasons other than simply cost, and that is reflected in historical market trends that are incorporated into the analysis. However, for the purposes of the analysis, the issue is whether *more* consumers would switch due to the higher incremental costs of standards-compliant products. DOE concludes that this is very unlikely and therefore market trends will be unaffected.

DOE compared the costs of a consumer switching from a baseline non-condensing gas-fired instantaneous water heater to three potential replacement options (standards-compliant gas-fired instantaneous water heater, baseline gas-fired storage water heater under the recently updated standard, and baseline electric storage water heater under the recently updated standard), in both residential new construction and replacement scenarios for existing households. In the new construction scenario, the analysis shows that average total installed costs are typically lowest for a standards-compliant gas-fired instantaneous water heater. In the replacement scenario, the factors considered in DOE's analysis show that average total installed costs are lower in some cases and marginally higher in others. However, switching to an alternative option also involves several additional costs to accommodate the alternative water heater, including new venting, electrical upgrades, and potential relocation of the water heater. Accordingly, even if, for a given household, a potential replacement option other than a standards-compliant gas-fired instantaneous water heater is cheaper to install, DOE expects that other factors will limit consumer incentives for product switching: logistical barriers arising from different physical and space requirements as described below, the greater LCC savings of a gas-fired instantaneous water heater, the longer lifetime of a gas-fired instantaneous water heater, and consumer preferences for instantaneous water heater attributes such as limitless hot water supply. DOE notes many consumers have already switched from a gas-fired storage to a gas-fired instantaneous water heater despite the high costs of doing so (to replace all the venting and potentially relocate the water heater), and does not expect this trend to reverse as a result of the amended standards.

In the hypothetical case of a consumer switching from a gas-fired instantaneous water heater to an electric storage water heater when replacing a water heater in an existing household, there are likely additional installation costs necessary to add an electrical connection since this type of water heater typically requires high wattage. These are costs above and beyond the normal equipment and installation costs. In some cases, it may be possible to install a 120-volt heat pump storage water heater with minimal additional installation costs, particularly if there is a standard electrical outlet nearby already. In most cases, however, a standard 240-volt electrical storage water heater would be installed. To do so, the consumer would need to add a 240-volt circuit to either an existing electrical panel or upgrade the entire panel if there is insufficient room for the additional amperage. The installation of a new 240-volt circuit by a qualified electrician will be at least several hundred dollars. Panel upgrade costs are significant and can be approximately $750 – $2,000 to upgrade to a 200-amp electrical panel.[b] Older homes and homes with gas-fired space heating (e.g., homes with gas furnaces) are more likely to need an electrical panel upgrade in order to install an electric storage water heater, given the relatively modest electrical needs of the home at the time of construction. The average total installed cost of a replacement standards-compliant electric storage water heater is $1,913,[c] therefore the average total costs to switch to an electric storage water heater, after accounting for electrical upgrade costs, easily exceed the average replacement cost of a standards-compliant gas-fired

[b] For example, see: www.homeadvisor.com/cost/electrical/upgrade-an-electrical-panel/#upgrade (last accessed August 29, 2024).

[c] These results are available in the May 2024 final rule LCC Results spreadsheet (EERE-2017-BT-STD-0019-1424), where LCC results are available separately for replacements and new construction. Available at: www.regulations.gov/document/EERE-2017-BT-STD-0019-1424 (last accessed: Aug. 29, 2024).

instantaneous water heater ($2,499). Given the significant additional installation costs for nearly all homes potentially switching to an electric water heater, DOE estimates that very few consumers would switch from gas-fired instantaneous water heaters to electric water heaters as a result of an energy conservation standard, especially at the adopted standard at TSL 2. When including the above additional costs, the average total installed cost to switch to an electric water heater is higher than the standards-compliant gas-fired instantaneous water heater. Instantaneous water heaters also provide differing utility to consumers compared to storage water waters (e.g., limitless hot water) and thus these products are not perfect substitutes. Additionally, storage water heaters require more space than a gas-fired instantaneous water heater and may require relocating the water heater, incurring even greater costs. Switching from a gas-fired instantaneous water heater to an electrical water heater is especially unlikely in the case of an emergency replacement where time is a critical factor. When a water heater fails, consumers typically have limited time to make a decision on what new water heater to purchase and rely upon replacing the water heater with one that is similar to the one that failed. Consumers are unlikely to invest in switching fuels to a water heater that utilizes a different fuel source in the emergency replacement scenario.

In the hypothetical case of a consumer switching from a gas-fired instantaneous water heater to electric storage water heater in new construction, DOE notes that it is already currently significantly cheaper to install a baseline electric storage water heater (less than $1000) and yet gas-fired instantaneous water heaters continue to be popular with builders, new home owners, and the market share is increasing. This is because instantaneous water heaters provide differing utility to consumers compared to storage water waters (e.g., limitless hot water) and the attributes of instantaneous water heaters are valued by consumers. It is unlikely that the relatively small incremental cost associated with a standards compliant gas instantaneous water heater would influence consumer purchasing decisions in the new construction market after the amended of standards, particularly since the total installed cost for electric storage water heaters will increase by a greater amount than for gas-fired instantaneous water heaters. Therefore, DOE estimates no switching to electric water heaters will occur in new construction as a result of the amended standards.

In the hypothetical case of a consumer switching from a gas-fired instantaneous water heater to a gas-fired storage water heater when replacing a water heater in an existing household, there are additional installation costs necessary as well. The vast majority of gas-fired storage water heaters (GSWHs) utilize non-condensing technology that utilizes Category I type B metal vent material, whereas gas-fired instantaneous water heaters require Category III or Category IV venting material, depending on the existing efficiency level. Condensing gas-fired instantaneous water heaters require Category IV venting. Switching from a gas-fired instantaneous water heater to a baseline GSWH would therefore require replacing the venting regardless of the existing efficiency of the gas-fired instantaneous water heater. Replacing the venting system would result in significant additional installation costs if a consumer opted to switch to a GSWH. The most comparable cost for this scenario is the average cost to install a GSWH in new construction ($2,095),[d] which requires all-new venting, however, this estimate does not include removal and

[d] These results are available in the May 2024 final rule LCC Results spreadsheet (EERE-2017-BT-STD-0019-1424), where LCC results are available separately for replacements and new construction. Available at: www.regulations.gov/document/EERE-2017-BT-STD-0019-1424 (last accessed: Aug. 29, 2024).

disposal costs for the old equipment or potentially relocating the water heater. GSWHs and gas-fired instantaneous water heaters have very different physical dimensions and space requirements, with GSWHs being significantly larger water heaters. Switching from a gas-fired instantaneous water heater to a GSWH may not always be possible in the available space and may require even larger costs to accommodate a GSWH (e.g., relocating the water heater in the home). This may be particularly acute in smaller households where space is at a premium (e.g., townhomes). All of these additional costs can easily exceed many hundreds of dollars, if not higher, depending on need to relocate the water heater.[e] Therefore, the total cost to switch to a GSWH can exceed the cost to simply replace with a standards-compliant gas-fired instantaneous water heater ($2,499). This situation is the same as exists today, prior to the amendment of standards for either gas-fired instantaneous water heaters or for GSWHs. The cost differential is very similar between the two and the market share of instantaneous water heaters is growing relative to storage tank water heaters, not the reverse.

Furthermore, the average lifetime of a gas-fired instantaneous water heater is approximately 20 years, compared to approximately 14.5 years for GSWHs, which results in a total annualized cost of ownership for instantaneous water heaters that is even lower compare to GSWHs. Instantaneous water heaters also provide differing utility to consumers (e.g., limitless hot water) and thus these products are not perfect substitutes. These attributes are clearly valued by consumers, given the recent increasing market share of gas-fired instantaneous water heaters. Consumers that have already paid the costs to switch from an existing GSWH to a gas-fired instantaneous water heater in the absence of any amended standard are highly unlikely to switch back to a GSWH due to amended standards and pay all of those extra costs again.

As a result of all the cost considerations above, DOE estimates that it is highly unlikely that consumers would switch from gas-fired instantaneous water heaters to GSWHs when needing to replace their existing water heater, specifically as a result of the incremental costs of an energy conservation standard, particularly in the case of an emergency replacement.

A summary of the total installed cost estimates when replacing an existing gas-fired instantaneous water heater are shown in Table 9.4.1.

[e] As an example of such costs, Table 8D.5.66 in the final rule TSD estimates permitting, removal, and disposal costs of $260. Section 8D.3.5.3 (3) of the May 2024 final rule TSD estimates that relocation costs in the case of electric storage water heaters could range up to $2,000. Relocating GSWHs would incur similar costs to accommodate all-new water and gas lines in a relocation. Available at: www.regulations.gov/document/EERE-2017-BT-STD-0019-1416 (last accessed: Aug. 29, 2024).

Table 9.4.1 Summary of Estimated Total Installed Cost to Replace an Existing Gas-Fired Instantaneous Water Heater

	Before Amended Standards		After Amended Standards		
	GIWH Baseline Non-Condensing (EL 0)	**GSWH Baseline Non-Condensing (EL 0)**	**GIWH Updated Standard Condensing (EL 2)**	**GSWH Updated Standard Non-Condensing (EL 2)**	**ESWH Updated Standard Heat Pump (EL 1)**
Avg. Total Installed Cost	$2,282	$1,958* + disposal/removal costs** + potential relocation costs†	$2,499	$2,095* + disposal/removal costs** + potential relocation costs†	$1,913 + electrical upgrade costs‡ + potential relocation costs†

* Replacing a gas-fired instantaneous water heater with a GSWH will require installing all-new venting. The most comparable cost for this scenario is the average cost to install a GSWH in new construction (cost estimate is from the May 2024 final rule for new construction).
** As an example of such costs, appendix 8D of this final rule TSD estimates removal and disposal costs of $260. Note that disposal and removal costs are already included in GIWH replacement estimates.
† Relocation costs can exceed $1,000 to accommodate all-new water and gas lines. The May 2024 final rule estimates that relocation costs in the case of an electric storage water heater can range up to $2,000.
‡ Electrical upgrade costs include adding a 240 V outlet and circuit and may require upgrading the electrical panel. Such costs are estimated to range from $750 - $2,000.

In new construction, the average total installed costs are different because new venting is always required if installed indoors, however the location of the water heater can be optimized to limit those venting costs for gas-fired instantaneous water heaters. Water heaters can also be installed outdoors in some cases. In today's market, the total installed cost of a gas-fired instantaneous water heater in new construction is typically less than a GSWH, a factor in the increasing market share of gas-fired instantaneous water heaters seen in recent historical shipments and projected in the no-new-standards case. With newly adopted standards for both GSWHs and gas-fired instantaneous water heaters, the average total installed cost (including all venting) of a minimally standards-compliant GSWH in residential new construction is $2,095,[f] which is similar to and slightly higher than a minimally compliant gas-fired instantaneous water heater in residential new construction at the amended standard level ($2,070). The adopted standard levels for both GSWHs and gas-fired instantaneous water heaters therefore preserve this market dynamic and gas-fired instantaneous water heaters will continue to have total installed costs that are similar to or lower on average in new construction compared to GSWHs. Furthermore, gas-fired instantaneous water heaters have longer lifetimes (representing a more cost-effective investment) and additional features (such as a smaller footprint and endless hot water supply) that will continue to be attractive to some builders and consumers. As a result,

[f] These results are available in the May 2024 final rule LCC Results spreadsheet (EERE-2017-BT-STD-0019-1424), where LCC results are available separately for replacements and new construction. The total installed costs for baseline models (reflecting the current minimally compliant models) are similarly less for gas-fired instantaneous water heaters compared to GSWHs. Available at: www.regulations.gov/document/EERE-2017-BT-STD-0019-1424 (last accessed: Aug. 29, 2024).

DOE estimates that the existing trend of increasing gas-fired instantaneous water heater market share in new construction will continue.

A summary of the total installed cost estimates when installing a water heater in new construction are shown in Table 9.4.2.

Table 9.4.2 Summary of Estimated Total Installed Cost to Install a Water Heater in New Construction

	GIWH Baseline Non-Condensing (EL 0)	GIWH Updated Standard Condensing (EL 2)	GSWH Updated Standard Non-Condensing (EL 2)
Avg. Total Installed Cost	$1,833	$2,070	$2,095*

*Cost estimate for GSWH in new construction is from the May 2024 final rule.

In existing installations of GSWHs, there are significant costs to switch from a GSWH to a gas-fired instantaneous water heater, since new venting is required. In today's market, however, some consumers are electing to make that switch despite the extra costs, because instantaneous water heaters have certain attributes that consumers value (e.g., smaller footprint, endless supply of hot water). Even with the adopted standard for gas-fired instantaneous water heaters, the relative incremental cost will be similar because DOE also recently adopted a revised standard for GSWH in a May 2024 final rule, so costs for both product classes will increase. For example, the average total installed cost of a pre-standard baseline GSWH in a residential replacement installation was estimated to be $1,376 in the May 2024 final rule, whereas the average total installed cost of a baseline gas-fired instantaneous water heater in a residential replacement installation is estimated to be $2,282.[g] Therefore, switching to baseline gas-fired instantaneous water heaters in existing GSWH installations in today's market already represents a significant additional cost, estimated to be $906 on average, nearly twice the cost of simply replacing a GSWH with another GSWH. Despite this extra cost, the market share of gas-fired instantaneous water heaters in replacement installations is increasing. With newly adopted standards for both product classes, the average installed costs in residential replacement installations for minimally compliant products are estimated to be $1,523 and $2,499 for GSWHs and gas-fired instantaneous water heaters, respectively, with a difference of $976. Therefore, there is still a significant additional cost to switch after the adoption of new standards, just as in today's market. However, instantaneous water heaters will continue to have the same attributes and features that some consumers prefer and those consumers will continue to make the switch when replacing their existing storage water heaters, despite the costs of doing so. The adopted standard level for gas-fired instantaneous water heaters is unlikely to significantly disrupt this existing market dynamic because there was already a high cost to switch from existing GSWHs to gas-fired instantaneous water heaters.

[g] Separate LCC results for residential vs. commercial buildings and replacement installations vs. new construction are available in the LCC results spreadsheets. The May 2024 final rule LCC results spreadsheet is available at: www.regulations.gov/document/EERE-2017-BT-STD-0019-1424 (last accessed Sept. 17, 2024).

A summary of the total installed cost estimates when replacing an existing GSWH are shown in Table 9.4.3.

Table 9.4.3 Summary of Estimated Total Installed Cost to Replace an Existing GSWH

	Before Amended Standards		**After Amended Standards**	
	GIWH Baseline Non-Condensing (EL 0)	**GSWH Baseline Non-Condensing (EL 0)**	**GIWH Updated Standard Condensing (EL 2)**	**GSWH Updated Standard Non-Condensing (EL 2)**
Avg. Total Installed Cost	$2,282*	$1,376**	$2,499*	$1,523**
Cost Differential	$906		$976	

* Replacing an existing GSWH with a gas-fired instantaneous water heater requires replacing the venting (these costs are included in the estimates).
** Replacing an existing non-condensing GSWH with another non-condensing GSWH typically does not require replacing the flue venting, which is why these costs are much lower than for new construction. Cost estimates for GSWH are from the May 2024 final rule.

9.4.2 Repair vs. Replace Model

For replacements, consumer decisions to purchase or repair a GIWH are influenced by the purchase price and operating cost of the product, and therefore may be different in the no-new-standards case and under standards cases at different efficiency levels (ELs).[h] These decisions were modeled by estimating the purchase price elasticity for GIWHs. The purchase price elasticity is defined as the change in the percentage of consumers acquiring a GIWH divided by a change in the *relative price* (defined below) for that product. This elasticity, along with information obtained from the life-cycle cost (LCC) and payback period (PBP) analysis on the change in purchase price and operating costs at different ELs, are used in the shipments model to estimate the change in shipments under potential standards at different ELs.

DOE used a study that conducted a literature review and an analysis of appliance price and efficiency data to estimate the effects on product shipments from increases in product purchase price and product energy efficiency.[12]

Existing studies of appliance markets suggest that the demand for durable goods, such as appliances, is price-inelastic. Other information in the literature suggests that appliances are a normal good, so that rising incomes increase the demand for appliances, and that consumer

[h] Because the percentage change in the cost of GIWH due to amended GIWH standards is relatively small in the new construction market, DOE assumed that the new construction market is unaffected by changes in either the total installed cost or operating costs of the product. That is, home builders are not likely to choose to not install a GIWH if the installed cost rises by a small amount.

behavior reflects relatively high implicit discount rates[i] when comparing appliance prices and appliance operating costs.

The study used the available data for the period 1989-2009 on household appliance purchases to evaluate broad market trends and conduct simple regression analyses. These data indicate that there has been a rise in appliance shipments and a decline in appliance purchase price and operating costs over the time period. Other relevant variables include household income, which has also risen during this time, new residential construction, and stock failures of existing appliances. Using these data, the study performed a regression analysis to estimate two parameters, the price elasticity of appliance demand and the shipments response to appliance efficiency, defined as follows:

$$\varepsilon_d = \frac{\frac{\Delta q}{q}}{\frac{\Delta p}{p}}$$

Eq. 9.11

Where:

ε_d = price elasticity of demand,
q = quantity of shipments, and
p = price

$$\varepsilon_e = \frac{\frac{\Delta q}{q}}{\frac{\Delta e}{e}}$$

Eq. 9.12

Where:

ε_e = "efficiency elasticity",
q = quantity of shipments, and
e = product efficiency.

The regression analysis suggests that the price elasticity of demand, based on aggregated data for five residential appliances, is -0.45. Thus, for example, a price increase of 10 percent would result in a shipments decrease of 4.5 percent, *all other factors held constant*. The

[i] An implicit discount rate refers to a rate than can be inferred from observed consumer behavior with regard to future operating cost savings realized from more-efficient appliances. An implicit discount rate is not a true discount rate because the observed consumer behavior is affected by lack of information, high transaction costs, and other market barriers. However, implicit discount rates can predict consumer purchase behavior with respect to energy-efficient appliances. A high implicit discount rate with regard to operating costs means that consumer reflects a high discounting of future operating cost savings realized from more-efficient appliances. In other words, consumers are much more concerned with higher purchase prices.

efficiency elasticity is estimated to be +0.2 (i.e., a 10 percent efficiency improvement would result in a shipments increase of 2%, *all else equal*).[j]

The price elasticity estimate of -0.45 is consistent with estimates of appliance and durables price effects in the literature. Nevertheless, the study stresses that the measure is based on a small data set, using simple statistical analysis. More importantly, the measure is based on the assumption that economic variables, including purchase price, operating costs, and household income, explain most of the trend in appliances per household in the United States between 1989 and 2009. Changes in appliance quality and consumer preferences may have occurred during this period, but DOE did not account for them in this analysis. Despite the uncertainties, DOE believes that its estimates provide a reasonable assessment of the effect that purchase price and efficiency have on product shipments.

Because DOE's projections of shipments and national impacts from potential standards consider a 30-year period, DOE needed to consider how price elasticity evolves in the years after a new standard takes effect. DOE considered the price elasticity developed above to be a short-term value, but was unable to identify sources specific to appliances sufficient model differences in short- and long-term price elasticities. Therefore, to estimate how the price elasticity changes through time, DOE relied on a study pertaining to automobiles.[13] This study shows that the price elasticity of demand for automobiles changes in the years following a change in purchase price, a trend also observed in appliances and other durables.[14,k] As time passes since the change in purchase price, the price elasticity becomes more inelastic until it reaches a terminal value around the tenth year after the price change. Table 9.4.4 shows the relative change over time in the price elasticity of demand for automobiles. As shown in the table, DOE developed a time series of price elasticity for residential appliances based on the relative change over time in the price elasticity of demand for automobiles. For years not shown in the table, DOE performed a linear interpolation to obtain the price elasticity.

Table 9.4.4 Change in Price Elasticity and Efficiency Elasticity Following a Purchase Price Change

	Years Following Price Change					
	1	**2**	**3**	**5**	**10**	**20**
Relative Change in Elasticity to first year	1.00	0.78	0.63	0.46	0.35	0.33
Price Elasticity	-0.45	-0.35	-0.28	-0.21	-0.16	-0.15
Efficiency Elasticity	0.20	0.16	0.13	0.09	0.07	0.07

Using the following equation, DOE estimated standards-case shipments by considering the effect of price and efficiency. Note that in the equation below, the *price*, the *price* elasticity, the *efficiency*, and the *efficiency elasticity* are functions of the year because they change with time.

[j] Note that DOE previously combined these impacts in a variable termed "relative price elasticity." Price and efficiency impacts are now separated for greater consistency with price elasticity measures reported in the literature.
[k] DOE relies on Hymens et al. (1970) for efficiency scaling factors because it provides the greatest detail out of the available studies on price elasticity over time.[13]

$$dRS_p(j) = \max\left[\left|\varepsilon_d(j)\right| \times \Delta P_p(j) - \left|\varepsilon_e(j)\right| \times \Delta E_p(j)\,,\,0\right]$$

Eq. 9.13

Where:

$dRS_p(j)$ = percentage replacement shipments drop for product class *p* in year *j*,

$\varepsilon_d(j)$ = price elasticity in year *j* (equals -0.45 for year 1),

$\Delta P_p(j)$ =change in price due to a standard level for product class *p* in year *j*, %

$\varepsilon_e(j)$ = efficiency elasticity in year *j* (equals 0.20 for year 1), and

$\Delta E_p(j)$ = change in efficiency due to a standard level for product class *p* in year *j*, %.

DOE assumes that the demand for water heating is inelastic and therefore that no household or commercial building will forgo either repairing or replacing their equipment (either with a new GIWH within the scope of this analysis or a suitable water heating alternative).

9.5 RESULTS

As detailed in chapter 10, DOE created trial standard levels (TSLs) that correspond specific efficiency levels (ELs). Table 9.5.1 show the TSLs and associated efficiency levels (ELs) for GIWHs.

Table 9.5.1 Trial Standard Levels for Gas-fired Instantaneous Water Heater Standards

Product Class	**Trial Standard Level**			
	1	**2**	**3**	**4**
	Efficiency Level			
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	1	2	3	4

9.5.1 No-New-Standards Case Shipments

Figure 9.5.1 presents the projected shipments of GIWHs in the no-new-standards case and the historical shipments DOE used to calibrate those projected shipments. Note the historical and projected shipments do not include a fraction of shipments reported as residential water heater shipments outside of the scope of this analysis as mentioned previously. Figure 9.5.2 and Figure 9.5.3 present the projected shipments of GIWHs respectively by market segment and market sector.

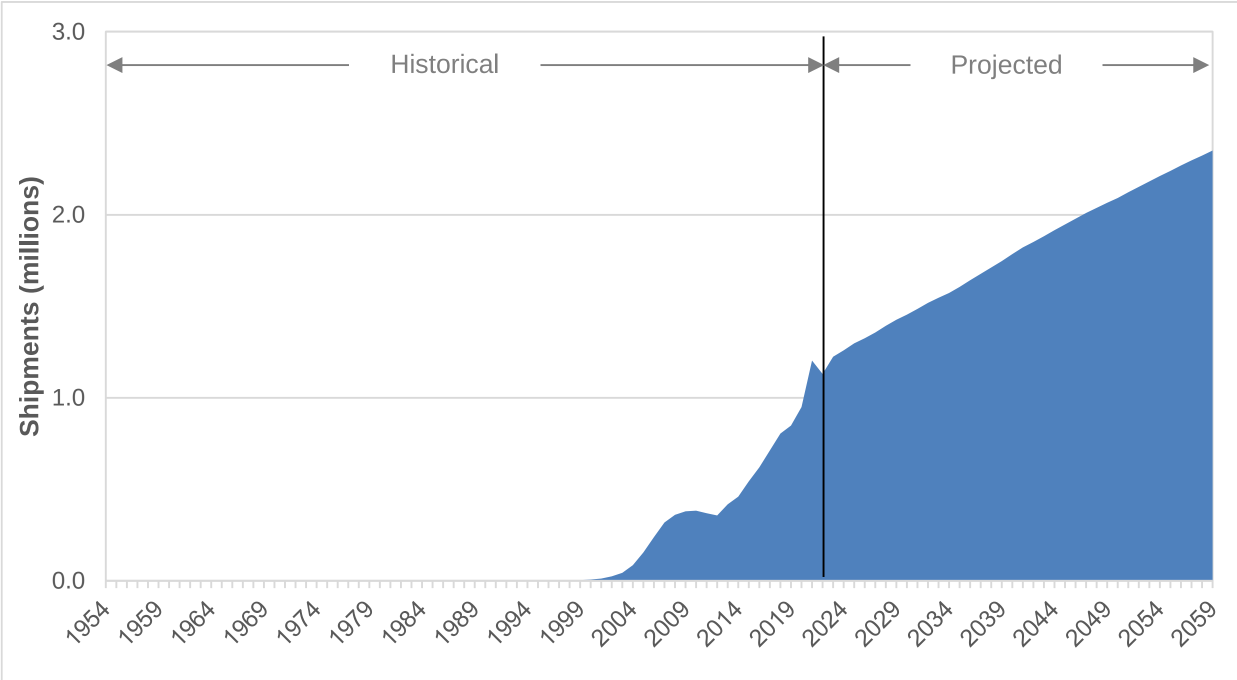

Figure 9.5.1 Historical Shipments and No-New-Standards Case Projection for Gas-fired Instantaneous Water Heaters, 1954-2059

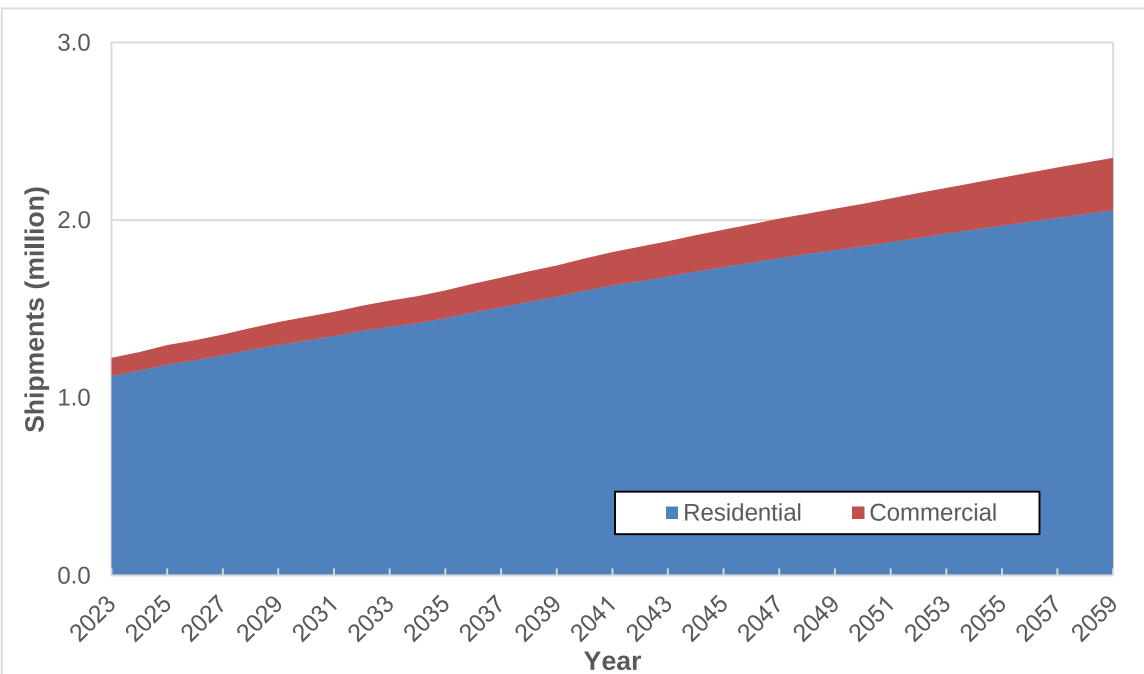

Figure 9.5.2 No-New-Standards Case Projection for Gas-fired Instantaneous Water Heaters by Market Sector, 2023-2059

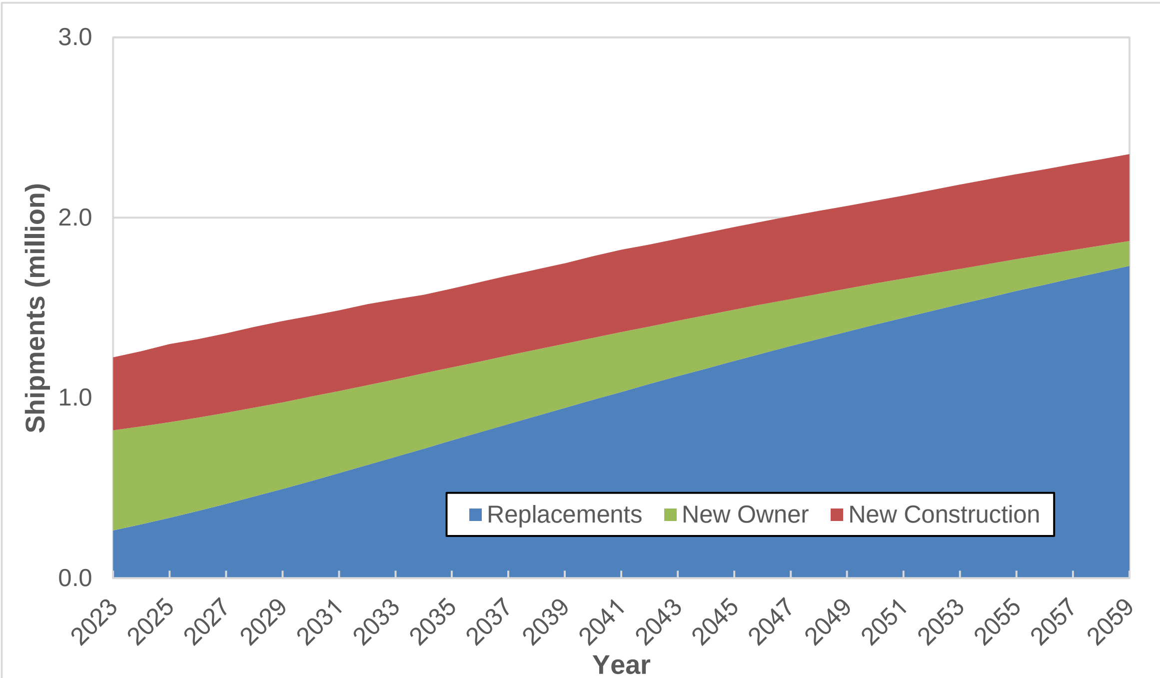

Figure 9.5.3 No-New-Standards Case Projection for Gas-fired Instantaneous Water Heaters by Market Segment, 2023-2059

9.5.2 Shipments Impacts Due to Standards

Figure 9.5.4 shows total projected shipments of GIWHs in the no-new-standards case and under each considered TSL. Notably, the impact on GIWH shipments at each considered TSL is minimal.

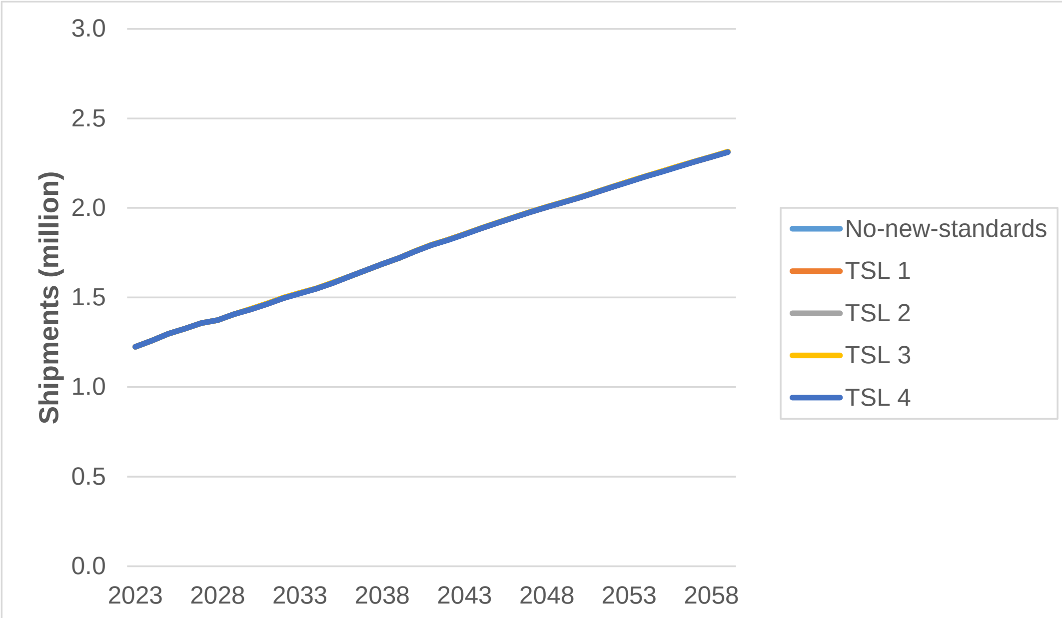

Figure 9.5.4 Total Projected Shipments of Gas-fired Instantaneous Water Heaters in the No-New-Standards Case and Each Standards Case

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

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CHAPTER 10. NATIONAL IMPACT ANALYSIS

10.1 INTRODUCTION

This chapter describes the methods the U.S. Department of Energy (DOE) used to conduct a national impact analysis (NIA) of potential energy efficiency standard levels for consumer gas-fired instantaneous water heaters (GIWHs), and the results of the analysis. For each potential standard level, DOE evaluated the following impacts: (1) national energy savings (NES), (2) monetary value of the energy savings for consumers of GIWHs,[a] (3) increased total installed costs, and (4) the net present value (NPV), which is the difference between the savings in operating costs and the increase in total installed costs.

DOE determined the NES and NPV for all the Trial Standard Levels (TSLs) considered for GIWHs. DOE performed all calculations using a Microsoft Excel spreadsheet model, which is accessible on the Internet at https://www.energy.gov/eere/buildings/consumer-water-heaters. The spreadsheet combines the calculations for determining the NES and NPV for each considered TSL with input from the appropriate shipments model. Details and instructions for using the NIA model are provided in appendix 10A of this technical support document (TSD).

The NIA calculation starts with the shipments model. Chapter 9 of this TSD provides a detailed description of the shipments model that DOE used to project future purchases of GIWHs, and how standards might affect the level of shipments.

The analysis is described more fully in subsequent sections. The descriptions include overviews of how DOE performed each model's calculations and summaries of the major inputs. Table 10.1.1 summarizes inputs to the NIA model.

[a] For gas-fired instantaneous water heaters installed in commercial applications, the consumer is the business or other entity that pays for the equipment (directly or indirectly) and its energy costs.

Table 10.1.1 Inputs to Calculating National Energy Savings and Net Present Value

Input	Data Description
Shipments	Annual shipments from shipments model (chapter 9).
Compliance date of standard	2030.
Analysis period	For products shipped between 2030 through 2059.
Energy efficiency in no-new-standards case	Based on historical shipment data and on current gas-fired instantaneous water heater model availability by efficiency level (see chapter 8). DOE estimated growth in shipment-weighted efficiency by assuming an increasing market share of water heaters meeting ENERGY STAR® requirements.
Energy efficiency in standards cases	Roll-up in the compliance year.
Annual energy consumption per unit	Annual weighted-average values as a function of shipments-weighted unit energy consumption (UEC).
Total installed cost per unit	Annual weighted-average values as a function of the efficiency distribution (see chapter 8). DOE incorporated future product price trends based on historical data.
Energy cost per unit	Annual weighted-average values as a function of the annual shipments-weighted UEC and energy prices at each efficiency level (see chapter 7 for energy use and chapter 8 for energy prices).
Repair and maintenance costs per unit	Annual values as a function of efficiency level (see chapter 8).
Rebound effect	Applied a rebound effect value dependent on application and sector (see section 10.3.6).
Baseline energy prices	Marginal energy prices based on Energy Information Administration (EIA) historical data and billing data from EIA's 2020 *Residential Energy Consumption Survey* (RECS 2020)[1] and 2018 *Commercial Buildings Energy Consumption Survey* (CBECS 2018).[2]
Trend in energy prices	Based on Energy Information Administration's (EIA's) Annual Energy Outlook (AEO) 2023 Reference case[3] projections to 2050 and extrapolation thereafter (see chapter 8).
Energy site-to-primary factor	A time-series conversion factor that includes losses due to electricity generation, transmission, and distribution.
Full-fuel-cycle multiplier	Developed to include the energy consumed in extracting, processing, and transporting or distributing primary fuels.
Discount rate	3 percent and 7 percent.
Present year	Future expenses are discounted to 2024.
Dollar year	DOE expressed all costs in 2023$.

10.1.1 Trial Standard Levels

DOE developed TSLs based on the analyzed efficiency levels (Els) for GIWHs. Table 10.1.2 presents the efficiency levels (ELs) for GIWHs in each TSL. The criteria used to develop trial standard levels for GIWHs rulemaking are as follows

- **TSL 1**: Constructed with EL 1 for GIWHs.
- **TSL 2**: Constructed with EL 2 for GIWHs, representing the Joint Stakeholder Recommendation.
- **TSL 3**: Constructed with EL 3 for GIWHs, representing an interim energy efficiency level between the Joint Stakeholder Recommendation (i.e., EL 2) and max-tech (EL 4).
- **TSL 4**: Constructed with EL 4 for GIWHs, representing the maximum technologically feasible ("max-tech") energy efficiency for GIWHs.

Table 10.1.2 Trial Standard Levels for Gas-fired Instantaneous Water Heater Standards

Product Class	Trial Standard Level			
	1	2	3	4
	Efficiency Level			
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	1	2	3	4

10.2 PROJECTED ENERGY EFFICIENCY TREND

The trend in forecasted energy efficiency is a key factor in estimating NES and NPV for the no-new-standards case and each potential standards case. For calculating the NES, per-unit average annual energy consumption is a direct function of product energy efficiency. For the NPV, both the per-unit total installed cost and the per-unit annual operating cost are dependent on product energy efficiency.

DOE used as a starting point the shipments-weighted energy efficiency distribution for 2030 (the assumed date of compliance with a new standard). To represent the distribution of product energy efficiencies in 2030, DOE used the same market shares as used in the no-new-standards case for the life-cycle cost analysis (described in chapter 8 of this TSD).

To project efficiencies for the no-new-standards case, DOE used historical shipment data and on current gas-fired instantaneous water heater model availability by efficiency level (see chapter 8). DOE estimated growth in shipment-weighted efficiency by assuming that the implementation of ENERGY STAR®'s performance criteria and other incentives would gradually increase the market shares an increasing market share of higher efficiency water heaters. Using historical BRG shipments data and ENERGY STAR criteria, DOE estimated the annual increase in market share for condensing units between 2015–2022 and assumed the increasing trend would continue would continue over the shipments projection period.

To determine the standards-case efficiencies, DOE assumed a "roll-up" scenario to establish the shipment-weighted efficiency for the year that standards are assumed to take effect (2030). DOE assumed that product efficiencies in the no-new-standard case that did not meet the standard under consideration would "roll up" to meet the new standard level. DOE also assumed that all product efficiencies in the no-new-standard case that exceeded the standard would not be affected. Taking this efficiency distribution as a starting point, DOE projected standards-case efficiencies based on assumptions regarding future efficiency improvements similar to that of the no-new-standards case. Table 10.2.1 presents the efficiency distributions in 2030 by for the no-new-standards case and standards cases for GIWHs.

Table 10.2.1 Efficiency Distributions for Gas-fired Instantaneous Water Heaters in 2030, percent

Product Class	EL	No-New-Standards Case	Trial Standard Level (TSL)			
			1	2	3	4
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	0	30.0				
	1	7.6	37.6			
	2	46.7	46.7	84.3		
	3	7.3	7.3	7.3	91.6	
	4	8.4	8.4	8.4	8.4	100.0

10.2.1 Projected Efficiency Trends After 2030

DOE estimated growth in shipment-weighted efficiency by assuming that the implementation of ENERGY STAR's performance criteria and other incentives would gradually increase the market shares of higher efficiency water heaters. Using historical BRG shipments data and ENERGY STAR criteria, DOE estimated the annual increase in market share for condensing units between 2015 – 2022 and assumed the increasing trend would continue over the shipments projection period. DOE estimated that the national market share of condensing gas-fired instantaneous water heaters would grow significantly as shown in the graphs below (Figure 10.2.1).

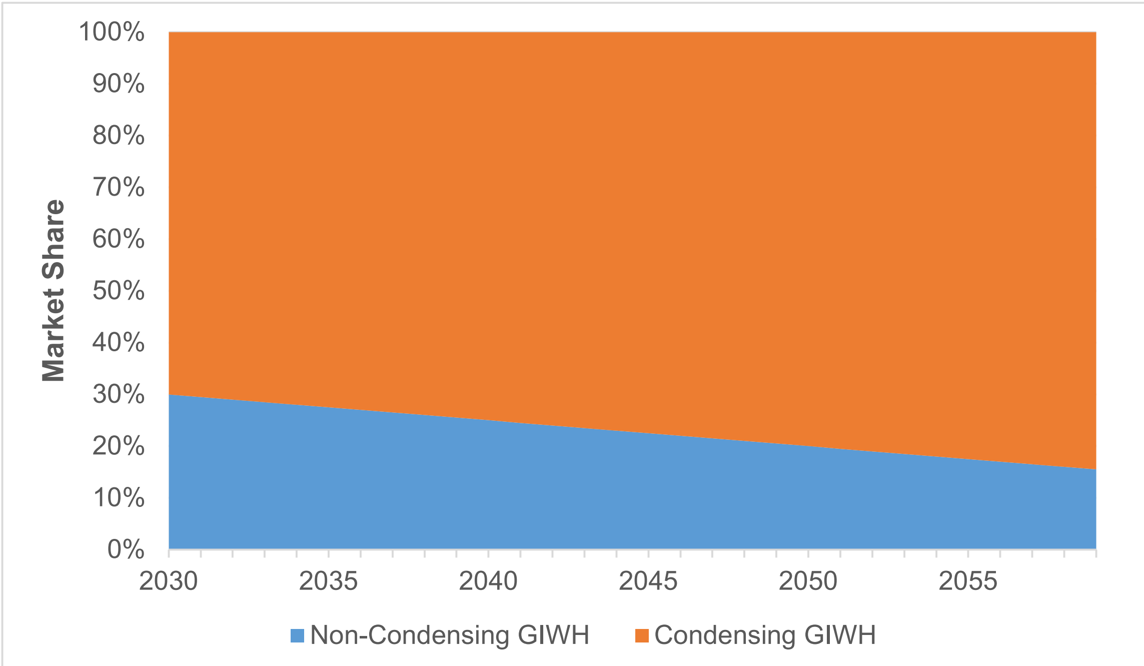

Figure 10.2.1 No-New-Standards Case Market Share of Non-Condensing and Condensing Gas-fired Instantaneous Water Heaters

10.3 NATIONAL ENERGY SAVINGS

DOE calculated the NES associated with the difference between the no-new-standards case and each standards case for GIWHs. DOE's analysis considers lifetime energy use of products shipped in the 30-year period beginning in the compliance year—in this case, 2030. The analysis period ends when all of the products shipped in the 30-year period are retired from the stock.

DOE calculates NES expressed as:

- Primary energy: Accounts for the energy used to generate, transmit, and distribute electricity,
- Full-fuel-cycle (FFC) energy: Accounts for the energy consumed in extracting, processing, and transporting or distributing primary fuels.

10.3.1 Definition

DOE calculates the cumulative NES for each energy measures (denoted by *e*, below) as the sum of annual NES for a given year (denoted by *y*; NES_y) throughout the analysis period, represented by the following equation:

$$NES^{(e)} = \sum_{y} NES_y^{(e)}$$

Where:

NES = cumulative national energy savings in quadrillion British thermal units (quads),
NES_y = national annual energy savings (quads),
y = year in the projection, and
e = energy measurement type (site, primary, or FFC).

DOE calculates the annual NES for each energy measures and for a given year as the difference between the national annual energy consumption (AEC) in the no-new-standards case scenario (AEC_{NNS}) and a standards case scenario (AEC_{STD}) corresponding to one of the TSLs. This is represented by the following equation:

$$NES_y^{(e)} = \left(AEC_{NNS,y}^{(e)} - AEC_{STD,y}^{(e)}\right) \times REF_y$$

Where:

NES_y = national annual energy savings projections for a standards case scenario (quads),
$AEC_{NNS,y}$ = national annual energy consumption projections for the no-new-standards case scenario (quads),
$AEC_{STD,y}$ = national annual energy consumption projections for the standards case scenario (quads),
REF = rebound effect factor in year y,
y = year in the projection,
e = energy measurement type (site, primary, or FFC),
NNS = designates the quantity corresponding to the no-new-standards case, and
STD = designates the quantity corresponding to the standards case corresponding to one of the TSLs.

DOE calculates the national annual energy consumption for each energy measurement type by multiplying the national annual site energy consumption (i.e., the energy consumed at the household or establishment; *ASEC*) for each energy source type (denote by f, below) by the conversion factor for each energy measurement type which varies by year, energy source type ($c_{y,f}$), as follows:

$$AEC_y^{(e)} = \sum_f ASEC_{y,f} \times c_{y,f}^{(e)}$$

Where:

AEC_y = national annual energy consumption projections for the no-new-standards case scenario or standards case scenario (quads),
$ASEC_{y,f}$ = national annual site energy consumption projections for the no-new-standards case scenario or standards case scenario for each energy source type (quads),
y = year in the projection,
e = energy measurement type (site, primary, or FFC),

f = energy source type (electricity, natural gas, or propone), and
$c_{y,f}$ = conversion factor by energy source type for converting site energy consumption to the primary and FFC energy consumption measurements (for site energy consumption, $c = 1$).

DOE calculates the national annual site energy consumption by multiplying the number or stock of the product (STOCK; by vintage, denoted by V) by its unit energy consumption (UEC; also by vintage), as follows:

$$ASEC_{y,f} = \sum_{V} STOCK_V \times UEC_{V,y,f}$$

Where:

$ASEC_{y,f}$ = annual national site energy consumption in quads, summed over vintages of the product stock, $STOCK_V$;
$STOCK_V$ = stock of GIWHs (millions of units) of vintage V that survive in the year for which DOE calculates the AEC,
$UEC_{V,y,f}$ = annual energy consumption per unit of GIWHs per year, which accounts for differences in UEC from year to year,
V = year in which the product was purchased as a new unit,
y = year in the forecast, and
f = energy source type (electricity, natural gas, or propone).

The stock of a product depends on annual shipments and the lifetime of the product. As described in chapter 9 of this final rule TSD, DOE projected product shipments under the no-new-standards case and standards cases. To avoid including savings attributable to shipments displaced (units not purchased) because of standards, DOE used the projected standards-case shipments and, in turn, the standards-case stock, to calculate the AEC for the no-new-standards case.

10.3.2 Annual Energy Consumption per Unit

DOE developed per-unit annual energy consumption as a function of product energy efficiency for GIWHs (see chapter 7 of this TSD). DOE used the shipments-weighted energy efficiencies for the no-new-standards case and standards cases, along with the estimates of annual energy use by efficiency level, to estimate the shipments-weighted annual average per-unit energy use under the no-new-standards and standards cases. Table 10.3.1 and Table 10.3.2 show the values applied for the residential and commercial sector, respectively, in both the no-new-standards case and standards case in 2030. The values after 2030 change according to the projected efficiency trends in each case.

Note that the results in Table 10.3.1 and Table 10.3.2 are not adjusted for the impact of the rebound effect discussed further in section 10.3.6. For this NIA, DOE applied a rebound effect parameter that reduces the estimated national energy savings. In addition, DOE considered the effects of climate changes on GIWH energy use. At this time, it is unclear the impact of increasingly warmer weather (as forecast by decreasing heating degree days (HDD) and increasing cooling degree days (CDD) in AEO 2023) will have on GIWH energy use, since warmer temperatures in the summer will tend to decrease GIWH load, which could be offset by increasing water heater load due to warmer temperatures in the colder months.

Table 10.3.1 Shipments-Weighted Average Per-Unit Annual Energy Consumption in 2030, Residential Sector

Product Class	Energy Use Source (Unit)	No-New-Standards Case	Trial Standard Level (TSL)			
			1	2	3	4
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	Electricity (kWh/yr)	34.0	35.7	35.6	35.5	24.8
	Fuel (MMBtu/yr)	12.4	12.0	11.8	11.6	11.5

Table 10.3.2 Shipments-Weighted Average Per-Unit Annual Energy Consumption in 2030, Commercial Sector

Product Class	Energy Use Source (Unit)	No-New-Standards Case	Trial Standard Level			
			1	2	3	4
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	Electricity (kWh/yr)	43.3	44.9	44.6	44.4	29.8
	Fuel (MMBtu/yr)	32.3	31.3	30.8	30.3	30.1

10.3.3 Shipments and Product Stock

As described in chapter 9, DOE forecasted shipments of GIWHs under the no-new-standard case and all standards cases. Because the increased total installed cost of more efficient products may cause some customers to choose to repair the broken unit rather than fix it, shipments forecasted under the standards cases may be lower than under the no-new-standard case. DOE believes it would be inappropriate to count energy savings that result from a decline in shipments because of standards. Therefore, each time a standards case was compared with the no-new-standard case, DOE used shipments associated with that particular standards case. As a result, all of the calculated energy savings are attributable to higher energy efficiency in the standards case.

The product stock in a given year ($STOCK_V$) is the number of products shipped from earlier years that survive in that year. The shipments model, which feeds into the NIA, tracks the number of units shipped each year. DOE assumed that products have an increasing probability of retiring as they age. The probability of survival as a function of years since purchase is called the survival function. Chapter 9 of this final rule TSD provides additional details on the survival function that DOE used for GIWHs.

10.3.4 Site-to-Primary Energy Conversion Factor

The site-to-primary energy conversion factor is a multiplicative factor used to convert site energy consumption into primary, or source, energy consumption, expressed in quads. For electricity from the grid, primary energy consumption is equal to the heat content of the fuels used to generate that electricity (which accounts for losses associated with the generation, transmission, and distribution of electricity).[b] For natural gas, and propane primary energy is equivalent to site energy.

DOE used annual conversion factors based on the version of the National Energy Modeling System (NEMS)[c] that corresponds to the *AEO 2023*.[3] The factors are marginal values, which represent the response of the national power system to incremental changes in consumption. The conversion factors change over time in response to projected changes in generation sources (the types of power plants projected to provide electricity). Specific conversion factors were generated from NEMS for a number of end uses in each sector. Appendix 10B describes how DOE derived these factors.

Table 10.3.3 shows the conversion factors for electricity use for GIWHs from 2030 to 2050. For years after 2050 (the last year in *AEO 2023*), DOE maintained the 2050 value. The conversion factors were generated from NEMS based on the estimated electricity load for "other uses". DOE used the factors corresponding to water heating in the residential and commercial sectors.

Table 10.3.3 Site-to-Primary Conversion Factors (MMBtu primary/MWh site) for Electricity Use for Gas-fired Instantaneous Water Heaters

	2025	2030	2035	2040	2045	2050+
Residential						
Water Heating	9.650	9.327	9.476	9.471	9.469	9.463
Commercial						
Water Heating	9.526	9.246	9.393	9.394	9.398	9.394

10.3.5 Full-Fuel-Cycle Multipliers

DOE uses an FFC multiplier to account for the energy consumed in extracting, processing, and transporting or distributing primary fuels, which are referred to as upstream activities. DOE developed FFC multipliers using data and projections generated for *AEO 2023*. *AEO 2023* provides extensive information about the energy system, including projections of future oil, natural gas, and coal supplies; energy use for oil and gas field and refinery operations; and fuel consumption and emissions related to electric power production. The information can be used to define a set of parameters that represent the energy intensity of energy production. For natural gas, the FFC multiplier includes leakage in upstream activities.

[b] For electricity sources such as nuclear energy and renewable energy, the primary energy is calculated using the convention used by EIA (see appendix 10B).

[c] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview 2000*, DOE/EIA-0581(2000), March 2000.[4] EIA approves use of the name NEMS to describe only an official version of the model with no modification to code or data.

The method used to calculate FFC energy multipliers is described in appendix 10B of this TSD. The multipliers are applied to primary energy consumption. Table 10.3.4 shows the FFC energy multipliers for selected years.

Table 10.3.4 Full-Fuel-Cycle Energy Multipliers (Based on AEO 2023)

	2025	2030	2035	2040	2045	2050+
Electricity	1.045	1.032	1.028	1.028	1.027	1.027
Natural gas	1.115	1.112	1.114	1.114	1.115	1.117
Petroleum fuels	1.194	1.198	1.204	1.208	1.212	1.211

10.3.6 Rebound Effect

A rebound effect may follow an energy conservation standard if consumers increase usage of a product because it costs less to operate than previous units.[d] A rebound effect reduces the energy savings attributable to a standard.[5,6,7,8] Where appropriate, DOE accounts for the direct rebound effect when estimating the NES from potential standards. For GIWHs, DOE applied a rebound effect of 10 percent for residential applications based on the rebound effect value used for GIWHs in the 2010 Final Rule for Heating Products[9] and zero percent for commercial applications. Although a lower value might be warranted, the analysis uses 10 percent to avoid understating the rebound effect. A rebound effect of 10 percent means that 10 percent of the estimated energy savings do not materialize because of increased use of the product (see chapter 8 for further discussion). See appendix 10E of this final rule TSD for further details and NIA results without a rebound effect.

10.4 NET PRESENT VALUE OF CONSUMER BENEFITS

DOE calculated the NPV of consumer benefits associated with the difference between the no-new-standards case and each standards case for GIWHs. The inputs for determining the NPV of the total costs and benefits experienced by consumers are (1) total annual installed cost, (2) total annual operating costs (energy costs and repair and maintenance costs), and (3) a discount factor to calculate the present value of costs and savings. DOE's analysis considers products shipped in the 30-year period beginning in the compliance year—in this case, 2030. DOE calculated NPV throughout the analysis period, which ends when all of the products shipped in 2059 are retired from the stock.

10.4.1 Definition

The NPV is the value in the present of a time-series of costs and savings. The NPV is described by the equation:

$$NPV = PVS - PVC$$

[d] This response is referred to as a direct rebound effect. It is difficult to account for economy-wide indirect rebound effects, which reflect how consumers spend the money saved by energy conservation.

Where:

PVS = present value of operating cost savings,[e] and
PVC = present value of increased total installed costs (purchase price and any installation costs).

DOE determined the PVS and PVC according to the following expressions:

$$PVS = \sum_y OCS_y \times DF_y$$

$$PVC = \sum_y TIC_y \times DF_y$$

Where:

OCS = total annual-savings in operating costs summed over vintages of the stock,
DF = discount factor in each year,
TIC = total annual increases in installed cost summed over vintages of the stock, and
y = year in the forecast.

DOE calculated the total annual consumer savings in operating costs by multiplying the number or stock of the product (by vintage) by its per-unit operating cost savings (also by vintage). DOE calculated the total annual increases in consumer product price by multiplying the number or shipments of the product (by vintage) by its per-unit increase in consumer cost (also by vintage). Total annual operating cost savings and total annual product cost increases are calculated by the following equations.

$$OCS_y = \sum_V STOCK_{V,y} \times UOCS_{V,y}$$

$$TIC_y = SHIP_y \times UTIC_y$$

Where:

OCS_y = total annual savings in operating cost each year summed over vintages of the product stock, $STOCK_V$,
$STOCK_{V,y}$ = stock of products of vintage V that survive in the year for which DOE calculated annual energy consumption,
$UOCS_{V,y}$ = annual operating cost savings per unit of vintage V,
V = year in which the product was purchased as a new unit,
y = year in the forecast,
TIC_y = total increase in installed product cost in year y,
$SHIP_y$ = shipments of the product in year y, and

[e] The operating cost includes energy, repair, and maintenance costs.

$UTIC_y$ = annual per-unit increase in installed product cost in year y.

DOE determined the total increased product cost for each year from 2030 to 2059. DOE determined the present value of operating cost savings for each year from 2030 to the year when all units purchased in 2059 are estimated to retire. DOE calculated installed cost and operating cost savings as the difference between a standards case and a no-new-standards case. As with the calculation of NES, DOE did not use no-new-standards case shipments to calculate total annual installed costs and operating cost savings. To avoid including savings attributable to shipments displaced by consumers deciding not to buy higher-cost products, DOE used the standards-case projection of shipments and, in turn, the standards-case stock, to calculate these quantities.

DOE developed a discount factor from the national discount rate and the number of years between the "present" (year to which the sum is being discounted) and the year in which the costs and savings occur.

10.4.2 Total Installed Cost

The per-unit total installed cost is a function of product energy efficiency. Therefore, DOE used the shipments-weighted efficiencies of the no-new-standards case and standards cases in combination with the total installed costs developed in chapter 8, to estimate the shipments-weighted average annual per-unit total installed cost under the various cases. Table 10.4.1 and Table 10.4.2 show the shipment-weighted average total installed cost for GIWHs in the residential and commercial sector in 2030 based on the efficiencies that correspond to the no-new-standards case and each TSL.

Table 10.4.1 Shipments-Weighted Average Total Installed Cost in 2030, Residential Sector

Product Class	No-New-Standards Case	Trial Standard Level (2023$)			
		1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	2,192	2,249	2,254	2,266	2,341

Table 10.4.2 Shipments-Weighted Average Total Installed Cost in 2030, Commercial Sector

Product Class	No-New-Standards Case	Trial Standard Level (2023$)			
		1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	2,539	2,619	2,623	2,634	2,708

As discussed in chapter 8 of this final rule TSD, DOE developed a price trend based on an experience curve. DOE used the price trend to project the prices of GIWH sold in each year of the forecast period (2030–2059). DOE applied the same values to project prices at each EL. For GIWHs, the estimated price trend is constant. To investigate the effect of different product price projections on the consumer NPV for various TSL, DOE also considered two alternative price trends as explained in chapter 8. See appendix 10C for the sensitivity analysis results.

The increase in total annual installed cost for any given TSL is the product of the total installed cost increase per unit under that standard and the number of units of each vintage. This approach accounts for differences in total installed cost from year to year.

For higher efficiency standards case, a fraction of households will install a high efficiency water heater a second or more time within the 30-year analytical period of the NIA. For these households, the additional installation cost adders for going from a lower efficiency to a higher efficiency water heater are not applied in the standards case, as the household already has a higher efficiency water heater.

10.4.3 Annual Operating Cost Savings

Per-unit annual operating costs encompass the annual costs for energy, repair, and maintenance. DOE determined the savings in per-unit annual energy cost by multiplying the savings in per-unit annual energy consumption by the appropriate energy price, and any associated costs or savings for repair and maintenance.

As described in chapter 8 of this TSD, to estimate energy prices in future years, DOE multiplied the recent energy prices by a projection of annual national-average residential and commercial energy prices based on EIA's *AEO 2023* reference case scenario. See appendix 10D for the sensitivity analysis on high and low economic growth scenarios.

The total savings in annual operating costs for an TSL is the product of the annual operating cost savings per unit under that standard and the number of units of each vintage. This approach accounts for differences in savings in annual operating costs from year to year.

10.4.4 Consideration of Rebound Effect

As previously discussed, a rebound effect may follow an energy conservation standard if consumers increase usage of a product because it costs less to operate than previous models. The increase in energy consumption associated with the rebound effect represents increased value to consumers (e.g., more hot water). The net effect is the sum of (1) the change in the cost of owning a product (that is, national consumer expenditures for total installed and operating costs) and (2) the increased value of the enhanced service from the product. In considering the consumer welfare gained due to the direct rebound effect, DOE accounted for change in consumer surplus attributed to additional heating from the purchase of a more efficient unit. Overall consumer surplus is generally understood to be enhanced from rebound. The net consumer impact of the rebound effect is included in the calculation of operating cost savings in the consumer NPV results. See appendix 10E of this final rule TSD for details on DOE's treatment of the monetary valuation of the rebound effect.

10.4.5 Discount Factor

DOE multiplied monetary values in future years by a discount factor to determine present values. The discount factor (DF) is described by the equation:

$$DF = \frac{1}{(1+r)^{(y-y_P)}}$$

Where:
r = discount rate,
y = year of the monetary value, and
y_P = year in which the present value is being determined.

DOE used both a 3-percent and a 7-percent real discount rate when estimating national impacts. Those discount rates were applied in accordance with the Office of Management and Budget (OMB)'s guidance to Federal agencies on developing regulatory analyses (OMB Circular A-4, September 17, 2003, and section E., "Identifying and Measuring Benefits and Costs," therein).[10] DOE defined the present year as 2024.

10.4.6 Present Value of Increased Installed Cost and Savings

The present value of increased installed costs is the annual increase in installed cost for each year (i.e., the difference between the standards case and no-new-standards), discounted to the present and summed over the forecast period (2030–2059). The increase in total installed cost refers to both product and installation costs associated with the higher energy efficiency of products purchased under a standards case compared to the no-new-standards case.[f] DOE calculated annual increases in installed cost as the difference in total cost of new products installed each year, multiplied by the shipments in the standards case.

The present value of operating cost savings is the annual savings in operating cost (the difference between the no-new-standards case and a standards case), discounted to the present and summed over the period that begins with the expected compliance date of potential standards and ends when the last installed unit is retired from service. Savings represent decreases in operating costs associated with the higher energy efficiency of products purchased in a standards case compared to the no-new-standards case. Total annual operating cost savings are the savings per unit multiplied by the number of units of each vintage that survive in a particular year. Because a product consumes energy throughout its lifetime, the energy consumption for units installed in a given year includes energy consumed until the unit is retired from service.

[f] For the NIA, DOE excludes sales tax from the product cost, because sales tax is essentially a transfer and therefore is more appropriate to include when estimating consumer benefits.

10.5 RESULTS

This section presents the NES and NPV results for the considered TSLs for GIWHs.

10.5.1 National Energy Savings

This section provides NES results that DOE calculated for each TSL analyzed for GIWHs. NES results are shown as savings in site, primary, and FFC energy in Table 10.5.1 through Table 10.5.3. Because DOE based the inputs to the NIA model on weighted-average values, results are discrete point values, rather than a distribution of values as produced by the life-cycle cost and payback period analysis.

Table 10.5.1 Cumulative Site National Energy Savings for Each Trial Standard Level for Gas-fired Instantaneous Water Heaters

Product Class	Trial Standard Level (quads*)			
	1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	0.32	0.53	0.77	0.91

* quads = quadrillion British thermal units.

Table 10.5.2 Cumulative Primary National Energy Savings for Each Trial Standard Level for Gas-fired Instantaneous Water Heaters

Product Class	Trial Standard Level (quads*)			
	1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	0.32	0.52	0.76	0.97

* quads = quadrillion British thermal units.

Table 10.5.3 Cumulative Full-Fuel-Cycle National Energy Savings for Each Trial Standard Level for Gas-fired Instantaneous Water Heaters

Product Class	Trial Standard Level (quads*)			
	1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	0.35	0.58	0.85	1.07

* quads = quadrillion British thermal units.

10.5.2 Net Present Value

This section provides results of calculating the NPV of consumer benefits for each TSL considered for GIWHs. Results, which are cumulative, are shown as the discounted value of the net savings in dollar terms. DOE based the inputs to the NIA model on weighted-average values, yielding results that are discrete point values, rather than a distribution of values as in the life-cycle cost and payback period analysis.

Table 10.5.4 and Table 10.5.5 show the results of calculating the NPV for the TSLs analyzed for GIWHs, at a 3-percent and a 7-percent discount rate, respectively.

Table 10.5.4 Cumulative Consumer Net Present Value for Each Trial Standard Level for Gas-fired Instantaneous Water Heaters at a 3-Percent Discount Rate

Product Class	Trial Standard Level (Billion, 2023$)			
	1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	1.26	3.06	4.89	4.50

Table 10.5.5 Cumulative Consumer Net Present Value for Trial Standard Level for Gas-fired Instantaneous Water Heaters at a 7-Percent Discount Rate

Product Class	Trial Standard Level (Billion, 2023$)			
	1	2	3	4
Gas-fired Instantaneous Water Heaters (Veff < 2 gal, Rated Input > 50,000 Btu/h)	0.24	0.87	1.45	0.98

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

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CHAPTER 11. CONSUMER SUBGROUP ANALYSIS

11.1 INTRODUCTION

The consumer subgroup analysis evaluates impacts on groups or customers who may be disproportionately affected by any national energy conservation standard. The U.S. Department of Energy (DOE) evaluated impacts on particular subgroups of consumers by analyzing the life-cycle cost (LCC) impacts and payback period (PBP) for those consumers from the considered energy efficiency levels. DOE determined the impact on consumer subgroups using the LCC spreadsheet models for gas-fired instantaneous water heaters (GIWHs). Chapter 8 explains in detail the inputs to the models used in determining LCC impacts and PBPs.

DOE evaluated the impacts of the considered energy efficiency levels for GIWHs on households occupied solely by senior citizens (i.e., senior-only households), low-income households, and GIWHs installed by small businesses. The analysis used subsets of the GIWH sample composed of households or buildings that meet the criteria for the subgroup. DOE used the LCC and PBP spreadsheet model to estimate the impacts of the considered efficiency levels on these subgroups.

This chapter describes the subgroup identification in further detail and gives the results of the LCC and PBP analyses for the considered subgroups for GIWHs.

11.2 SUBGROUPS DEFINITION

11.2.1 Senior-Only Households Development

Senior-only households have occupants who are all at least 65 years of age. Based on the Energy Information Administration's (EIA)'s 2020 Residential Energy Consumption Survey (RECS 2020)[1], senior-only households comprised 23.5 percent of the country's households. In estimating the LCC impacts to senior-only households, it is assumed that any residual value of a long-lived product is capitalized in the value of the home. DOE uses the same energy prices by State as in the main LCC analysis.

11.2.2 Low-Income Households

As defined by the US Census, low-income households are those at or below the "poverty line," which varies with household size, head of household age, and family income.[a] EIA's RECS 2020 does not include information that identifies "low income" households directly, but it does include income by bins and number of occupants.

To identify potential low-income households in RECS 2020, DOE used the poverty thresholds in 2020 defined by the U.S. Bureau of the Census (see Table 11.2.1) along with the RECS 2020 reported household income bins by household size. Of the households selected as low income, 76 percent of households are reported with income bins under the US census poverty thresholds, and 24 percent of households are reported with an income bin that is within the US Census poverty value. For the latter, DOE assumed that the distribution of incomes within the bin was proportional, so that the RECS weight would be adjusted by a factor derived by the difference between the US Census poverty value and the minimum of the RECS 2020 income bin divided by the difference between the high and low of the RECS 2020 income bin (i.e., $12,500 US Census poverty value in a $10-15,000 RECS 2020 income bin would be equal to 50 percent weighting factor). The average weighting factors for households with different income bin and household member number combinations are shown in Table 11.2.2.

The resulting fraction of RECS 2020 households classified as low income is 13.4 percent of the total households.[b] For the product class analyzed, low income households comprise 3.2 percent of GIWH households.

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[a] If a household's total income is less than the household's threshold (i.e., poverty-line), then that household and every individual in it is considered in poverty. The official poverty thresholds do not vary geographically, but they are updated for inflation using the Consumer Price Index. The poverty definition uses money income before taxes and does not include capital gains or noncash benefits (such as public housing, Medicaid, and food stamps). Although the thresholds in some sense reflect a household's needs, they are intended for use as a statistical yardstick, not as a complete description of what people and families need to live. For further information about poverty thresholds, see US Census poverty threshold tables[2] and how the Census Bureau measures poverty.[3]

[b] Note that this low-income fraction coincides with the increase in government support offered in 2020 during the COVID-19 pandemic, so this could partly explain the decreased fraction compared to the RECS 2009 survey, which classified approximately 14.8 percent of U.S. households as low-income.

Table 11.2.1 US Census Poverty Thresholds for 2020 by Household Size and Number of Related Children Under 18 Years

Household Size	Weighted Average Threshold *2020$*	Related children under 18 years, *2020$*								
		None	1	2	3	4	5	6	7	8+
1	13,171									
Under 65	13,465	13,465								
Over 65	12,413	12,413								
2	16,733									
Under 65	17,413	17,331	17,839							
Over 65	15,659	15,644	17,771							
3	20,591	20,244	20,832	20,852						
4	26,496	26,695	27,131	26,246	26,338					
5	31,417	32,193	32,661	31,661	30,887	30,414				
6	35,499	37,027	37,174	36,408	35,674	34,582	33,935			
7	40,406	42,605	42,871	41,954	41,314	40,124	38,734	37,210		
8	44,755	47,650	48,071	47,205	46,447	45,371	44,006	42,585	42,224	
9+	53,905	57,319	57,597	56,831	56,188	55,132	53,679	52,366	52,040	50,035

Source: US Census poverty threshold values for 2020.[2]

Table 11.2.2 Estimated Fraction of Low-income Households by RECS 2020 Income Bins and Household Size

Household Size	RECS 2020 Income Bins									
	less than $10,000	$10,000 - $12,499	$12,500 - $14,999	$15,000 - $19,999	$20,000 - $24,999	$25,000 - $29,999	$30,000 - $34,999	$35,000 - $39,999	$40,000 - $49,999	$50,000 or more
1	100	98	12	0	0	0	0	0	0	0
2	100	100	100	30	0	0	0	0	0	0
3	100	100	100	100	12	0	0	0	0	0
4	100	100	100	100	100	32	0	0	0	0
5	100	100	100	100	100	100	31	0	0	0
6	100	100	100	100	100	100	96	18	0	0
7	100	100	100	100	100	100	100	100	12	0

11.2.3 Characterization of Renters in the Consumer Subgroups

For this consumer subgroup analysis, DOE considers the impact on low-income and senior-only households narrowly, excluding costs or benefits that are accrued by either a landlord or subsidized housing agency. This allows DOE to better determine whether low-income and senior-only households are disproportionately affected by an amended energy conservation standard in a more representative manner. The main LCC results implicitly assume all equipment costs are ultimately paid for by the household, as an upper-bound estimate of costs paid for by each household. However, for the low-income subgroup analysis, DOE did not make this assumption in order to better understand the likely impacts on this specific subgroup, excluding the impact to landlords, who are not part of the low-income subgroup.

RECS 2020 indicates if a household rents the dwelling unit or owns it. RECS 2020 also includes data on whether a household pays for the electricity and/or gas bill. The distribution of these households is shown in Table 11.2.3. Low-income households are more likely to be renters or live in subsidized or public housing units, or in rent-controlled units, compared to the entire household sample.

The first column on the right side of Table 11.2.3 indicates for each category whether the households pay for the energy bill, and therefore whether they would benefit from energy savings of a standards-compliant GIWH. Renters are unlikely to be responsible for the selection and purchase of a GIWH, and therefore are not responsible for the incremental cost of a standards-compliant GIWH, but are often responsible for energy costs. RECS 2020 includes a category for households that pay only some of the electricity and/or gas bill. For the consumer subgroup analysis, DOE assumes that these households pay 50 percent of the bill, and, therefore, would receive 50 percent of energy cost benefits from an amended energy conservation standard.

For the renter portion of the subgroup analysis, DOE assumes that the incremental cost is not passed through in the rent. DOE assumes that the landlord does not pass on any higher upfront costs of new equipment, nor lower costs from reduced electricity and/or natural gas bills when the landlord pays the energy bill, through changes in rent. There is no evidence DOE is aware of that suggests a price increase on the installation of a GIWH, paid for by a landlord, would be passed down to any significant extent to low-income renters. Rental prices are largely determined by housing supply and demand, and low-income rents can be restricted by local requirements or subsidies. Therefore, low-income renters living in subsidized or public housing are less likely to bear the higher upfront GIWH costs. There are some indications that premium, efficient appliances can result in higher rents, but this correlation applies to premium rental properties, not low-income households. Even if some fraction of total installed costs were passed through to tenants through rent increases, the increase in rent would be averaged over many years, and discounting of future costs would reduce their present value considerably. The share of low-income renters that live in subsidized or public housing units, or in rent-controlled units, in the RECS data is not known. For the homeowner portion of the subgroup analysis, DOE assumes that households bear the upfront costs of new equipment as well as lower costs from reduced electricity and/or natural gas bills.

The renter and homeowner proportions of the low-income subgroup are combined and weighted by their relative prevalence in the low-income subgroup to arrive at the total consumer costs and LCC savings for the subgroup. Finally, DOE uses the same energy prices by State as in the main LCC analysis.

Table 11.2.3 Summarized Low Income Statistics

Type of Household* (Pay for Energy?)**	GIWH
Owners (Pay for energy Bill)	62%
Owners (Do Not Pay for energy Bill)	0%
Owners (Subtotal)	*62%*
Renters (Pay for energy Bill)	26%
Renters (Do Not Pay for energy Bill)	12%
Renters (Subtotal)	*38%*
Total	100%

* RECS 2020 lists three categories: (1) Owned or being bought by someone in your household (classified as "Owners" in this table); (2) Rented (classified as "Renters" in this table); (3) Occupied without payment of rent (also classified as "Renters" in this table). Therefore, renters include occupants in subsidized housing including public housing, subsidized housing in private properties, and other households that do not pay rent. RECS 2020 does not distinguish homes in subsidized or public housing.
** RECS 2020 lists four categories: (1) Household is responsible for paying for all energy used in this home; (2) All energy used in this home is included in the rent or condo fee; (3) Some is paid by the household, some is included in the rent or condo fee; and 4) Paid for some other way. "Pay for Energy Bill" includes category (1) and category (3), all other categories are included in "Do not Pay for Energy Bill".

11.2.4 Small Business Subsample Development

DOE identified small businesses within EIA's 2018 Commercial Buildings Energy Consumption Survey (CBECS 2018)[4] database by using threshold levels for maximum number of employees within each building principal building activity. DOE estimated the fraction of commercial buildings that could house a small business based on the small business employment share by industry for 2020 (see Table 11.2.4).[5]

Table 11.2.4 Fraction of Small Business Employment Share by Industry, 2020

Industry (from CBECS Principal Building Activity)	Mapped Industry (from Small Business Profile Report)	Fraction of Small Business Employment Share (%)
Vacant	Industries Not Classified	100
Office	Professional, Scientific, and Technical Services & Management of Companies and Enterprises & Administrative, Support, and Waste Management & Finance and Insurance	36.8
Laboratory	Professional, Scientific, and Technical Services	58.3
Nonrefrigerated warehouse	Transportation and Warehousing & Wholesale Trade	46.4
Food sales	Accommodation and Food Services	60.6
Public order and safety	All	47.1
Outpatient health care	Health Care and Social Assistance	44.4
Refrigerated warehouse	Transportation and Warehousing	46.4
Religious worship	All	47.1
Public assembly	Arts, Entertainment, and Recreation	60.3
Education	Educational Services	44.6
Food service	Accommodation and Food Services	60.6
Inpatient health care	Health Care and Social Assistance	44.4
Nursing	Health Care and Social Assistance	44.4
Lodging	Accommodation and Food Services	60.6
Strip shopping mall	Retail Trade	35.2
Enclosed mall	Retail Trade	35.2
Retail other than mall	Retail Trade	35.2
Service	Other Services (except Public Administration) & Construction	83.5
Other	Industries Not Classified	100

11.2.4.1 Small Business Discount Rate

DOE estimated commercial discount rates as the real weighted average cost of capital (WACC), which incorporates the cost of equity as estimated with the capital asset pricing model (CAPM), as described in discount rate section of chapter 8. In CAPM, the risk premium β is used to account for the higher returns associated with greater risk. However, for small companies, particularly very small companies, historic returns have been significantly higher than the CAPM equation predicts; this phenomenon is known as the size effect.[6,7] To account for the size effect, a size premium (S) can be incorporated into the CAPM equation to provide an alternative estimate of the small company cost of equity, and thus, the weighted average cost of capital specific to small businesses. To incorporate the size premium, the cost of equity for small firms is estimated as:

$$k_e = R_f + (\beta \times ERP) + S$$

k_e = Cost of equity,
R_f = Expected return on risk-free assets,
β = Risk coefficient of the firm,
ERP = Equity risk premium, and
S = Size Premium.

DOE primarily obtained size premium data from the *Stocks, Bonds, Bills, and Inflation Yearbook* for 1998-2017. For 2018-2020, size premium data were extracted from the Duff & Phelps online "Cost of Capital Navigator" system; the 2021 and 2022 size premium comes from the Kroll online "Cost of Capital Navigator" (see Table 11.2.5).[6,7,8,9,10,11] For each year, the size premium is the historical average difference in performance between small companies and the market average. The size effect is most pronounced for the smallest firms, in terms of market capitalization. In order to provide a conservative estimate of the value of discounted future energy cost savings, we focus on size effect of "microcap" companies (i.e., companies within the smallest two deciles of the overall market as measured by market capitalization). For example, for the period of 1926-2007, the average size premium for the smallest companies in all industries is 3.74%, implying that on average, historic performance of small companies was 3.74% higher than the CAPM estimate of the small company cost of equity over this period.

Table 11.2.5 Size Premium by Year

Year	Market Cap. of Largest Firm (Decile 10, $million)	Market Cap. of Largest Firm (Decile 9, $million)	Size Premium (Deciles 9,10 Microcap , %)
1998	--	252.0	2.60
1999	97.9	214.6	2.21
2000	84.5	192.6	2.62
2001	141.5	314.0	3.53
2002	166.4	330.6	4.01
2003	262.7	505.4	4.02
2004	264.9	586.4	3.95
2005	314.4	626.9	3.88
2006	363.5	723.3	3.65
2007	218.5	456.3	3.74
2008	214.1	431.3	3.99
2009	235.6	477.5	4.07
2010	206.8	422.8	3.89
2011	253.8	514.2	3.81
2012	253.7	514.2	3.81
2013	338.8	632.8	3.84
2014	300.7	548.8	3.74
2015	--	--	3.58
2016	--	--	3.67
2017	--	--	5.40
2018	--	--	3.39
2019	--	--	3.16
2020	189.8	451.8	3.21
2021	289.0	627.8	3.02
2022	289.0	627.8	4.80

DOE calculated the real weighted average cost of capital by sector (as described in chapter 8) using the cost of equity including a size premium for small companies instead of the CAPM cost of equity.[11] Table 11.2.6 presents DOE's estimates of the discount rates for entire sectors, small companies specifically, and the small company discount rate premium. To estimate the impact of standards specifically on small businesses, the small company discount rates for each sector were used instead of the sector average discount rates.

Table 11.2.6 Discount Rate Difference between Small Company and Sector Average

Sector with a Furnace	Average Discount Rate (%)		
	Entire Sector	Small Business	Small Business Differential
Education	7.21	10.41	3.20
Food Sales	5.68	8.20	2.52
Food Service	6.58	9.53	2.95
Health Care	6.99	9.84	2.86
Lodging	6.57	8.91	2.34
Mercantile	7.03	9.90	2.86
Office	6.87	9.61	2.74
Public Assembly	7.31	10.12	2.81
Service	6.23	8.41	2.18
All Commercial	6.76	9.42	2.65
Agriculture	7.16	9.65	2.49
Industrial	7.29	10.20	2.91
Utilities	4.20	6.23	2.03
REIT/Property	6.56	8.91	2.34
State/Local/Public Edu*	2.51	--	--
Federal Gov.*	2.03	--	--

* Note that it is not appropriate to calculate a separate small company discount rate for public sectors.

11.2.5 Estimation of Impacts

To calculate the subgroup results, DOE extracted the results of the households/buildings in the subgroup from the national LCC results. Then DOE calculated the LCC and PBP statistics for the subgroup from the individual households/buildings.

11.3 RESULTS

Table 11.3.1 to Table 11.3.4 compare the LCC savings and simple payback period for the considered subgroups with those for all households. In most cases, the considered subgroups are not disproportionately impacted compared to all households. As gas instantaneous water heaters are a long lived durable good (20 years on average), some senior only households may not directly experience the services of the water heater over the lifetime of the equipment. In the results that follow, DOE assumes that the value of reduced operating cost not directly experienced by the household would be fully capitalized into housing prices, and therefore experienced by these households through the value of their home.

Table 11.3.1 LCC Results by Efficiency Level for Gas Instantaneous Water Heaters (Low Income)

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost ($)	First Year Oper. Cost ($)	Lifetime Oper. Cost* ($)	LCC ($)	Simple PBP (yrs)	LCC Savings ($)	Net Cost
Gas-fired Instantaneous Water Heaters	0	1,388	226	3,788	5,175	NA	NA	0%
	1	1,543	211	3,542	5,085	9.9	141	8%
	2	1,552	203	3,421	4,972	7.1	248	6%
	3	1,561	200	3,368	4,929	6.6	152	11%
	4	1,617	197	3,325	4,942	7.9	123	32%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 11.3.2 LCC Results by Efficiency Level for Gas Instantaneous Water Heaters (Senior Only)

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost ($)	First Year Oper. Cost ($)	Lifetime Oper. Cost* ($)	LCC ($)	Simple PBP (yrs)	LCC Savings ($)	Net Cost
Gas-fired Instantaneous Water Heaters	0	1,983	282	4,302	6,286	NA	NA	0%
	1	2,217	264	4,073	6,290	13.5	(38)	20%
	2	2,230	256	3,944	6,174	9.6	80	17%
	3	2,246	252	3,889	6,135	8.9	75	26%
	4	2,336	249	3,850	6,185	10.9	18	57%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution. Negative values denoted in parentheses.

Table 11.3.3 LCC Results by Efficiency Level for Gas Instantaneous Water Heaters (Small Business)

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost ($)	First Year Oper. Cost ($)	Lifetime Oper. Cost* ($)	LCC ($)	Simple PBP (yrs)	LCC Savings ($)	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,421	431	3,771	6,192	NA	NA	0%
	1	2,710	402	3,535	6,246	10.2	(158)	25%
	2	2,724	388	3,412	6,136	7.2	(51)	26%
	3	2,740	383	3,360	6,100	6.6	10	43%
	4	2,830	378	3,321	6,152	7.8	(44)	67%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product. Negative values denoted in parentheses.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 11.3.4 Comparison of Average LCC Savings, LCC, PBP, and Net Cost for Consumer Subgroups and All Households for Gas Instantaneous Water Heaters

Product Class	EL	Average LCC Savings** 2023$				Simple Payback Period* *years*				Net Cost** %			
		Low Income	Senior Only	Small Bus.	Ref.	Low Income	Senior Only	Small Bus.	Ref.	Low Income	Senior Only	Small Bus.	Ref.
GIWH	1	141	(38)	(158)	(1)	9.9	13.5	10.2	12.6	8%	20%	25%	18%
	2	248	80	(51)	112	7.1	9.6	7.2	8.9	6%	17%	26%	15%
	3	152	75	10	90	6.6	8.9	6.6	8.3	11%	26%	43%	25%
	4	123	18	(44)	39	7.9	10.9	7.8	10.3	32%	57%	67%	56%

* The calculation considers only affected consumers. It excludes purchasers whose purchasing decision would not change under a standard set at the corresponding EL, i.e., those with zero LCC savings. Negative values denoted in parentheses.

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

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CHAPTER 12. MANUFACTURER IMPACT ANALYSIS

12.1 INTRODUCTION

In determining whether a standard is economically justified, the U.S. Department of Energy (DOE) is required to consider the economic impact of the standard on the manufacturers and consumers of product subject to such a standard. (42 U.S.C. 6295(o)(2)(B)(i)(I)) The law also calls for an assessment of the impact of any lessening of competition as determined in writing by the Attorney General. DOE conducted a manufacturer impact analysis (MIA) to estimate the financial impact of amended energy conservation standards on manufacturers of gas-fired instantaneous water heaters and assessed the impact of such standards on direct employment and manufacturing capacity.

The MIA has both quantitative and qualitative aspects. The quantitative part of the MIA primarily relies on the Government Regulatory Impact Model (GRIM), an industry cash-flow model adapted for the product in this rulemaking. The GRIM inputs include information on industry cost structure, shipments, and pricing strategies. The GRIM's key output is the industry net present value (INPV). The model estimates the financial impact of more stringent energy conservation standards by comparing changes in INPV between a no-new-standards-case and the various trial standard levels (TSLs) in the standards case. The qualitative part of the MIA addresses product characteristics, manufacturer characteristics, and market and product trends, as well as the impact of standards on subgroups of manufacturers.

12.2 METHODOLOGY

DOE conducted the MIA in three phases, and further tailored the analytical framework based on the comments it received. Phase I, "Industry Profile," consisted of preparing an industry characterization for the gas-instantaneous water heater industry and identifying important issues that require consideration. In Phase II, "Industry Cash Flow Analysis and Interview Guide," DOE prepared an industry cash-flow model and considered what information it might gather in manufacturer interviews. In Phase III, "Industry and Subgroup Analyses," DOE interviewed manufacturers and assessed the impacts of standards both quantitatively and qualitatively. DOE assessed impacts on competition, manufacturing capacity, direct employment, and cumulative regulatory burden. Each phase of the MIA is described in greater detail in the following sections.

12.2.1 Phase I: Industry Profile

In Phase I of the MIA, DOE prepared a profile of the gas-fired instantaneous water heater industry that built on the market and technology assessment prepared for this rulemaking (refer to chapter 3 of this final rule TSD). Before initiating detailed impact analyses, DOE collected information on past and present market characteristics of the industry. This information included shipment data, manufacturer markups, and manufacturer model counts. As part its industry profile research, DOE also collected information on industry financial parameters, such as net plant, property, and equipment (PPE); selling, general and administrative (SG&A) expenses;

research and development (R&D) expenses, depreciation, revenue, cost of goods sold, *etc*. These parameters allowed DOE to derive preliminary industry financial inputs for the GRIM.

DOE used public and private information to develop its initial characterization of the industry, including industry reports, prior DOE consumer water heater rulemakings, U.S. Securities and Exchange Commission (SEC) Form 10-K,[1] market research tools (i.e., D&B Hoovers[2]), corporate annual reports, the U.S. Census Bureau's *Annual Survey of Manufactures* (*ASM*),[3] and the U.S. Census Bureau's *Quarterly Survey of Plant Capacity Utilization*.[4]

12.2.2 Phase II: Industry Cash-Flow Analysis and Interview Guide

Phase II activities occur after publication of the preliminary analysis. In Phase II, DOE performs a draft industry cash-flow analysis and prepares an interview guide for manufacturer interviews.

12.2.2.1 Industry Cash-Flow Analysis

DOE uses the GRIM to analyze the financial impacts of potential new and/or amended energy conservation standards. The implementation of these standards may require manufacturer investments (i.e., conversion costs), raise manufacturer production costs (MPCs), and/or affect revenue possibly through higher prices and lower shipments. The GRIM uses a suite of factors to determine annual cash flows for the years leading up to the compliance date of new and/or amended energy conservation standards and for 30 years after the compliance date. These factors include industry financial parameters, MPCs, conversion costs, shipment forecasts, and price forecasts. DOE compares the GRIM results for potential standard levels against the results for the no-new-standards case, in which energy conservation standards are not amended. The financial impact of analyzed new and/or amended energy conservation standards is the difference between the two sets of discounted annual cash flows.

12.2.2.2 Interview Guide

DOE conducts interviews with manufacturers to gather information on the effects new and/or amended energy conservation standards could have on revenues and finances, direct employment, capital assets, and industry competitiveness. These interviews take place during Phase III of the MIA. Before the interviews, DOE distributes an interview guide that will help identify the impacts of potential standard levels on individual manufacturers or subgroups of manufacturers within the gas-fired instantaneous water heater industry. The interview guide covers financial parameters, MPCs, shipment projections, market share, product mix, conversion costs, manufacturer markups and profitability, assessment of the impact on competition, manufacturing capacity, and other relevant topics. The interview guide is presented in Appendix 12A.

12.2.3 Phase III: Industry and Subgroup Analysis

In Phase III of its analysis, DOE identified any subgroups of manufacturers that may be affected in different ways by new and/or amended standards. DOE identified small manufacturers as a subgroup that could be disproportionately affected by new and/or amended standards, and as a result, DOE conducted a separate analysis for small businesses in the industry.

12.2.3.1 Manufacturer Interviews

DOE supplements the information gathered in Phase I and the cash-flow analysis constructed in Phase II with information gathered through interviews with manufacturers and written comments from stakeholders during Phase III.

DOE conducts detailed interviews with manufacturers to gain insight into the potential impacts of any new and/or amended energy conservation standards. Generally, interviews are scheduled well in advance to provide every opportunity for key individuals to be available for comment. Although a written response to the questionnaire is acceptable, DOE prefers interactive interviews, if possible, which help clarify responses and provide the opportunity to identify additional issues.

A non-disclosure agreement allows DOE to consider confidential or sensitive information in the decision-making process. Confidential information, however, is not made available in the public record. At most, sensitive or confidential information may be aggregated and presented in the form of industry-wide representations.

12.2.3.2 Revised Industry Cash Flow Analysis

During interviews, DOE requests information about profitability impacts, necessary plant changes, and other manufacturing impacts. Following any such interviews, DOE revises the preliminary cash-flow prepared in Phase II based on the feedback it receives during interviews.

12.2.3.3 Manufacturer Subgroup Analysis

The use of average cost assumptions to develop an industry cash flow estimate may not adequately assess differential impacts of potential new and/or amended energy conservation standards among manufacturer subgroups. Smaller manufacturers, niche players, and manufacturers exhibiting a cost structure that differs largely from the industry average could be more negatively or positively affected. DOE customarily uses the results of the industry characterization to group manufacturers with similar characteristics. When possible, DOE discusses the potential subgroups that have been identified for the analysis in manufacturer interviews. DOE asks manufacturers and other interested parties to suggest what subgroups or characteristics are most appropriate for the analysis.

Small Business Manufacturers

DOE used the U.S. Small Business Administration (SBA) small business size standards as amended by the Office of Management and Budget on January 1, 2022, and effective March 17, 2023 (88 FR 9970), and the North American Industry Classification System (NAICS) code, presented in Table 12.2.1, to determine whether any small entities would be affected by the rulemaking.[5] For the product class under review, the SBA bases its small business definition on a company's total number of employees. This includes its subsidiaries and its parent companies.

An aggregated business entity with fewer employees than the listed limit is considered a small business.

Table 12.2.1 SBA and NAICS Classification of Small Businesses Potentially Affected by this Rulemaking

Industry Description	Revenue Limit	Employee Limit	NAICS
Major Household Appliance Manufacturing	N/A	1,500	335220

DOE began its assessment by reviewing its Certification Compliance Database (CCD),[6] Air-Conditioning, Heating, and Refrigeration Institute's (AHRI's) Directory of Certified Product Performance database,[7] California Energy Commission's Modernized Appliance Efficiency Database System (MAEDbS),[8] EPA's Energy Star Product Finder dataset,[9] and individual company websites to identify companies that import, private label, produce, or manufacture gas-fired instantaneous water heaters. DOE then consulted publicly available data, such as manufacturer websites, manufacturer specifications and product literature, import/export logs (e.g., bills of lading from ImportYeti),[10] and basic model numbers to identify OEMs of gas-fired instantaneous water heaters. DOE then relied on public sources and subscription-based market research tools (e.g., reports from D&B Hoovers) to determine company structure, location, headcount, and annual revenue. DOE asked industry representatives if they were aware of any small manufacturers during manufacturer interviews in advance of the July 2023 NOPR. 88 FR 49058. DOE screened out companies that do not offer products covered by this rulemaking, do not meet the SBA's definition of a "small business," or are foreign owned and operated.

Based on this analysis, DOE identified 15 OEMs of gas-fired instantaneous water heaters sold in the United States. Of these 15 OEMs, 12 OEMs produce gas-fired instantaneous water heaters subject to more stringent standards.[a] Of the 15 OEMs, DOE did not identify any small, domestic manufacturers of gas-fired instantaneous water heaters. As such, DOE does not expect this rulemaking would impact small business manufacturers of gas-fired instantaneous water heaters.

12.2.3.4 Manufacturing Capacity Impact

One of the potential outcomes of new and/or amended energy conservation standards is the obsolescence of existing manufacturing assets, including tooling and other investments. The manufacturer interview guide has a series of questions to help identify impacts on manufacturing capacity, specifically capacity utilization and plant location decisions in North America with and without new and/or amended energy conservation standards; the ability of manufacturers to upgrade or remodel existing facilities to accommodate the new requirements; the nature and value of any stranded assets; and estimates for any one-time restructuring or other charges, where applicable. DOE's estimates of the one-time capital changes and stranded assets that affect the cash flow estimates in the GRIM can be found in section 12.3.8. A discussion on the potential impacts of standards on manufacturing capacity can be found in section 12.5.2.

[a] The remaining three manufacturers only make products sold in the United States that are subject to new UEF-based energy conservation standards translated from EF-based energy conservation standards. See chapter 3 of the final rule TSD for additional information.

12.2.3.5 Direct Employment Impact

The impact of potential new and/or amended energy conservation standards on domestic direct employment is considered in DOE's analysis. Manufacturer interviews and public comments in response to the July 2023 NOPR and the July 2024 NODA aid in assessing how domestic employment patterns might be impacted by new and/or amended energy conservation standards. 89 FR 59692. Typically, the interview guide contains a series of questions that are designed to explore current employment trends in the industry and to solicit manufacturers' views on changes in direct employment patterns that may result from increased standard levels. These questions focus on current employment levels at production facilities, expected future direct employment levels with and without changes in energy conservation standards, differences in workforce skills, and employee retraining. The direct employment impacts are reported in section 12.5.1.

12.2.3.6 Cumulative Regulatory Burden

DOE seeks to mitigate the overlapping effects on manufacturers of potential new and/or amended energy conservation standards and other Federal regulatory actions affecting the same products or companies within a short timeframe. DOE analyzes and considers the impact of multiple, product-specific, Federal regulatory actions on manufacturers. Discussion of the cumulative regulatory burden can be found in section 12.5.3.

12.3 GRIM INPUTS AND ASSUMPTIONS

The GRIM serves as the main tool for assessing the impacts on industry due to new and/or amended energy conservation standards. DOE relies on several sources to obtain inputs for the GRIM. DOE then feeds data and assumptions from these sources into an accounting model that calculates the industry cash flow both with and without new and/or amended energy conservation standards.

12.3.1 Overview of the Government Regulatory Impact Model

The basic structure of the GRIM, illustrated in Figure 12.3.1, is an annual cash-flow analysis that uses manufacturer prices, manufacturing costs, shipments, and industry financial information as inputs, and accepts a set of regulatory conditions such as changes in costs, investments, and associated margins. The GRIM spreadsheet uses these and other inputs to calculate a series of annual cash flows, beginning with the reference year of the analysis, 2024, and continuing to 2059, 30 years after the analyzed compliance year of the rulemaking. The model calculates the INPV by summing the stream of annual discounted cash flows during this period and adding a discounted terminal value.[11]

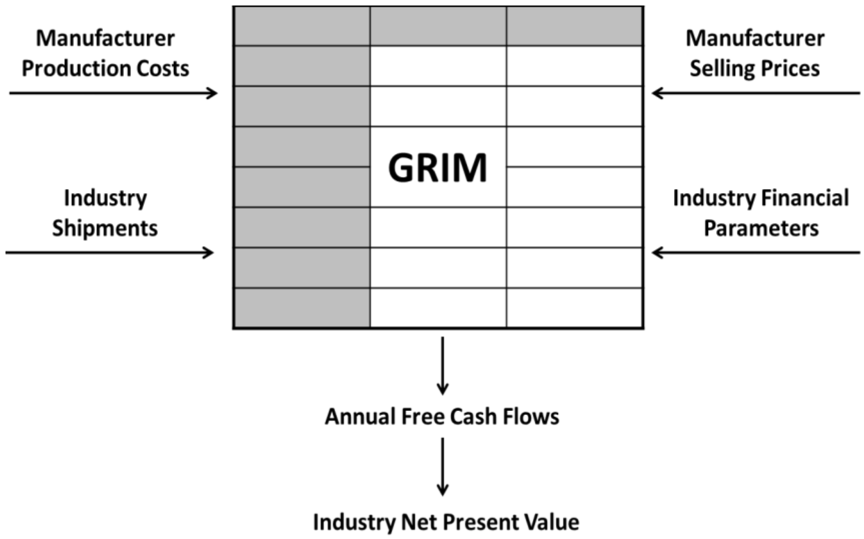

Figure 12.3.1 Using the GRIM to Calculate Cash Flow

The GRIM projects cash flows using standard accounting principles and compares INPV between the no-new-standards-case and the standard-case scenarios. The difference in INPV between the no-new-standards case and the standard case(s) represents the estimated financial impact of the amended energy conservation standards on manufacturers. Appendix 12B provides more technical details and user information for the GRIM.

12.3.2 Sources for GRIM Inputs

The GRIM uses several different sources for data inputs in determining industry cash flow. These sources include prior rulemakings, corporate annual reports, company profiles, the shipments model, the engineering analysis, and the manufacturer interviews.

12.3.2.1 April 2010 Final Rule

DOE used the prior rulemaking as a starting point for determining manufacturer markups. The April 2010 Final Rule[b] gas-fired instantaneous water heater manufacturer markup was vetted by multiple manufacturers in confidential interviews and went through public notice and comment. The results are the most robust product-specific estimates publicly available. DOE presented these values to manufacturers during confidential interviews conducted in support of this rulemaking analysis to confirm the manufacturer markup was still relevant.

12.3.2.2 Corporate Annual Reports

Corporate annual reports for publicly held companies are freely available to the general public through the SEC as filings of Form 10-K. Additionally, some privately held companies publish annual financial reports on their corporate websites. DOE developed initial financial inputs to the GRIM by examining the publicly available annual reports of companies primarily engaged in the manufacture of appliances whose combined product range includes consumer

[b] The April 2010 Final Rule published on April 16, 2010. DOE prescribed the current energy conservation standards for gas-fired instantaneous water heaters manufactured on and after April 16, 2015. 75 FR 20112

water heaters. As these companies do not provide detailed information about their individual product lines, DOE used the aggregate financial information at the corporate level in developing its initial estimates of the financial parameters to be used in the GRIM. In doing so, DOE assumes that the industry-average figures calculated for these companies were representative of manufacturing for gas-fired instantaneous water heaters. These figures were later revised using feedback from interviews in advance of the July 2023 NOPR to be representative of the consumer water heater manufacturing industry. DOE used corporate annual reports to derive the following initial inputs to the GRIM:

- Tax rate;
- Working capital;
- SG&A;
- R&D;
- Depreciation;
- Capital expenditures; and
- Net PPE.

12.3.2.3 Shipments Model

The GRIM used shipments projections derived from DOE's shipments model in the NIA. Total product shipments for gas-fired instantaneous water heaters are developed by considering the demand from replacements for units in stock that fail and the demand from new installations in newly constructed homes. Chapter 9 of the final rule TSD describes the methodology and analytical model DOE used to forecast shipments.

12.3.2.4 Engineering Analysis

The engineering analysis develops the relationship between the MPC and energy efficiency for the products analyzed in this rulemaking. This relationship serves as the basis for the cost-benefit calculations for consumers, manufacturers, and the Nation. In determining the cost-efficiency relationship, DOE estimates the increase in manufacturing costs associated with increasing the efficiency of product above the baseline up to the maximum technologically feasible (max-tech) efficiency level.

DOE conducted the engineering analysis for this rulemaking using a combination of the efficiency-level and design option approaches. DOE conducted a market analysis of currently available models listed in DOE's CCD to determine which efficiency levels were most representative of the current distribution of gas-fired instantaneous water heaters available on the market. DOE also completed physical teardowns of commercially available units to determine which design options manufacturers may use to achieve certain efficiency levels. This approach involved testing and physically disassembling a representative sample of commercially available products, reviewing publicly available cost information, and modeling equipment and tooling cost.

From this information, DOE estimated the MPCs for a range of products currently available on the market, considering the design options and the steps manufacturers would likely take to reach a certain efficiency level. The analysis yielded the labor, materials, overhead, and total production costs for products at each efficiency level. Chapter 5 of the final rule TSD describes the engineering analysis in detail.

12.3.2.5 Manufacturer Interviews

As part of the MIA, DOE conducted interviews in advance of the July 2023 NOPR with a representative cross-section of manufacturers. Through these discussions, DOE obtained information to determine and verify GRIM input assumptions. Key topics discussed during the interviews and reflected in the MIA include:

- Key issues
- Product classes
- Manufacturer production costs
- Technologies
- Financial parameters
- Organization and market share
- Manufacturer markup structure
- Conversion costs
- Cumulative regulatory burden
- Capacity and competition concerns
- Industry consolidation
- Small business impacts

The manufacturer interview guide can be found in appendix 12A of the final rule TSD. DOE notes that manufacturer interviews were conducted in advance of the July 2023 NOPR, and, therefore, the interview guide contains questions related to consumer water heater product classes other than gas-fired instantaneous water heaters since new and amended standards for all consumer water heater product classes were considered in the July 2023 NOPR.

12.3.3 Financial Parameters

In the manufacturer interviews, DOE used the financial parameters from 2014 to 2020 for three publicly-held manufacturers of consumer water heaters as a starting point for determining the industry financial parameters. The industry financial parameters were determined by weighting each manufacturer's individual financial parameters by their respective estimated market share, and correcting for the fraction of the market that was not represented. Table 12.3.1 below shows the data used to determine the initial financial parameter estimates.

Table 12.3.1 Initial Financial Parameters 2014–2020 Weighted Company Financial Data

Parameter	Industry Weighted Average
Tax Rate *(% of Taxable Income)*	24.0
Working Capital *(% of Revenue)*	24.9
SG&A *(% of Revenue)*	22.8
R&D *(% of Revenue)*	2.6
Depreciation *(% of Revenue)*	2.3
Capital Expenditures *(% of Revenue)*	2.5
Net Property, Plant, and Equipment *(% of Revenue)*	16.3

During interviews, manufacturers were asked to provide their own figures for the parameters listed in Table 12.3.1. Where applicable, DOE adjusted the financial parameters according to manufacturer feedback and market share information. The adjusted financial parameters used in the GRIM are listed in Table 12.3.2.

Table 12.3.2 Financial Parameters Used for the Gas-fired Instantaneous Water Heater GRIM

Parameter	Industry Weighted Average
Tax Rate *(% of Taxable Income)*	24.6
Working Capital *(% of Revenue)*	20.1
SG&A *(% of Revenue)*	13.7
R&D *(% of Revenue)*	2.3
Depreciation *(% of Revenue)*	2.3
Capital Expenditures *(% of Revenue)*	2.6
Net Property, Plant, and Equipment *(% of Revenue)*	14.8

12.3.4 Corporate Discount Rate

DOE used the weighted average cost of capital (WACC) as the discount rate to calculate the INPV. A company's assets are financed by a combination of debt and equity. The WACC is the total cost of debt and equity weighted by their respective proportions in the capital structure of the industry. DOE estimated the WACC for the gas-fired instantaneous water heater industry based on representative companies, using the following formula:

$$WACC = After\ Tax\ Cost\ of\ Debt\ x\ Debt\ Ratio + Cost\ of\ Equity\ x\ Equity\ Ratio$$

DOE estimated a real discount rate of 9.6 percent.

12.3.5 Trial Standard Levels

DOE developed TSLs to analyze the impact on manufacturers of amended energy efficiency standards for gas-fired instantaneous water heaters. Table 12.3.3 presents the TSLs and the corresponding efficiency levels.

Table 12.3.3 Trial Standard Levels for Gas-fired Instantaneous Water Heaters

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (V_{eff} < 2 gal, Rated Input > 50,000 Btu/h)	EL 1	EL 2	EL 3	EL 4

12.3.6 NIA Shipment Forecast

The GRIM estimates manufacturer revenues based on total-unit-shipment forecasts and the distribution of these values by efficiency level. Changes in the efficiency mix at each standard level are a key driver of manufacturer finances. For this analysis, the GRIM used the gas-fired instantaneous water heater shipment data from the NIA. Chapter 9 of this final rule TSD explains DOE's calculations of total shipments in detail. In the no-new-standards case, the total shipments forecast is 1.434 million for gas-fired instantaneous water heaters in 2030, the year amended standards for gas-fired instantaneous water heaters will take effect.

12.3.6.1 No-New-Standards-Case Shipments Efficiency Distribution

As part of the shipment analysis, DOE estimated the distribution of shipments by efficiency level for gas-fired instantaneous water heaters. Table 12.3.4 shows the no-new-standards case distributions of shipments by efficiency level estimated in the NIA for the gas-fired instantaneous water heaters in 2024 (the reference year) and 2030 (the compliance year). Figure 12.3.2 shows the no-new-standards case shipments by efficiency level over the analysis period.

To develop efficiency trends after 2030, DOE used historical shipment data and current gas-fired instantaneous water heater model availability by efficiency level (see chapter 8 of the final rule TSD). DOE estimated growth in shipment-weighted efficiency by assuming that the implementation of ENERGY STAR's performance criteria and other incentives would gradually increase the market shares of higher efficiency water heaters meeting ENERGY STAR requirements such as EL 1 and above for gas-fired instantaneous water heaters. See chapter 8 of the final rule TSD for information on the derivation of the efficiency distributions. See chapter 10 of the final rule TSD for the projected product efficiency trends.

Table 12.3.4 No-New-Standards Shipments Distribution for Gas-fired Instantaneous Water Heaters:

Shipments Distribution	Baseline	EL 1	EL 2	EL 3	EL 4
2024 (Reference Year)	32.9%	7.3%	44.7%	7.0%	8.1%
2030 (Compliance Year)	30.0%	7.6%	46.7%	7.3%	8.4%

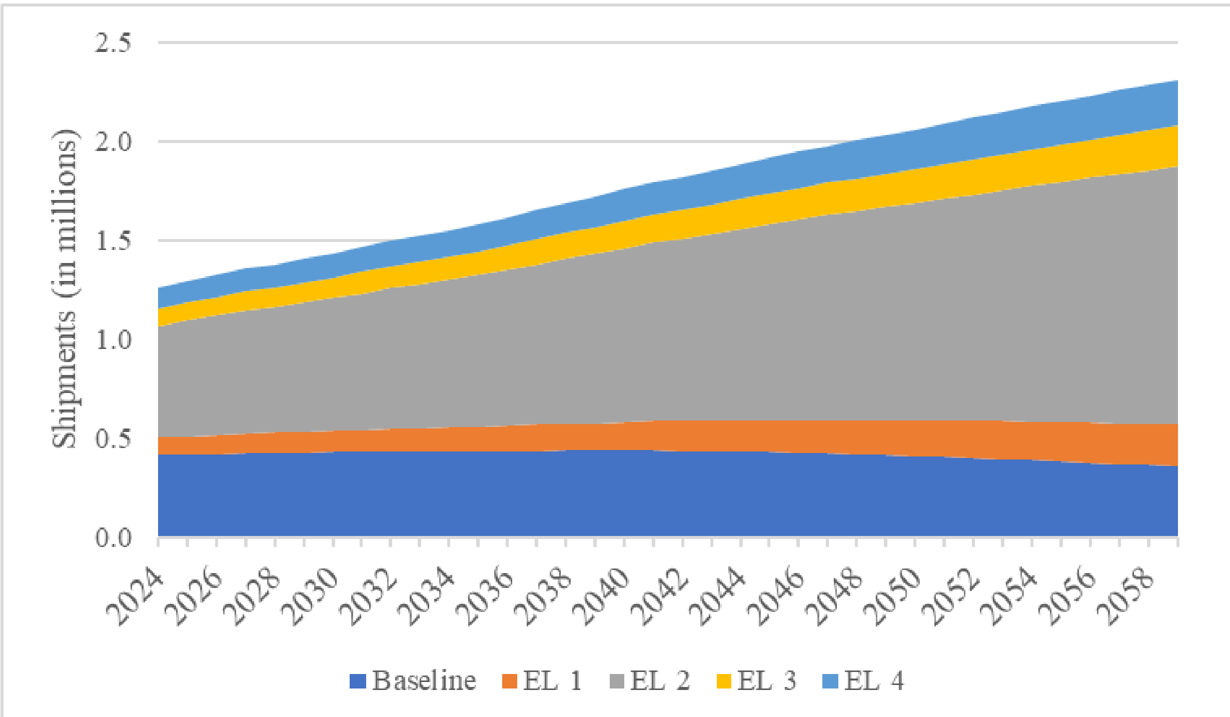

Figure 12.3.2 No-New-Standards Shipments for Gas-fired Instantaneous Water Heaters by Efficiency Level (2024-2059)

12.3.6.2 Standards-Case Shipments Forecast

To examine the impact of new and/or amended energy conservation standards on shipments, which in turn affects the INPV, DOE used the no-new-standards-case shipments described in the previous section as a point of comparison for shipments forecast in the standards case. For each TSL described in the standards case, DOE used the shipments forecasts developed in the NIA for gas-fired instantaneous water heaters. For the standards cases, DOE used a "roll-up" scenario to establish the shipment-weighted efficiency for the year that standards are assumed to become effective (2030). In this scenario, the market shares of products in the no-new-standards case that do not meet the standard under consideration would "roll up" to meet the new standard level, and the market share of products above the standard would remain unchanged from the no-new-standards case.

See chapter 9 of the final rule TSD for the additional information regarding the shipments analysis.

12.3.6.3 Draw Pattern Distributions

For the MIA, DOE relied on the draw pattern distribution from the NIA to shipment-weight the MPCs derived in the engineering analysis. DOE applied the market share weighting by medium and high draw pattern to develop the gas-fired instantaneous water heater MPCs used in the GRIM. See Table 12.3.5 for the market share breakdown by draw pattern.

Table 12.3.5 Market Share Breakdown by Draw Pattern for Gas-fired Instantaneous Water Heaters

Draw Pattern	Market Share
Medium Draw	13.8%
High Draw	86.2%

12.3.7 Manufacturer Production Costs

Manufacturing more efficient products is typically more expensive than manufacturing baseline products due to the use of more complex components, which are typically more costly than baseline components. Changes in the MPCs of gas-fired instantaneous water heaters can affect revenues, gross margins, and cash flow of the industry, making product cost data key GRIM inputs for DOE's analysis. The GRIM relied on the gas-fired instantaneous water heater MPCs for medium and high draw patterns derived in the engineering analysis (chapter 5 of the final rule TSD) and market share weights from the NIA. The engineering analysis involved testing and physically disassembling a representative sample of commercially available products, reviewing publicly available cost information, and modeling equipment and tooling cost to estimate gas-fired instantaneous water heater production costs.

The cost model disaggregated the MPCs at each efficiency level into material, labor, overhead, and depreciation. For materials, DOE used the incremental component and raw material costs that correspond to the design options at each efficiency level. For labor, DOE estimated the labor contribution at each efficiency level by examining how the design options may influence manufacturing and assembly practices. For depreciation, DOE used a depreciation value that is consistent with historical information in SEC 10-Ks. The remainder of total overhead was allocated to factory overhead.

Manufacturers validated these estimates and assumptions during interviews. DOE used the resulting MPCs and cost breakdowns, detailed in chapter 5 of this final rule TSD, for each efficiency level analyzed in the GRIM.

The manufacturer selling price (MSP) is comprised of production costs (the direct manufacturing costs or MPCs), non-production costs (indirect costs including SG&A and R&D), and profit. DOE calculated the MSPs by multiplying the MPCs by the manufacturer markup. Table 12.3.6 shows the production cost estimates used in the GRIM for gas-fired instantaneous water heaters.

As discussed in section 12.3.6.3, DOE relied on the draw pattern distributions from the NIA to market share weight the MPCs derived in the engineering analysis to calculate the MPCs used in the GRIM.

Table 12.3.6 Manufacturer Production Cost Breakdown for Gas-fired Instantaneous Water Heaters

EL	Materials	Labor	Depreciation	Overhead	MPC	Mfr. Markup	MSP
Baseline	$196.98	$82.33	$10.86	$35.33	$325.50	1.45	$471.97
EL 1	$259.25	$130.21	$15.29	$53.62	$458.37	1.45	$664.63
EL 2	$262.50	$131.38	$15.45	$53.87	$463.20	1.45	$671.64
EL 3	$267.74	$132.65	$15.68	$54.14	$470.22	1.45	$681.81
EL 4	$319.65	$130.84	$17.06	$44.01	$511.55	1.45	$741.75

12.3.8 Conversion Costs and Stranded Assets

New and/or amended energy conservation standards typically cause manufacturers to incur one-time conversion costs to bring their production facilities and product designs into compliance with new regulations. For the MIA, DOE classified these one-time conversion costs into two major groups: capital conversion costs and product conversion costs. Capital conversion costs are one-time investments in property, plant, and equipment needed to adapt or change existing production facilities in order to fabricate and assemble product designs that comply with new and/or amended energy conservation standards. Product conversion costs are investments in research, development, testing, marketing, and other non-capitalized costs to make product designs comply with new and/or amended energy conservation standards. In the instance where changes to energy conservation standards result in the obsolescence of manufacturing capital, the un-depreciated value of any obsolete equipment is considered a stranded asset. In addition to product and capital conversion costs, stranded assets also factor into the GRIM's calculation of annual cash flows. The following sections describe the inputs DOE used in the GRIM in greater detail.

12.3.8.1 Capital and Product Conversion Costs

In the July 2023 NOPR and the July 2024 NODA, DOE relied on manufacturer feedback to evaluate the level of capital and product conversion costs that gas-fired instantaneous water heater manufacturers would likely incur to meet each analyzed efficiency level. 88 FR 49058, 49127-49128; 89 FR 59692, 59699-59700. During confidential interviews, DOE asked manufacturers to estimate the capital conversion costs (e.g., changes in production processes, equipment, and tooling), needed to meet the various efficiency levels. DOE also asked manufacturers to estimate the redesign effort and engineering resources required at various efficiency levels to quantify the product conversion costs. DOE then estimated industry-level conversion costs by scaling feedback from OEMs by the estimated number of manufacturers that would need to make these investments at each TSL.

At lower TSLs, manufacturer feedback and a review of the market indicate that most manufacturers already have sufficient condensing production capacity and offer range of models that meet the required efficiency levels. Thus, DOE modeled low-levels of capital and product conversion costs for most manufacturers at TSL 1 and TSL 2. As TSLs increase in stringency, DOE expects most manufacturers would need to add production capacity as fewer shipments currently meet the required levels and product designs increase in complexity. DOE also expects product conversion costs would increase at higher TSLs since fewer manufacturers offer fewer models that meet the efficiency levels required. For the July 2024 NODA, DOE refined its conversion cost estimates to reflect feedback submitted by Rinnai in response to the July 2023 NOPR.[c] DOE incorporated Rinnai's estimate of $15 million required to retrofit its Griffin, Georgia factory to produce condensing gas-fired instantaneous water heaters into its conversion cost estimates at TSL 1 and modeled additional incremental investments to reach higher TSLs, consistent with manufacturer feedback from confidential interviews. DOE incorporated Rinnai's estimate to convert its U.S. production facility in its analysis to avoid underestimating the potential investments required to meet potential amended standards. Alternatively, Rinnai could choose to maintain condensing capabilities in its existing facilities in Japan, in which case industry conversion costs would be lower.

For the final rule, DOE updated its conversion cost estimates from 2022$ to 2023$ but otherwise maintained its conversion cost methodology used in the July 2024 NODA.

In general, DOE assumes all conversion-related investments occur between the year of publication of the final rule and the compliance year, when manufacturers must comply with the new standard.

Table 12.3.7 shows DOE's estimates of the capital and product conversion costs necessary at each trial standard level identified.

Table 12.3.7 Conversion Costs for Gas-fired Instantaneous Water Heaters

Trial Standard Level	**Capital Conversion Costs** *(millions 2023$)*	**Product Conversion Costs** *(millions 2023$)*
Baseline	$0.0	$0.0
TSL 1	$13.9	$2.5
TSL 2	$16.7	$3.7
TSL 3	$55.3	$4.8
TSL 4	$55.3	$4.8

12.3.8.2 Stranded Assets

In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets (i.e., tooling and equipment that would have enjoyed longer use if energy conservation standard had not made them obsolete). In the compliance year, manufacturers write down the remaining book value of existing tooling and equipment rendered obsolete by new energy conservation standards.

[c] Rinnai's comment can be downloaded here: www.regulations.gov/comment/EERE-2017-BT-STD-0019-1186 (p.23)

Based on manufacturer feedback and the engineering analysis, DOE aligned stranded assets with capital investments. Industry stranded assets is driven by the transition to condensing technology and expansion of condensing production lines. Table 12.3.8 shows DOE's estimates stranded assets at each trial standard level identified.

Table 12.3.8 Stranded Assets for Gas-fired Instantaneous Water Heaters

Trial Standard Level	**Stranded Assets** *(millions 2023$)*
Baseline	$0.0
TSL 1	$1.4
TSL 2	$1.7
TSL 3	$5.5
TSL 4	$5.5

12.3.9 Manufacturer Markup Scenarios

MSPs include direct manufacturing production costs (i.e., labor, material, overhead, and depreciation estimated in DOE's MPCs) and all non-production costs (i.e., SG&A, R&D, and interest), along with profit. To calculate the MSPs in the GRIM, DOE applied manufacturer markups to the MPCs estimated in the engineering analysis. Based on publicly available financial information for manufacturers of gas-fired instantaneous water heaters, the April 2010 Final Rule, and comments from manufacturer interviews in advance of the July 2023 NOPR, DOE estimated the industry average no-new-standards-case manufacturer markup to be 1.45 for gas-fired instantaneous water heaters.

In the standards case, DOE modeled two scenarios to represent the uncertainty about the potential impacts on prices and profitability following the implementation of amended energy conservation standards: (1) a preservation of gross margin percentage scenario, and (2) a preservation of operating profit scenario. These scenarios lead to different manufacturer markup values that, when applied to the MPCs, result in varying revenue and cash flow impacts.

12.3.9.1 Preservation of Gross Margin Percentage Scenario

Under the preservation of gross margin percentage scenario, DOE assumed a manufacturer "gross margin percentage" of 31 percent for gas-fired instantaneous water heaters, corresponding to a manufacturer markup of 1.45, which assumes that a manufacturer would be able to maintain the same amount of profit as a percentage of revenues at all efficiency levels. As manufacturer production costs increase with efficiency, this scenario implies that the per-unit dollar profit will increase as well. Manufacturers tend to believe it is optimistic to assume that they would be able to maintain the same gross margin percentage as their production costs increase, particularly for minimally efficient products. Therefore, DOE assumes that this scenario represents a high bound to industry profitability under an amended energy conservation standard.

12.3.9.2 Preservation of Operating Profit Scenario

DOE also modeled the preservation of operating profit scenario to estimate a lower bound of profitability for the industry. Under this scenario, as the cost of production and the cost of sales increase, manufacturers are generally required to reduce their manufacturer markups to a level that maintains the no-new-standards case operating profit. As a result, manufacturers are not able to earn additional operating profit from the increased production costs and the investments that are required to comply with amended standards. DOE implemented this scenario in the GRIM by lowering the manufacturer markups at each TSL to yield approximately the same earnings before interest and taxes in the standards case as in the no-new-standards case in the year after the expected compliance date of the amended standards. The assumption behind this manufacturer markup scenario is that the industry can only maintain its operating profit in absolute dollars after the standard. As a result, operating margin in percentage terms is reduced between the no-new-standards case and standards case as manufacturer production costs increase.

While all compliant products receive the gross margin percentage of 31 percent in the preservation of gross margin scenario, the manufacturer markup is reduced for compliant products under the preservation of operating profit scenario. [d] Table 12.3.9 lists the calibrated manufacturer markups by TSL.

Table 12.3.9 Preservation of Operating Profit Manufacturer Markups for Gas-fired Instantaneous Water Heaters by Trial Standard Level

Efficiency Level	No-New-Stds Case	TSL 1	TSL 2	TSL 3	TSL 4
Baseline	1.450				
EL 1	1.450	1.391			
EL 2	1.450	1.450	1.423		
EL 3	1.450	1.450	1.450	1.422	
EL 4	1.450	1.450	1.450	1.450	1.407

12.4 INDUSTRY FINANCIAL IMPACTS

Using the inputs and scenarios described in the previous sections, DOE used the GRIM to estimate the financial impacts on the gas-fired instantaneous water heater industry. The MIA uses two key financial metrics: INPV and annual cash flows. The main results of the MIA are reported in this section.

12.4.1 Impacts on Industry Net Present Value

The INPV measures the industry value and is used in the MIA to compare the economic impacts of different TSLs in the standards case. The INPV is different from DOE's NPV, which is applied to the U.S. economy at large. The INPV is specific to the gas-fired instantaneous water

[d] The gross margin percentage of 31 percent is based on a manufacturer markup of 1.45.

heater manufacturing industry and is the sum of all annual net cash flows discounted at the industry's WACC. The GRIM for the gas-fired instantaneous water heater industry models cash flows from 2024 to 2059. This timeframe models both the short-term impacts on the industry from the announcement of the standard until the compliance year of 2030, and a long-term assessment over the 30-year analysis period immediately thereafter.

In the MIA, DOE compares the INPV at the no-new-standards case (no new or amended energy conservation standards) to that at each TSL in the standards case. The difference between the no-new-standards case and a standards case INPV is an estimate of the economic impacts that implementing that particular TSL would have on the industry. For the gas-fired instantaneous water heater industry, DOE examined the two manufacturer markup scenarios described in section 12.3.9: the preservation of gross margin percentage scenario and the preservation of operating profit scenario. DOE's estimates of INPV for the full analysis period (2024–2059) for the no-new-standards case and at each TSL in the standards case are presented in Table 12.4.1 and Table 12.4.2 below.

Table 12.4.1 Manufacturer Impact Analysis for Gas-fired Instantaneous Water Heaters – Preservation of Gross Margin Percentage Scenario

		No-New-Standards Case	**Trial Standard Level**			
			1	**2**	**3**	**4**
INPV	*(2023$ millions)*	1,193.9	1,234.0	1,234.4	1,217.6	1,275.2
Change in INPV	*(2023$ millions)*	-	40.1	40.5	23.7	81.2
	(%)	-	3.4	3.4	2.0	6.8

Table 12.4.2 Manufacturer Impact Analysis for Gas-fired Instantaneous Water Heaters – Preservation of Operating Profit Scenario

		No-New-Standards Case	**Trial Standard Level***			
			1	**2**	**3**	**4**
INPV	*(2023$ millions)*	1,193.9	1,171.1	1,160.2	1,132.1	1,119.5
Change in INPV	*(2023$ millions)*	-	(22.9)	(33.7)	(61.8)	(74.5)
	(%)	-	(1.9)	(2.8)	(5.2)	(6.2)

*Values in parenthesis indicate negative numbers

12.4.2 Impacts on Industry Annual Cash Flow

While INPV is useful for evaluating the long-term effects of new and/or amended energy conservation standards, short-term changes in cash flow are also important indicators of the industry's financial situation. For example, a large investment over one or two years could strain the industry's capital reserves and cash flow. Consequently, the sharp drop in financial performance could cause investors to flee, even if recovery is possible. Thus, a short-term disturbance can have long-term effects that the INPV cannot capture. To get an idea of the behavior of annual net cash flows, see Figure 12.4.1 and Figure 12.4.2 below, which present the annual net or free cash flows from 2024 through 2035 for the no-new-standards case and each TSL in the standards case.

Annual cash flows are discounted to the base year, 2024. Between 2024 and the 2030 compliance date, cash flows are driven by the level of conversion costs and the portion of these investments made each year. After the standard announcement date (i.e., the publication date of the final rule), industry cash flows begin to decline as companies use their financial resources to prepare for the new and/or amended energy conservation standard. The more stringent the new and/or amended energy conservation standard, the greater the impact on industry cash flows in the years leading up to the compliance date, as product conversion costs lower cash flows from operations and capital conversion costs increase outlays of cash for capital expenditures.

Free cash flow in the year the amended energy conservation standards take effect is driven by two competing factors. In addition to capital and product conversion costs, amended energy conservation standards could create stranded assets, i.e., the residual un-depreciated value of tooling and equipment that would have enjoyed longer use if the energy conservation standard had not made them obsolete. In this year, manufacturers write down the remaining book value of existing tooling and equipment, the value of which is affected by the amended energy conservation standards. This one time write down acts as a tax shield that mitigates decreases in cash flow from operations in the year of the write-down. In this year, there is also an increase in working capital that reduces cash flow from operations. A large increase in working capital can be attributed to more costly production components and materials, higher inventory carrying to sell more expensive products, and higher accounts receivable for more expensive products. Depending on these two competing factors, cash flow can either be positively or negatively affected in the year the standard takes effect.

In the years following the compliance date of the standard, the impact on cash flow depends on the operating revenue. Under the preservation of gross margin percentage scenario, more stringent TSLs typically have a positive impact on cash flows relative to the no-new-standards case because in marking up more costly products, manufacturers are able to earn a higher operating profit, which increases cash flow from operations. There is very little impact on cash flow from operations under the preservation of operating profit scenario because this scenario is calibrated to have the same earnings before interest and taxes in the standards case at each TSL as the no-new-standards case as in the year after the standard takes effect. In this scenario production costs increase in the standards case but per-unit operating profit remains approximately equal to the no-new-standards case, effectively decreasing profit margins as a percentage of revenue. Table 12.4.3 presents free cash flow impacts in the year before the standard takes effect.

Table 12.4.3 Industry Free Cash Flow Impacts in the Year Before Compliance (2029)

		No-New-Standards Case	Trial Standard Level*			
			1	**2**	**3**	**4**
Free Cash Flow (2029)	*(2023$ millions)*	91.7	84.6	82.9	65.2	65.2
Change in Free Cash Flow	*(2023$ millions)*	-	(7.1)	(8.8)	(26.5)	(26.5)
	(%)	-	(7.8)	(9.6)	(28.9)	(28.9)

*Values in parenthesis indicate negative numbers

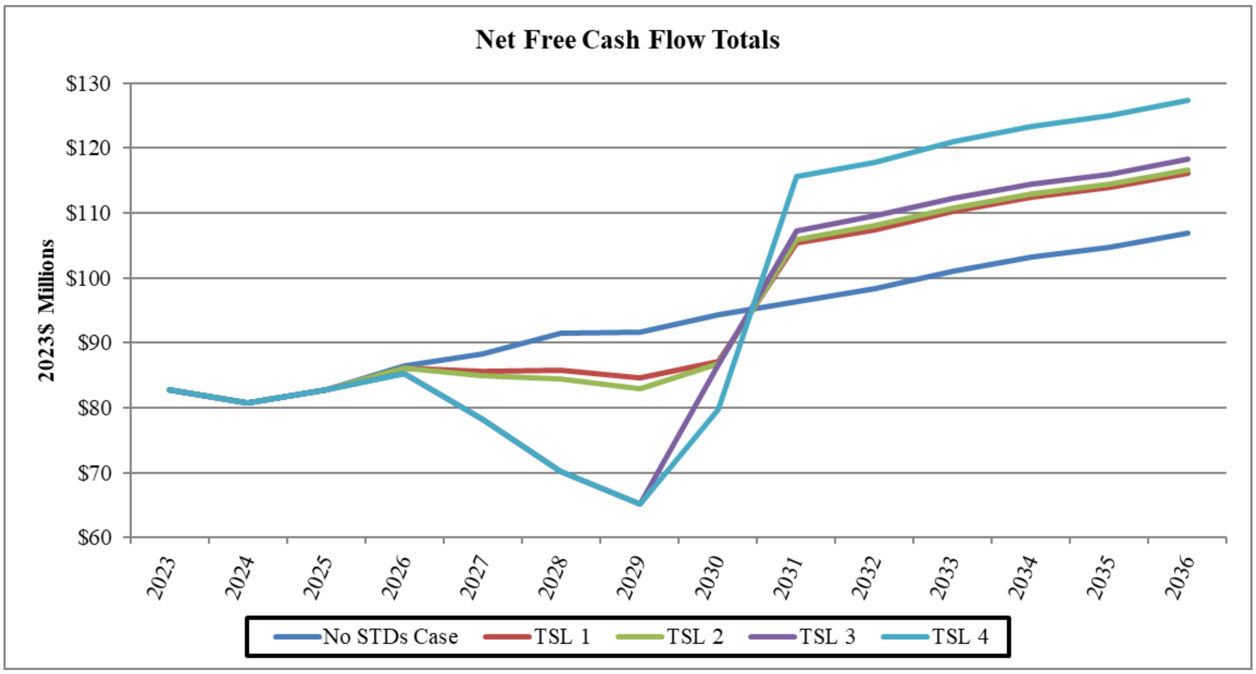

Figure 12.4.1 Annual Industry Net Cash Flows for Gas-fired Instantaneous Water Heaters (Preservation of Gross Margin Scenario)

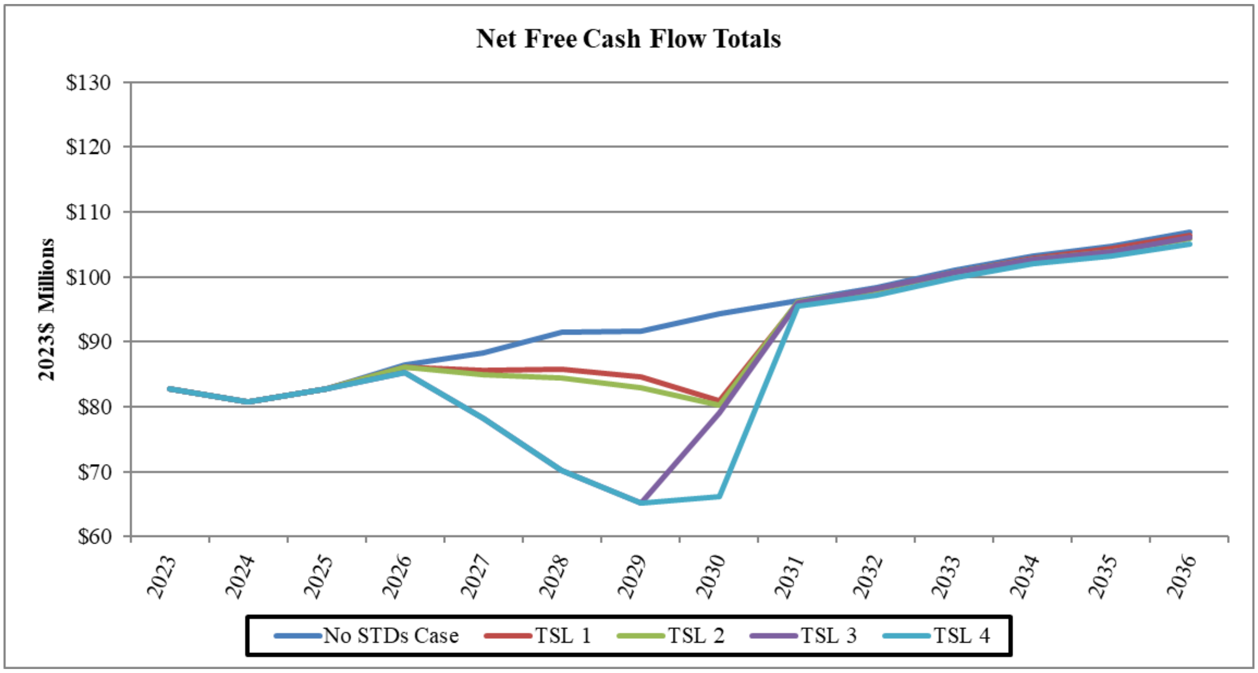

Figure 12.4.2 Annual Industry Net Cash Flows for Gas-fired Instantaneous Water Heaters (Preservation of Operating Profit Scenario)

12.5 OTHER IMPACTS

12.5.1 Direct Employment

In the July 2023 NOPR, DOE estimated that approximately 70 percent of consumer water heaters subject to the proposed amended standards were produced domestically. Of that 70 percent, DOE estimated that all gas-fired instantaneous water heaters (which account for approximately 12 percent of the overall consumer water heater market in 2024) were produced outside of the United States. For the July 2024 NODA, DOE revised its direct employment analysis to account for Rinnai's new domestic production facility dedicated to manufacturing gas-fired instantaneous water heaters. In the July 2024 NODA, DOE estimated that approximately 20 percent of gas-fired instantaneous water heaters were produced domestically. DOE derived this value by using its shipments analysis and public market share feedback.[e] DOE maintained the 20 percent estimate from the July 2024 NODA for this analysis.

In addition to Rinnai's market share feedback, DOE relied on the employment figures provided in Rinnai's comments in response to the July 2023 NOPR to estimate the potential range of direct employment impacts in 2030 (the analyzed compliance year) in the July 2024

[e] In 2023, DOE estimates that approximately 0.41 million out of the 1.22 million gas-fired instantaneous water heater unit shipments are non-condensing. In response to the July 2023 NOPR, Rinnai commented that its domestic market share of non-condensing gas-fired instantaneous water heaters is 60 percent: $(60\% \times 0.41\ million) \div 1.22\ million = 20\%$. Rinnai's comment can be downloaded at: www.regulations.gov/comment/EERE-2017-BT-STD-0019-1186 (p. 1)

NODA. Rinnai's comments indicated that there were 122 domestic production workers dedicated to manufacturing non-condensing gas-fired instantaneous water heaters in 2023.[f] Using results of the shipments analysis, DOE projected that there would be approximately 128 domestic production workers in 2030 (the analyzed compliance year) in the no-new-standards case.

To establish a conservative lower bound, DOE assumed all domestic manufacturers would shift production to foreign countries at efficiency levels that would likely necessitate condensing technology. The upper bound domestic direct employment estimate corresponds to a potential increase in the number of domestic workers that would result from amended energy conservation standards if manufacturers continue to produce the same scope of covered products within the United States after compliance takes effect (i.e., 20 percent of gas-fired instantaneous water heater shipments continue to be manufactured domestically). Results of DOE's engineering and product teardown analyses indicate that additional labor is required (on a per-unit basis) to produce a condensing gas-fired instantaneous water heater compared to a non-condensing gas-fired instantaneous water heater. As such, DOE modeled an increase in domestic direct employment in the upper bound scenario.

For this final rule, DOE updated its estimate of domestic production workers from 128 to 190 in 2030 based on stakeholder comments in response to the July 2024 NODA but otherwise maintained its direct employment methodology.[g]

As such, for the conservative lower bound for this final rule, DOE models a decrease of domestic direct employment of 190 production workers at TSL 1 through TSL 4 in 2030. This lower bound reflects the scenario where Rinnai chooses to continue to source condensing gas-fired instantaneous water heaters from Japan. In response to the July 2023 NOPR and July 2024 NODA, Rinnai commented that due to the large upfront investment required to repurpose its Georgia facility to accommodate production of condensing gas-fired instantaneous water heaters and its current production capacity of condensing gas-fired instantaneous water heaters in Japan, it is possible that manufacturing could shift overseas.[h]

For the upper bound of direct employment impacts, using a shipment-weighted average, DOE estimates that the labor content required to produce a condensing gas-fired instantaneous water heater is approximately 62 percent more than the labor content required to produce a non-condensing gas-fired instantaneous water heater (see Table 12.3.6 for the estimated labor content required at each analyzed EL and Table 12.3.4 for the 2030 shipments distribution at each analyzed EL). Therefore, DOE models an upper-bound increase in domestic direct employment of 62 percent (an increase of approximately 117 production workers, for a total of 307 domestic production workers) at TSL 1 through TSL 4 in 2030. DOE expects that domestic non-production employment would not be significantly impacted at TSL 1 through TSL 4.

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[f] *Id.*

[g] Rinnai's comment can be downloaded at: www.regulations.gov/comment/EERE-2017-BT-STD-0019-1443 (p.1)

[h] www.regulations.gov/comment/EERE-2017-BT-STD-0019-1186 (p. 23), www.regulations.gov/comment/EERE-2017-BT-STD-0019-1443 (pp. 21-22)

12.5.2 Production Capacity

Nearly all gas-fired instantaneous water heater OEMs currently offer condensing gas-fired instantaneous water heater models. Of the 12 manufacturers identified, 11 manufacturers already offer a range of condensing gas-fired instantaneous water heater models that meet TSL 1. DOE estimates that condensing gas-fired instantaneous water heaters account for 67 percent of current shipments.[i] For a condensing-level standard, most manufacturers would have to repurpose and retool assembly lines to produce only condensing models since the manufacturing processes (e.g., production of secondary heat exchangers) differ between condensing and non-condensing gas-fired instantaneous water heater models. Manufacturer feedback indicates that most manufacturers could meet TSL 1 and TSL 2 without adding new production lines. However, at TSL 3 and TSL 4, DOE expects most manufacturers would have to add production lines due to increased complexity and incorporation of a larger, more efficient heat exchanger design. Additionally, while most shipments already meet TSL 2, fewer shipments meet TSL 3 or TSL 4. Currently, 60 percent of shipments meet TSL 2 whereas 15 percent and 8 percent of shipments meet TSL 3 and TSL 4, respectively. At the adopted level (TSL 2), DOE expects that manufacturers would be able to add the necessary capacity and adjust product designs in the five-year period between the announcement year of the amended standard and the compliance year of the amended standard.

12.5.3 Cumulative Regulatory Burden

One aspect of assessing manufacturer burden involves looking at the cumulative impact of multiple DOE standards and the product-specific regulatory actions of other Federal agencies that affect the manufacturers of a covered product or equipment. While any one regulation may not impose a significant burden on manufacturers, the combined effects of several existing or impending regulations may have serious consequences for some manufacturers, groups of manufacturers, or an entire industry. Assessing the impact of a single regulation may overlook this cumulative regulatory burden. In addition to energy conservation standards, other regulations can significantly affect manufacturers' financial operations. Multiple regulations affecting the same manufacturer can strain profits and lead companies to abandon product lines or markets with lower expected future returns than competing products. For these reasons, DOE conducts an analysis of cumulative regulatory burden as part of its rulemakings pertaining to appliance efficiency.

Some gas-fired instantaneous water heater manufacturers also make other products or equipment that could be subject to energy conservation standards set by DOE. DOE looks at other regulations that affects manufacturer of gas-fired instantaneous water heater manufacturers that are Federal, are product-specific, and that will take effect three years before or after the estimated 2030 compliance date (2027–2033). This information is presented in Table 12.5.1.

DOE does not incorporate any regulations not yet finalized into its analysis, as cost and timing would be speculative. However, stakeholders listed a number of on-going appliance standards as cumulative regulatory burden. Where these DOE appliance standard rulemakings have reached the NOPR stage, DOE includes them in Table 12.5.1 for tracking purposes.

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[i] "Current" shipments refers to no-new-standards case shipments in 2024 (the reference year) from the NIA.

Table 12.5.1 Compliance Dates and Expected Conversion Expenses of Federal Energy Conservation Standards Affecting Gas-fired Instantaneous Water Heater Manufacturers

Federal Energy Conservation Standard	Number of OEMs*	Number of OEMs Affected by Today's Rule**	Approx. Standards Compliance Year	Industry Conversion Costs (millions)	Industry Conversion Costs / Equipment Revenue***
Consumer Pool Heaters 88 FR 34624 (May 30, 2023)	20	3	2028	$48.4 (2021$)	1.5%
Consumer Boilers† 88 FR 55128 (August 14, 2023)	24	8	2030	$98.0 (2022$)	3.6%
Commercial Refrigerators, Refrigerator-Freezers, and Freezers† 88 FR 70196 (October 10, 2023)	83	1	2028	$226.4 (2022$)	1.6%
Dehumidifiers† 88 FR 76510 (November 6, 2023)	20	1	2028	$6.9 (2022$)	0.4%
Consumer Furnaces 88 FR 87502 (December 18, 2023)	14	3	2029	$162.0 (2022$)	1.8%
Refrigerators, Refrigerator-Freezers, and Freezers 89 FR 3026 (January 17, 2024)	63	2	2029 and 2030‡	$830.3 (2022$)	1.3%
Consumer Conventional Cooking Products 89 FR 11434 (February 14, 2024)	35	1	2028	$66.7 (2022$)	0.3%
Consumer Clothes Dryers 89 FR 18164 (March 12, 2024)	19	2	2028	$180.7 (2022$)	1.4%
Residential Clothes Washers 89 FR 19026 (March 15, 2024)	22	2	2028	$320.0 (2022$)	1.8%
Dishwashers 89 FR 31398 (April 24, 2024)	21	2	2027	$126.9 (2022$)	2.1%
Consumer Water Heaters 89 FR 37778 (May 6, 2024)	16	4	2029	$239.8 (2022$)	1.9%
Miscellaneous Refrigeration Products 89 FR 38762 (May 7, 2024)	49	1	2029	$130.7 (2022$)	2.9%

Federal Energy Conservation Standard	Number of OEMs*	Number of OEMs Affected by Today's Rule**	Approx. Standards Compliance Year	Industry Conversion Costs (millions)	Industry Conversion Costs / Equipment Revenue***
Air-Cooled Unitary Air Conditioners and Heat Pumps 89 FR 44052 (May 20, 2024)	9	1	2029	$288.0 (2022$)	2.1%
Walk-in Coolers and Freezers††	87	1	2028	$91.5 (2023$)	0.6%

* This column presents the total number of OEMs identified in the energy conservation standard rule that is contributing to cumulative regulatory burden.
** This column presents the number of OEMs producing gas-fired instantaneous water heaters that are also listed as OEMs in the identified energy conservation standard that is contributing to cumulative regulatory burden.
*** This column presents industry conversion costs as a percentage of product revenue during the conversion period. Industry conversion costs are the upfront investments manufacturers must make to sell compliant products/equipment. The revenue used for this calculation is the revenue from just the covered product/equipment associated with each row. The conversion period is the timeframe over which conversion costs are made and lasts from the publication year of the final rule to the compliance year of the energy conservation standard. The conversion period typically ranges from 3 to 5 years, depending on the rulemaking.
† These rulemakings are at the NOPR stage, and all values are subject to change until finalized through publication of a final rule.
‡ For the refrigerators, refrigerator-freezers, and freezers energy conservation standards direct final rule, the compliance year (2029 or 2030) varies by product class.
†† At the time of issuance of the final rule, the WICFs final rule has been issued and is pending publication in the *Federal Register*. Once published, the final rule pertaining to WICFs will be available at: www.regulations.gov/docket/EERE-2017-BT-STD-0009.

12.6 CONCLUSION

This section summarizes the likely range of financial impacts gas-fired instantaneous water heater manufacturers will experience as a result of amended energy conservation standards. DOE also notes that while these scenarios bound the range of most plausible impacts on manufacturers, circumstances could potentially cause manufacturers to experience impacts outside of this range. Table 12.6.1 summarizes INPV impacts and conversion costs projected to result from each of the trial standard levels analyzed.

Table 12.6.1 Manufacturer Impact Analysis Results

	Units	No-New-Standards Case	Trial Standard Level			
			1	**2**	**3**	**4**
INPV	*2023$ millions*	1,193.9	1,171.1 to 1,234.0	1,160.2 to 1,234.4	1,132.1 to 1,217.6	1,119.5 to 1,275.2
Change in INPV*	*2023$ millions*	-	(22.9) to 40.1	(33.7) to 40.5	(61.8) to 23.7	(74.5) to 81.2
	%	-	(1.9) to 3.4	(2.8) to 3.4	(5.2) to 2.0	(6.2) to 6.8
Free Cash Flow (2029)	*2023$ millions*	91.7	84.6	82.9	65.2	65.2
Change in Free Cash Flow*	*2023$ millions*	-	(7.1)	(8.8)	(26.5)	(26.5)
	%	-	(7.8)	(9.6)	(28.9)	(28.9)
Product Conversion Costs	*2023$ millions*	-	2.5	3.7	4.8	4.8
Capital Conversion Costs	*2023$ millions*	-	13.9	16.7	55.3	55.3
Total Conversion Costs	*2023$ millions*	-	16.5	20.4	60.1	60.1

* Parentheses indicate negative values.

At TSL 1, DOE estimates that impacts on INPV would range from -$22.9 million to $40.1 million, or a change in INPV of -1.9 percent to 3.4 percent. At TSL 1, industry free cash flow is $84.6 million, which is a decrease of $7.1 million, or a drop of 7.8 percent, compared to the no-new-standards case value of $91.7 million in 2029, the year leading up to the standards year. Approximately 70 percent of gas-fired instantaneous water heater shipments are expected to meet TSL 1 by the analyzed 2030 compliance date in the no-new-standards case.

TSL 1 would set the energy conservation standard for gas-fired instantaneous water heaters at EL 1. Compared to the non-condensing design considered at baseline, the design options analyzed at TSL 1 includes a tube design condensing heat exchanger. Out of the 12 gas-fired instantaneous water heater OEMs identified, 11 offer models that meet TSL 1.[j] These 11 manufacturers currently offer 84 unique basic models, accounting for 61 percent of model listings, that meet this TSL. Based on feedback from manufacturer interviews and a review of the market, DOE does not expect that most manufacturers would need to add production capacity or incur significant capital conversion costs to meet this level. However, in response to the July 2023 NOPR, one manufacturer commented that its U.S. production facility is currently optimized to produce non-condensing models. Converting this U.S. production facility to produce condensing gas-fired instantaneous water heaters would require significant investment. To avoid underestimating the potential investments required to meet levels that may necessitate

[j] The OEM counts detailed in this TSD refer to OEMs with gas-fired instantaneous water heater models that will be subject to more stringent standards under this rulemaking.

condensing technology (i.e., TSL 1 through TSL 4), DOE incorporated the expected investments required to convert its U.S. production facility to accommodate production of condensing gas-fired instantaneous water heaters. DOE does not expect that there would be notable product conversion costs at this TSL since most manufacturers offer a range of models that already meet this level. DOE estimates that industry would incur approximately $13.9 million in capital conversion costs and $2.5 million in product conversions at TSL 1. Industry conversion costs total $16.5 million.

At TSL 1, the shipment-weighted average MPC for gas-fired instantaneous water heaters increases by 9.4 percent relative to the no-new-standards case shipment-weighted average MPC for gas-fired instantaneous water heaters in 2030. In the preservation of gross margin percentage scenario, the increase in cashflow from the higher MSP outweighs the $16.5 million in conversion costs, causing a positive change in INPV at TSL 1 under this scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case, but manufacturers do not earn additional profit from their investments. In this scenario, the manufacturer markup decreases in 2030, the analyzed compliance year. This reduction in the manufacturer markup and the $16.5 million in conversion costs incurred by manufacturers cause a slightly negative change in INPV at TSL 1 under the preservation of operating profit scenario. *See* section 12.3.9 for a discussion of the manufacturer markup scenarios.

At TSL 2, DOE estimates that impacts on INPV would range from -$33.7 million to $40.5 million, or a change in INPV of -2.8 percent to 3.4 percent. At TSL 2, industry free cash flow is $82.9 million, which is a decrease of $8.8 million, or a drop of 9.6 percent compared to the no-new-standards case value of $91.7 million in 2029, the year leading up to the standards year. Approximately 62 percent of gas-fired instantaneous water heater shipments are expected to meet TSL 2 by the analyzed 2030 compliance date in the no-new-standards case.

TSL 2 would set the energy conservation standard for gas-fired instantaneous water heaters at EL 2. The design options analyzed at TSL 2 include increasing the tube design condensing heat exchanger area relative to TSL 1. Of the 12 gas-fired instantaneous water heater OEMs, 10 manufacturers offer models that meet TSL 2. These 10 OEMs currently offer 71 unique basic models, accounting for 51 percent of model listings, that meet this TSL. As with TSL 1, DOE does not expect that most manufacturers would need to add production capacity (or incur notable capital conversion costs) to meet this level. However, the larger condensing heat exchanger that manufacturers may implement to meet TSL 2 could necessitate some capital investments to optimize production lines. Similar to TSL 1, DOE does not expect that there would be significant product conversion costs at this level since most manufacturers already offer a range of models that meet TSL 2. DOE estimates that industry would incur approximately $16.7 million in capital conversion costs and $3.7 million in product conversions at TSL 2. Industry conversion costs total $20.4 million.

At TSL 2, the shipment-weighted average MPC for gas-fired instantaneous water heaters increases by 9.8 percent relative to the no-new-standards case shipment-weighted average MPC for gas-fired instantaneous water heaters in 2030. In the preservation of gross margin percentage scenario, the increase in cashflow from the higher MSP outweighs the $20.4 million in conversion costs, causing a positive change in INPV at TSL 2 under this scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case, but manufacturers do not earn additional profit from their investments. In this scenario, the manufacturer markup decreases in 2030, the analyzed compliance year. This reduction in the manufacturer markup and the $20.4 million in conversion costs incurred by manufacturers cause a slightly negative change in INPV at TSL 2 under the preservation of operating profit scenario.

At TSL 3, DOE estimates that impacts on INPV would range from -$61.8 million to $23.7 million, or a change in INPV of -5.2 percent to 2.0 percent. At TSL 3, industry free cash flow is $65.2 million, which is a decrease of $26.5 million, or a drop of 28.9 percent, compared to the no-new-standards case value of $91.7 million in 2029, the year leading up to the standards year. Approximately 16 percent of gas-fired instantaneous water heater shipments are expected to meet TSL 3 by the analyzed 2030 compliance date in the no-new-standards case.

TSL 3 would set the energy conservation standard for gas-fired instantaneous water heaters at EL 3. The design options analyzed at TSL 3 include a more efficient heat exchanger design (i.e., replacing a tube condensing heat exchanger with a flat plate condensing heat exchanger) and increasing the condensing heat exchanger area relative to TSL 2. Of the 12 gas-fired instantaneous water heater OEMs, 10 manufacturers offer models that meet TSL 3. These 10 manufacturers currently offer 48 unique basic models, accounting for 34 percent of model listings, that meet this TSL. Based on feedback from manufacturer interviews and public comments, DOE understands that implementing the larger, improved condensing heat exchanger technology would increase the complexity of the manufacturing process compared to the tube design condensing heat exchanger technology analyzed at TSL 1 and TSL 2.

At this level, most manufacturers would need to add additional assembly lines to meet demand, which would require a large capital investment. The investment required to add production capacity would vary by manufacturer as it depends on floor space availability in and around existing manufacturing plants. Compared to TSL 1 and TSL 2, manufacturers offer fewer models that meet the required efficiency levels. Manufacturers without any models that meet TSL 3 would need to develop new gas-fired instantaneous water heater products with more complex, efficient condensing heat exchanger designs. Manufacturers with gas-fired instantaneous water heaters that meet TSL 3 may need to allocate technical resources to provide a full range of product offerings since most manufacturers currently only offer a handful of models that meet TSL 3. DOE estimates that manufacturers would incur approximately $55.3 million in capital conversion costs and $4.8 million in product conversions at TSL 3. Industry conversion costs total $60.1 million.

At TSL 3, the shipment-weighted average MPC for gas-fired instantaneous water heaters increases by 11.2 percent relative to the no-new-standards case shipment-weighted average MPC for gas-fired instantaneous water heaters in 2030. In the preservation of gross margin percentage scenario, the increase in cashflow from the higher MSP outweighs the $60.1 million in conversion costs, causing a slightly positive change in INPV at TSL 3 under this scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case, but manufacturers do not earn additional profit from their investments. In this scenario, the manufacturer markup decreases in 2030, the analyzed compliance year. This reduction in the manufacturer markup and the $60.1 million in conversion costs incurred by manufacturers cause a negative change in INPV at TSL 3 under the preservation of operating profit scenario.

At TSL 4, DOE estimates that impacts on INPV would range from -$74.5 million to -$81.2 million, or a change in INPV of -6.2 percent to 6.8 percent. At TSL 4, industry free cash flow is $65.2 million, which is a decrease of $26.5 million, or a drop of 28.9 percent, compared to the no-new-standards case value of $91.7 million in 2029, the year leading up to the standards year. Approximately 8 percent of gas-fired instantaneous water heater shipments are expected to meet TSL 4 by the analyzed 2030 compliance date in the no-new-standards case.

TSL 4 would set the energy conservation standard for gas-fired instantaneous water heaters at EL 4 (i.e., max-tech). The design options analyzed at TSL 4 include replacing the step-modulating burner with a fully modulating burner and increasing the condensing heat exchanger area relative to TSL 3. Of the 12 gas-fired instantaneous water heaters, five manufacturers offer models that meet this TSL. These five manufacturers currently offer 19 unique basic models, accounting for 14 percent of model listings, that meet this TSL. As with TSL 3, DOE understands that implementing the larger, improved condensing heat exchanger design would add a significant amount of complexity to the manufacturing process compared to the tube design condensing heat exchanger technology at TSL 1 and TSL 2. As such, DOE expects similar capital conversion costs at TSL 3 and TSL 4. At max-tech, fewer manufacturers offer fewer models that meet the required efficiencies compared to TSL 3. DOE estimates that manufacturers would incur approximately $55.3 million in capital conversion costs and $4.8 million in product conversions at TSL 4. Industry conversion costs total $60.1 million.

At TSL 4, the shipment-weighted average MPC for gas-fired instantaneous water heaters increases by 20.1 percent relative to the no-new-standards case shipment-weighted average MPC for gas-fired instantaneous water heaters in 2030. The increase in cashflow from the higher MSP outweighs the $60.1 million in conversion costs, causing a positive change in INPV at TSL 4 under this scenario.

Under the preservation of operating profit scenario, manufacturers earn the same per-unit operating profit as would be earned in the no-new-standards case , but manufacturers do not earn additional profit from their investments. In this scenario, the manufacturer markup decreases in 2030, the analyzed compliance year. This reduction in the manufacturer markup and the $60.1 million in conversion costs incurred by manufacturers cause a negative change in INPV at TSL 4 under the preservation of operating profit scenario.

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

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CHAPTER 13. EMISSIONS IMPACT ANALYSIS

13.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector emissions and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and mercury (Hg). The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the impacts to emissions of all species due to "upstream" activities in the fuel production chain, which are included in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011). These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion.

The analysis of power sector emissions of CO_2, NO_X, SO_2, and Hg uses emissions intensity factors intended to represent the marginal impacts of the change in electricity consumption associated with amended or new standards. The methodology is based on results published for the *Annual Energy Outlook (AEO)* prepared by the Energy Information Administration, including a set of side cases that implement a variety of efficiency-related policies. The methodology is described in appendix 13A in this TSD, and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin 2019).[1,2] The analysis presented in this chapter uses projections from *AEO 2023*.[3]

Emissions of SO_2 and NO_X from site combustion of natural gas or petroleum fuels are calculated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[4] Power sector combustion emissions of CH_4 and N_2O are derived using Emission Factors for Greenhouse Gas Inventories published by the EPA, as are site combustion emissions of CO_2, CH_4 and N_2O.[a]

The FFC upstream emissions are estimated based on the methodology and data described in appendix 10B and in Coughlin (2013).[5] The upstream emissions include emissions from fuel combustion during extraction, processing, and transportation of fuels, and direct leakage to the atmosphere of CH_4 and CO_2 from the oil and natural gas industry and coal mining.

The emissions intensity factors are expressed in terms of physical units per MWh or MMBtu of site energy savings. Total emissions reductions are estimated by multiplying the emissions intensity factor by the energy savings calculated in the national impact analysis (chapter 10). The emissions factors used in the calculations are provided in appendix 13A. For power sector emissions, the factors depend on the sector and end use. The results presented here use factors for the power plant types that supply electricity for water heating in homes and commercial buildings.

Each annual version of the *AEO* incorporates the projected impacts of existing air quality regulations on emissions. The *AEO* generally represents current Federal and State legislation and

[a] https://www.epa.gov/sites/default/files/2021-04/documents/emission-factors_apr2021.pdf.

final implementation regulations in place as at the time of its preparation. After publication of the *AEO 2023*, EPA finalized the *Federal ''Good Neighbor Plan'' for the 2015 Ozone National Ambient Air Quality Standards* in March 2023 (88 FR 36654). Among other requirements, this rule reduces allowable emissions in ozone season, from May 1 through September 30, from fossil fuel-fired power plants in 22 states beginning in 2023. EPA projects a nationwide annual decrease in power sector ozone-season NO_X, annual NO_X, SO_2, and CO_2 emissions of 9%, 5%, 4%, and 1% respectively in 2026 when the regulation is fully implemented, and 15%, 12%, 17% and 2% in 2030.[b] For each of these pollutants and years, the percentage reduction from baseline emissions is greater in the 22 states subject to the regulation relative to national emissions. After 2030 the percentage reductions decline as baseline power sector emissions are expected to fall as a result of other economic factors. The estimates of power sector emissions changes reported in this chapter would likely be lower if the Good Neighbor rule were accounted for in the baseline power sector emissions projection.

For details of the regulations reflected in the AEO 2023, see Summary of Legislation and Regulations Included in the *AEO 2023*, Appendix, Electric power sector.[c]

13.2 EMISSIONS IMPACT RESULTS

Table 13.2.1 presents the estimated cumulative emissions reductions for the lifetime of products sold in 2030-2059 for each TSL. Negative values indicate that emissions increase.

[b] EPA, 2023. *Regulatory Impact Analysis for the Final Federal Good Neighbor Plan Addressing Regional Ozone Transport for the 2015 Ozone National Ambient Air Quality Standard*. https://www.epa.gov/csapr/good-neighbor-plan-2015-ozone-naaqs Accessed 8/29/2023.
[c] https://www.eia.gov/outlooks/aeo/assumptions/

Table 13.2.1 Cumulative Emissions Reduction for Potential Standards for Gas-Fired Instantaneous Water Heaters

	TSL			
	1	**2**	**3**	**4**
Power Sector and Site Emissions				
CO_2 (million metric tons)	17	28	40	47
CH_4 (thousand tons)	0.3	0.6	0.8	1.1
N_2O (thousand tons)	0.03	0.06	0.08	0.11
NO_X (thousand tons)	15	25	35	41
SO_2 (thousand tons)	0.04	0.10	0.17	0.75
Hg (tons)	-0.0004	-0.0004	-0.0003	0.0035
Upstream Emissions				
CO_2 (million metric tons)	2	4	6	7
CH_4 (thousand tons)	244	397	575	669
N_2O (thousand tons)	0.00	0.01	0.01	0.01
NO_X (thousand tons)	38	62	89	104
SO_2 (thousand tons)	0.01	0.02	0.03	0.04
Hg (tons)	-0.000001	-0.000001	-0.000001	0.00001
Total Emissions				
CO_2 (million metric tons)	19	32	46	54
CH_4 (thousand tons)	244	398	576	671
N_2O (thousand tons)	0.04	0.06	0.09	0.12
NO_X (thousand tons)	53	86	125	145
SO_2 (thousand tons)	0.05	0.12	0.20	0.79
Hg (tons)	-0.0004	-0.0004	-0.0003	0.0035

Negative values refer to an increase in emissions.

Figure 13.2.1 through Figure 13.2.6 show the annual reductions for total emissions for each type of emission from each TSL. The reductions reflect the lifetime impacts of products sold in 2030-2059.

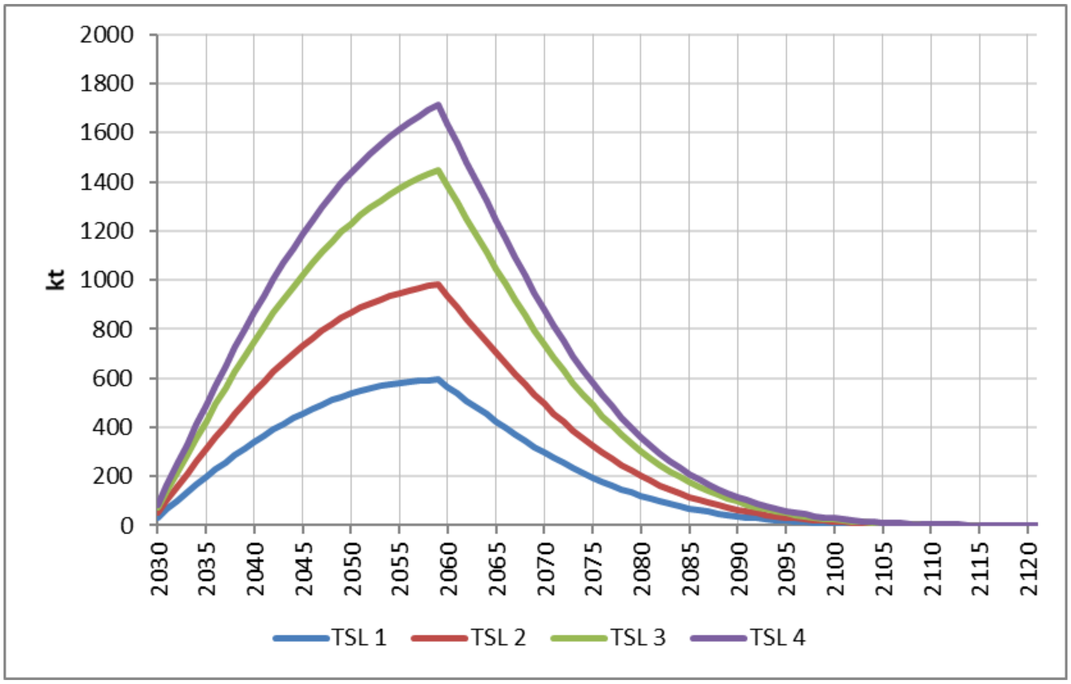

Figure 13.2.1 Gas-Fired Instantaneous Water Heaters: CO_2 Total Emissions Reduction

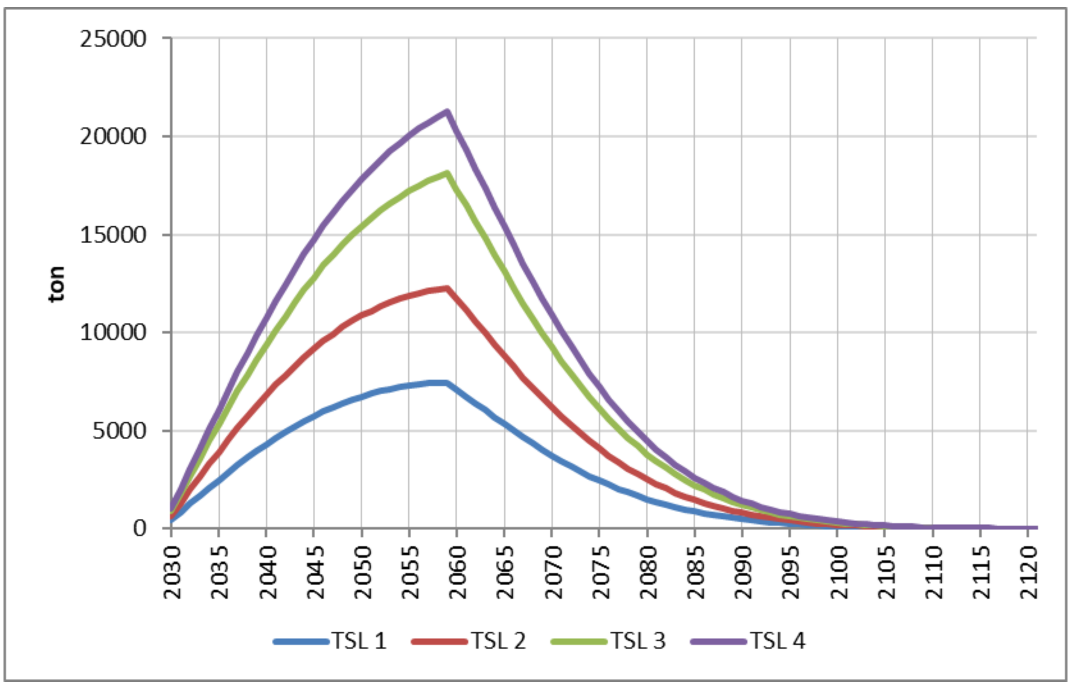

Figure 13.2.2 Gas-Fired Instantaneous Water Heaters: CH_4 Total Emissions Reduction

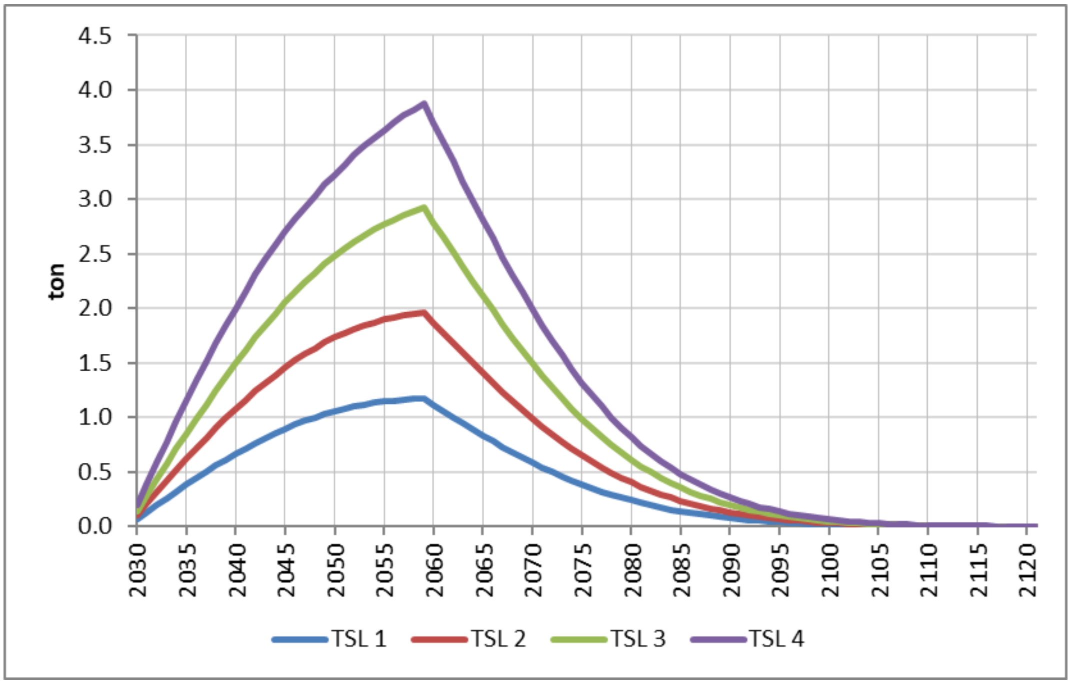

Figure 13.2.3 Gas-Fired Instantaneous Water Heaters: N_2O Total Emissions Reduction

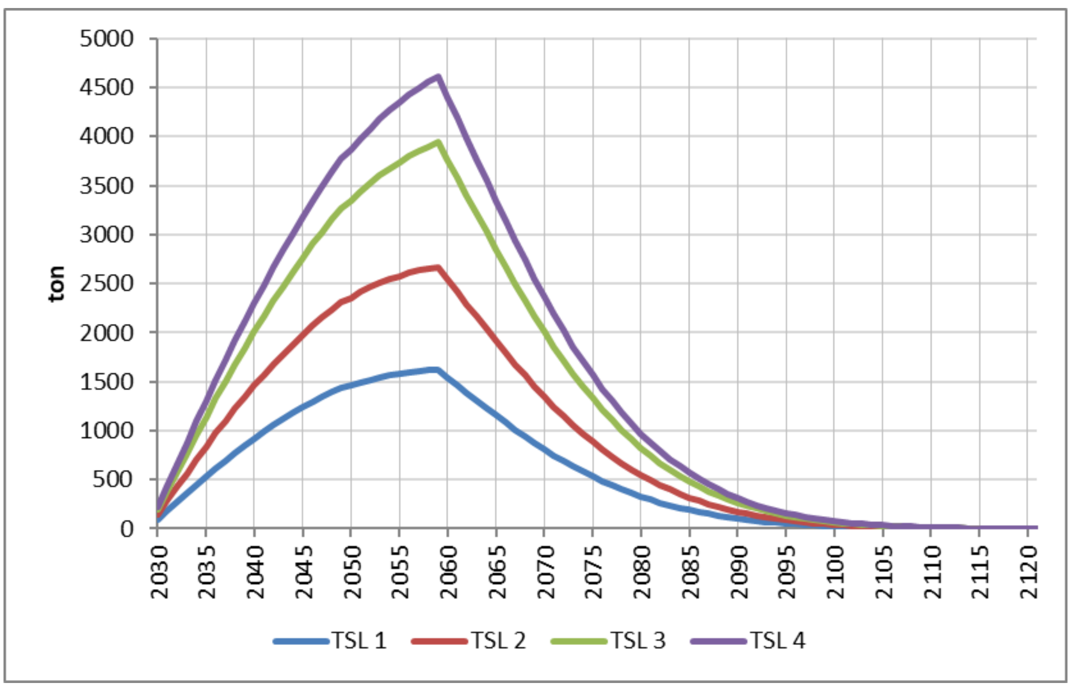

Figure 13.2.4 Gas-Fired Instantaneous Water Heaters: NO_x Total Emissions Reduction

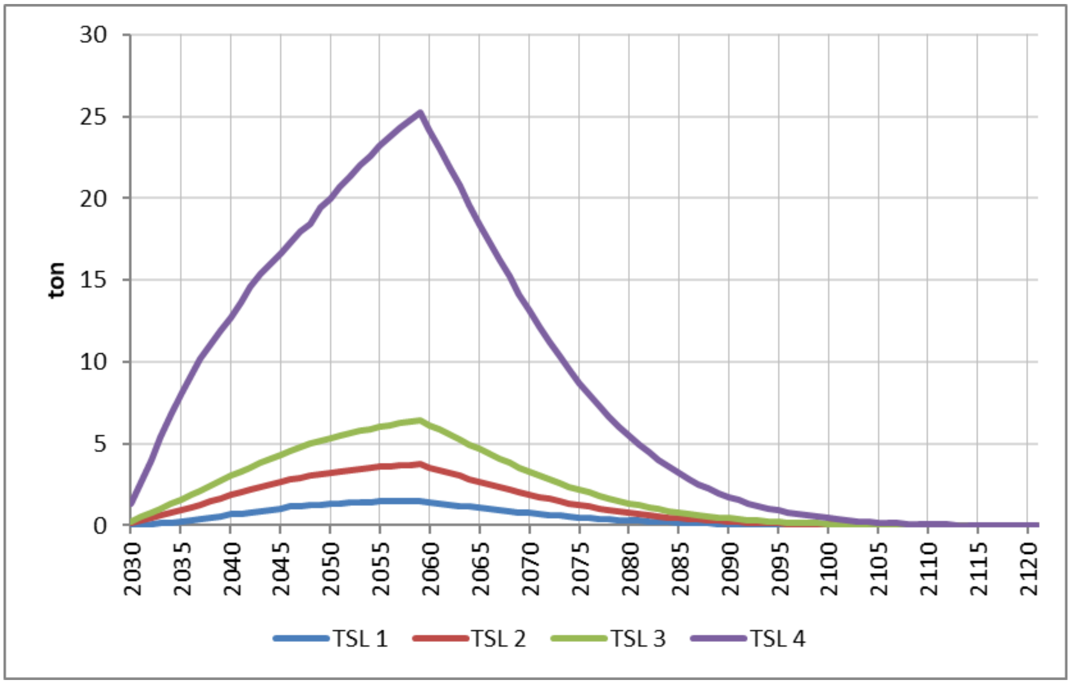

Figure 13.2.5 Gas-Fired Instantaneous Water Heaters: SO_2 Total Emissions Reduction

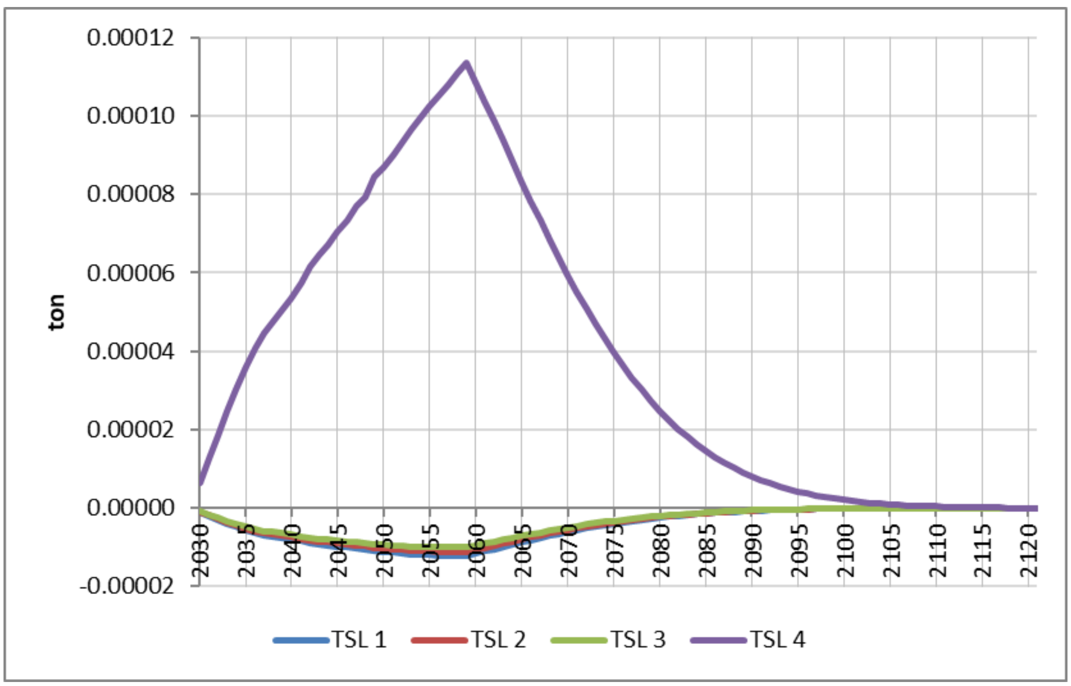

Figure 13.2.6 Gas-Fired Instantaneous Water Heaters: Hg Total Emissions Reduction

Table 13.2.2 displays annual emissions reductions from the selected standards (TSL 2).

Table 13.2.2 Emissions Reduction at Selected Standard Level (TSL 2)

Emissions Year	CO_2 (million metric tons)	CH_4 (‘000 tons)	N_2O (‘000 tons)	NO_X (‘000 tons)	SO_2 (‘000 tons)	Hg (tons)
2030	0.053	0.66	0.000103	0.139	0.00014	-0.0000010
2031	0.105	1.32	0.000207	0.280	0.00030	-0.0000019
2032	0.158	1.98	0.000312	0.423	0.00045	-0.0000028
2033	0.210	2.63	0.000414	0.565	0.00060	-0.0000037
2034	0.262	3.28	0.000516	0.704	0.00076	-0.0000045
2035	0.312	3.91	0.000615	0.838	0.00091	-0.0000053
2036	0.361	4.53	0.000712	0.973	0.00108	-0.0000059
2037	0.409	5.13	0.000808	1.100	0.00126	-0.0000064
2038	0.455	5.71	0.000900	1.223	0.00146	-0.0000067
2039	0.500	6.27	0.000990	1.343	0.00165	-0.0000070
2040	0.543	6.81	0.001077	1.457	0.00185	-0.0000073
2041	0.585	7.33	0.001159	1.567	0.00200	-0.0000078
2042	0.624	7.83	0.001238	1.677	0.00216	-0.0000083
2043	0.662	8.30	0.001314	1.781	0.00232	-0.0000085
2044	0.698	8.75	0.001387	1.887	0.00250	-0.0000088
2045	0.731	9.17	0.001455	1.974	0.00265	-0.0000091
2046	0.763	9.58	0.001520	2.076	0.00281	-0.0000093
2047	0.792	9.93	0.001579	2.149	0.00293	-0.0000096
2048	0.819	10.3	0.001636	2.239	0.00308	-0.0000097
2049	0.844	10.6	0.001686	2.310	0.00314	-0.0000102
2050	0.866	10.9	0.001731	2.357	0.00324	-0.0000103
2051	0.886	11.1	0.001772	2.412	0.00332	-0.0000105
2052	0.904	11.3	0.001809	2.462	0.00340	-0.0000107
2053	0.921	11.5	0.001841	2.506	0.00346	-0.0000108
2054	0.935	11.7	0.001870	2.545	0.00352	-0.0000110
2055	0.948	11.9	0.001895	2.579	0.00358	-0.0000111
2056	0.958	12.0	0.001917	2.608	0.00362	-0.0000111
2057	0.967	12.1	0.001935	2.632	0.00367	-0.0000112
2058	0.974	12.2	0.001949	2.652	0.00370	-0.0000112
2059	0.980	12.3	0.001961	2.667	0.00373	-0.0000112
2060	0.934	11.7	0.001869	2.542	0.00356	-0.0000107
2061	0.887	11.1	0.001776	2.415	0.00338	-0.0000101
2062	0.841	10.5	0.001682	2.288	0.00320	-0.0000096
2063	0.794	9.96	0.001590	2.162	0.00303	-0.0000091
2064	0.748	9.38	0.001497	2.037	0.00285	-0.0000085
2065	0.703	8.81	0.001407	1.913	0.00268	-0.0000080

Emissions Year	CO_2 (million metric tons)	CH_4 ('000 tons)	N_2O ('000 tons)	NO_X ('000 tons)	SO_2 ('000 tons)	Hg (tons)
2066	0.659	8.26	0.001318	1.792	0.00251	-0.0000075
2067	0.615	7.71	0.001231	1.675	0.00235	-0.0000070
2068	0.573	7.19	0.001148	1.561	0.00219	-0.0000065
2069	0.533	6.68	0.001067	1.450	0.00204	-0.0000060
2070	0.494	6.19	0.000989	1.344	0.00189	-0.0000056
2071	0.457	5.72	0.000914	1.243	0.00175	-0.0000052
2072	0.421	5.28	0.000843	1.146	0.00161	-0.0000048
2073	0.387	4.86	0.000775	1.054	0.00148	-0.0000044
2074	0.355	4.45	0.000711	0.967	0.00136	-0.0000040
2075	0.325	4.08	0.000651	0.885	0.00125	-0.0000037
2076	0.297	3.72	0.000594	0.808	0.00114	-0.0000033
2077	0.270	3.39	0.000541	0.735	0.00104	-0.0000030
2078	0.245	3.08	0.000491	0.668	0.00094	-0.0000028
2079	0.222	2.79	0.000445	0.605	0.00085	-0.0000025
2080	0.201	2.52	0.000402	0.547	0.00077	-0.0000023
2081	0.181	2.27	0.000363	0.493	0.00070	-0.0000020
2082	0.163	2.04	0.000326	0.444	0.00063	-0.0000018
2083	0.146	1.83	0.000293	0.398	0.00056	-0.0000016
2084	0.131	1.64	0.000262	0.356	0.00050	-0.0000015
2085	0.117	1.46	0.000234	0.318	0.00045	-0.0000013
2086	0.104	1.30	0.000208	0.283	0.00040	-0.0000012
2087	0.093	1.16	0.000185	0.252	0.00036	-0.0000010
2088	0.082	1.03	0.000164	0.223	0.00032	-0.0000009
2089	0.073	0.91	0.000145	0.197	0.00028	-0.0000008
2090	0.064	0.80	0.000128	0.174	0.00025	-0.0000007
2091	0.056	0.70	0.000112	0.153	0.00022	-0.0000006
2092	0.049	0.62	0.000099	0.134	0.00019	-0.0000005
2093	0.043	0.54	0.000086	0.117	0.00017	-0.0000005
2094	0.037	0.47	0.000075	0.102	0.00014	-0.0000004
2095	0.033	0.41	0.000065	0.089	0.00013	-0.0000004
2096	0.028	0.35	0.000057	0.077	0.00011	-0.0000003
2097	0.024	0.31	0.000049	0.067	0.00009	-0.0000003
2098	0.021	0.26	0.000042	0.057	0.00008	-0.0000002
2099	0.018	0.23	0.000036	0.049	0.00007	-0.0000002
2100	0.016	0.19	0.000031	0.042	0.00006	-0.0000002
2101	0.013	0.17	0.000027	0.036	0.00005	-0.0000001
2102	0.011	0.14	0.000023	0.031	0.00004	-0.0000001
2103	0.010	0.12	0.000019	0.026	0.00004	-0.0000001

Emissions Year	CO_2 (million metric tons)	CH_4 ('000 tons)	N_2O ('000 tons)	NO_X ('000 tons)	SO_2 ('000 tons)	Hg (tons)
2104	0.008	0.10	0.000016	0.022	0.00003	-0.0000001
2105	0.007	0.09	0.000014	0.018	0.00003	-0.0000001
2106	0.006	0.07	0.000011	0.015	0.00002	-0.0000001
2107	0.005	0.06	0.000009	0.013	0.00002	-0.0000001
2108	0.004	0.05	0.000008	0.011	0.00002	-0.00000004
2109	0.003	0.04	0.000006	0.009	0.00001	-0.00000003
2110	0.003	0.03	0.000005	0.007	0.00001	-0.00000003
2111	0.002	0.03	0.000004	0.006	0.00001	-0.00000002
2112	0.002	0.02	0.000003	0.004	0.00001	-0.00000002
2113	0.001	0.02	0.000003	0.003	0.000005	-0.00000001
2114	0.001	0.01	0.000002	0.003	0.000004	-0.00000001
2115	0.001	0.01	0.000001	0.002	0.000003	-0.00000001
2116	0.0005	0.01	0.000001	0.001	0.000002	-0.000000005
2117	0.0003	0.004	0.000001	0.001	0.000001	-0.000000003
2118	0.0001	0.002	0.0000003	0.0003	0.0000005	-0.000000001
Cumulative	31.7	398	0.063	86.2	0.12	-0.00038

Negative values refer to increased emissions.

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CHAPTER 14. MONETIZATION OF EMISSIONS REDUCTION BENEFITS

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14.1 INTRODUCTION

As part of its assessment of energy conservation standards for gas-fired instantaneous water heaters (GIWHs), the U.S. Department of Energy (DOE) considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur dioxide (SO_2), and nitrogen oxides (NO_x) that are expected to result from each of the potential standard levels considered. This chapter summarizes the basis for the benefit-per-ton values used for each of these emissions and presents the estimated total benefits for each TSL.

14.2 MONETIZING AVOIDED GREENHOUSE GAS EMISSIONS

To monetize the benefits of reducing GHG emissions, the July 2023 NOPR for consumer water heaters used the interim social cost of greenhouse gases (SC-GHG) estimates presented in the *Technical Support Document*: *Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates Under Executive Order 13990* published in February 2021 by the Interagency Working Group ("IWG") (2021 Interim SC-GHG estimates). As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agreed that the interim SC-GHG estimates represented the most appropriate estimate of the SC-GHG until revised estimates were developed reflecting the latest, peer-reviewed science. See 87 FR 78382, 78406-78408 for discussion of the development and details of the IWG SC-GHG estimates. The IWG has continued working on updating the interim estimates, but has not published final estimates.

Accordingly, in the regulatory analysis of its December 2023 Final Rule, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," the Environmental Protection Agency (EPA) estimated climate benefits using a new, updated set of SC-GHG estimates ("2023 SC-GHG estimates"), which EPA documented the methodology underlying the new estimates in the RIA for the December 2023 Final Rule and in greater detail in a technical report entitled "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances" that was presented as Supplementary Material to the RIA.[a] The 2023 SC-GHG estimates "incorporate recent research addressing recommendations of the Natural Academies of Science, Engineering, and Medicine (National Academies), responses to public comments on an earlier sensitivity analysis using draft SC-GHG estimates included in EPA's December 2022 proposal in the oil and natural gas sector standards of performance rulemaking, and comments from a 2023 external peer review of the accompanying technical report."[b]

On December 22, 2023, the IWG issued a memorandum directing that when agencies "consider applying the SC-GHG in various contexts … agencies should use their professional

[a] https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-final-rule-20231130.pdf; https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf (last accessed July 3, 2024)
[b] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf

judgment to determine which estimates of the SC-GHG reflect the best available evidence, are most appropriate for particular analytical contexts, and best facilitate sound decision-making" consistent with OMB Circular A-4 and applicable law.[c]

DOE has been extensively involved in the IWG process and related work on the SC-GHGs for over a decade. This involvement includes DOE's role as the federal technical monitor for the seminal 2017 report on the SC-GHG issued by the National Academies, which provided extensive recommendations on how to strengthen and update the SC-GHG estimates.[d] DOE has also participated in the IWG's work since 2021. DOE technical experts involved in this work reviewed the 2023 SC-GHG methodology and report in light of the National Academies' recommendations and DOE's understanding of the state of the science.

Based on this review, in the July 2024 NODA, DOE proposed for public comment its preliminary determination that the updated 2023 SC-GHG estimates, including the approach to discounting, represent a significant improvement in estimating the SC-GHG through incorporating the most recent advancements in the scientific literature and by addressing recommendations on prior methodologies. As of the date of this final rule, DOE has not yet made a final decision regarding adoption of the updated 2023 SC-GHG estimates. In this final rule, DOE is not making a final determination in regards to that preliminary assessment and is presenting estimates using both the updated 2023 SC-GHG values, and the interim IWG SC-GHG estimates. While DOE did not present results using the updated 2023 SC-GHG values in the proposal, DOE believes that providing this information here, in addition to results calculated using the interim 2021 IWG SC-GHG values, is appropriate to give the public more complete information regarding the benefits of this rule. DOE notes, however, that the adopted standards would be economically justified even without the inclusion of the estimated monetized benefits of reduced GHG emissions.

As DOE explained in the July 2024 NODA, it was the agency's preliminary assessment that the 2023 SC-GHG estimates represent a significant improvement because the 2023 SC-GHG estimates implement the key recommendations of the National Academies, and they incorporate the extensive scientific findings and methodological advances that have occurred since the last IWG substantive updates to the methodology in 2013 and the methodologically consistent updates to add estimates for methane and nitrous oxide in 2016.

The 2023 SC-GHG estimates have also been peer-reviewed. As indicated by their statements, the peer reviewers strongly supported the new methodology, calling it "a huge advance," "a real step change" and "an important improvement" in estimating the SC-GHG, and noting that it addressed the National Academies' and others' recommendations and "generally represents well the emerging consensus in the literature."

DOE also preliminarily determined that the most significant improvements in the 2023 SC-GHG estimates are consistent with the recommendations made by the National Academies. In its report, the National Academies' principal recommendation was to develop and use "a new

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[c] https://www.whitehouse.gov/wp-content/uploads/2023/12/IWG-Memo-12.22.23.pdf

[d] Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide | The National Academies Press.

framework that would strengthen the scientific basis, provide greater transparency, and improve characterization of the uncertainties of the estimates."[e] The IWG's estimates since 2010 have relied on averaging the values produced by three integrated assessment models, each of which generates a set of SC-GHG estimates based on the inputs and assumptions built into that particular model.[f] The National Academies recommended an entirely new approach that would "unbundle" this process and instead use a framework in which each step of the SC-GHG calculation is developed as one of four separate but integrated "modules": the socioeconomic module, the climate module, the damages module, and the discounting module. The report provided detailed recommendations on developing and using these modules, including how to address discounting, socioeconomic projections, climate modeling, and uncertainty.

In accordance with these recommendations, the 2023 SC-GHG estimates use four separate modules, each of which represents one of the four key elements that goes into generating an estimate of the SC-GHG. The modules address, respectively: (1) socioeconomic and emissions projections, such as projections of future populations, economic activity, and the associated emissions; (2) climate modeling, which projects how the earth's climate systems will respond to different levels of emissions over time; (3) estimations of the economic damages that would result from various projected levels of climate change; and (4) discounting to appropriately translate a stream of future costs into a present value. Data generated by the socioeconomic module feeds into each of the other three modules, and the temperature changes generated by the climate module inform the damages module. As DOE explained in the July 2024 NODA, it was DOE's preliminary determination that each module represents a major scientific and economic advancement over the previous methodology, and each module and scenario input is based on the latest available peer-reviewed literature.

With respect to the first module, as EPA explains, the socioeconomic input scenarios from the Resources for the Future Socioeconomic Projections (RFF-SPs) "represent a state-of-the-art set of probabilistic socioeconomic and emissions scenarios based on high-quality data, robust statistical techniques, and expert elicitation."[g] DOE preliminarily agreed with the assessment that "[t]he RFF-SPs represent a significant advancement over the now outdated and deterministic EMF-22 scenarios and offer improvements over other recently developed socioeconomic and emissions projections."[h]

DOE also preliminarily endorsed the 2023 SC-GHG's use of the climate model, FaIR (Finite Amplitude Impulse Response model) 1.6.2, which the National Academies specifically called out as meeting their criteria for an updated climate model that would comprise one of the modules.[i] DOE preliminarily agreed that FaIR is an appropriate reduced-complexity climate

[e] Report Recommends New Framework for Estimating the Social Cost of Carbon | National Academies (available at: https://www.nationalacademies.org/news/2017/01/report-recommends-new-framework-for-estimating-the-social-cost-of-carbon) (last accessed July 3, 2023).

[f] See https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf, 6. (last accessed July 3, 2023)

[g] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 26.

[h] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 26.

[i] Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide | The National Academies Press at 14.

model to use in SC-GHG estimation. As EPA explains, "[FaIR] provides, with high confidence, an accurate representation of the latest [Intergovernmental Panel on Climate Change sixth assessment report] scientific consensus on the relationship between global emissions and global mean surface temperature under [a] wide range of socioeconomic emissions scenarios. . . ."[j] EPA further notes that FaIR "also offers a code base that is fully transparent and available online . . . , and the uncertainty capabilities in FaIR 1.6.2 have been calibrated to the most recent assessment of the [Intergovernmental Panel on Climate Change].[k]

Further, it was DOE's preliminary determination that the 2023 SC-GHG estimates also address the National Academies' recommendations for a "damages module [that] should improve and update existing formulations of climate change damages, make calibrations transparent, present disaggregated results, and address correlation between different formulations. This update should draw on recent scientific literature relating to both empirical estimation and process-based modeling of damages."[l]

To meet the National Academies' recommendations, the 2023 SC-GHG damage module incorporates three separate damage functions: (1) a subnational-scale, sectoral damage function estimation (based on the Data-driven Spatial Climate Impact Model (DSCIM) developed by the Climate Impact Lab (CIL 2023, Carleton et al. 2022, Rode et al. 2021)); (2) a country-scale, sectoral damage function estimation (based on the Greenhouse Gas Impact Value Estimator (GIVE) model developed under RFF's Social Cost of Carbon Initiative (Rennert et al. 2022b); and (3) a meta-analysis-based global damage function estimation (based on Howard and Sterner (2017)).[m] EPA explains that the damage functions in the DSCIM and GIVE models represent "the forefront of scientific understanding about how temperature change and [sea level rise] lead to monetized net market and nonmarket damages for several categories of climate impacts. The models' spatially explicit and impact-specific modeling of relevant processes allows for improved understanding and transparency about mechanisms through which climate impacts are occurring and how each damage component contributes to the overall results…."[n] In addition, the 2023 SC-GHG estimates include a third damage function based on a meta-analysis approach "that reflects a synthesis of the state of knowledge in other published climate damages literature," using results from a Howard and Sterner (2017) meta-analysis, which supplements the still relatively narrow sectoral coverage of the prior two damage functions.[o] GIVE is a new process-based model that incorporates the latest scientific understanding. DSCIM is a new model that uses empirical estimation and represents a large leap forward in including state of the art data and data regression methodologies. Lastly, the meta-analysis by Howard and Sterner is the most recent rigorous synthesis of the literature for both process-based and empirical estimation. Thus, DOE preliminarily found that the combined approach used in the 2023 SC-GHG estimates for the damage module follows the recommendations laid out by the National Academies and is

[j] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 36.
[k] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 36-37.
[l] Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide | The National Academies Press at 3.
[m] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 47.
[n] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 55.
[o] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 56.

a significant improvement over the damage functions underlying the prior IWG SC-GHG estimates.

Lastly, the 2023 SC-GHG estimates incorporate dynamic discount rates through the application of the Ramsey formula, which is widely used in the peer-reviewed literature.[p] The National Academies called for the IWG to replace the prior discount rates with a structural approach that addresses the connection between discounting and consumption growth. Specifically, the National Academies itself used the Ramsey discounting formula in developing its recommendations, and it concluded that "[t]he Ramsey formula provides a feasible and conceptually sound framework for modeling the relationship between economic growth and discounting uncertainty."[q] DOE preliminarily found that the 2023 SC-GHG estimates use of the Ramsey formula follows the National Academies' (2017) recommendations on discounting, and that it "provides important [scientific and economic] improvements over the use of a static discount rate and incorporates links between the modules."[r]

In the July 2024 NODA, DOE preliminarily concluded that the 2023 SC-GHG estimates are consistent with the National Academies' (2017) recommendations and represent major scientific advancements over the IWG's approach. In addition, DOE preliminarily supported the incorporation of more recent scientific findings and data throughout the development of each of the 2023 SC-GHG modules and the underlying components of those modules, such as, for example, in the RFF-SPs socioeconomic factors, the FaIR climate model, the DSCIM and GIVE damage functions, the Howard and Sterner (2017) meta-analysis, and the use of dynamic discount rates that take uncertainty into account.

In this final rule, DOE is presenting climate benefits using both the 2021 Interim SC-GHG estimates and the 2023 SC-GHG estimates. DOE used both sets of SC-GHG values to monetize the climate benefits of the emissions reductions associated at each EL for gas-fired instantaneous water heaters. Using both sets of estimates provides more complete information on the potential climate benefits associated with amended standards. In future rulemakings, DOE will continue to evaluate the applicability in context and use our professional judgment to apply the SC-GHG estimates that are most appropriate to use at that time.

The 2023 EPA technical report presents SC-GHG values for emissions years through 2080, therefore, DOE did not monetize the climate benefits of GHG emissions reductions occurring after 2080 when using the 2023 estimates for the SC-GHG. DOE expects additional climate impacts to accrue from GHG emissions changes post 2080, but due to a lack of readily available SC-GHG estimates for emissions years beyond 2080 and the relatively small emission effects expected from those years, DOE has not monetized these additional impacts in this analysis. Similarly, the interim 2021 SC-GHG estimates include values through 2070. DOE expects additional climate benefits to accrue for products still operating after 2070, but a lack of available SC-GHG estimates published by the IWG for emissions years beyond 2070 prevents DOE from monetizing these potential benefits in this analysis.

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[p] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 66.
[q] Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide | The National Academies Press at 18.
[r] https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf at 66.

The overall climate benefits are generally greater when using the higher, updated 2023 SC-GHG estimates, compared to the climate benefits calculated using the older 2021 interim SC-GHG estimates, which were used in the July 2023 NOPR. The net benefits of the rule are positive, however, under either SC-GHG calculation methodology. The adopted standards would be economically justified even without inclusion of the estimated monetized benefits of reduced GHG emissions using either methodology, therefore the conclusions of the analysis (as presented in section V.C of the final rule notice) are not dependent on which set of estimates of the SC-GHG are used in the analysis. The adopted standard level would remain the same under either SC-GHG calculation methodology.

DOE's derivations of the SC-GHGs (i.e., SC-CO_2, SC-N_2O, and SC-CH_4) values are discussed in the following sections.

14.2.1 Social Cost of Carbon Dioxide

The SC-CO_2 values used for this final rule are presented using two sets of SC-GHG estimates. One set is the 2023 SC-GHG estimates published by the EPA, which are shown in Table 14.2.1 in 5-year increments from 2020 to 2080.[s] The set of annual values that DOE used is presented in appendix 14A. DOE expects additional climate benefits to accrue for products still operating after 2080, but a lack of available SC-CO_2 estimates for emissions years beyond 2080 prevents DOE from monetizing these potential benefits in this analysis.

[s] https://www.epa.gov/system/files/documents/2023-12/eo12866_oil-and-gas-nsps-eg-climate-review-2060-av16-final-rule-20231130.pdf; https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf (last accessed July 3, 2024)

Table 14.2.1 Annual SC-CO_2 Values Based on 2023 SC-GHG Estimates, 2020–2080 (2020$ per Metric Ton CO_2)

Emissions Year	Near-term Ramsey Discount Rate		
	2.5%	**2.0%**	**1.5%**
2020	117	193	337
2025	130	212	360
2030	144	230	384
2035	158	248	408
2040	173	267	431
2045	189	287	456
2050	205	308	482
2055	220	326	505
2060	234	345	528
2065	246	360	547
2070	258	375	565
2075	271	391	583
2080	284	407	601

DOE also presents results using interim SC-CO_2 values based on the values developed for the February 2021 SC-GHG TSD, which are shown in Table 14.2.2 in 5-year increments from 2020 to 2070. The set of annual values that DOE used, which was adapted from estimates published by EPA in 2021,[t] is presented in appendix 14A. These estimates are based on methods, assumptions, and parameters identical to the estimates published by the IWG (which were based on EPA modeling). Similar to DOE's approach to calculating climate benefits based on the 2023 SC-GHG estimates, DOE relied on the 2021 SC-GHG estimates from 2029 through 2070 to calculate the climate benefits from the projected emissions reductions resulting from standards set at each TSL.

[t] *See* EPA, *Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis*, Washington, D.C., December 2021. Available at nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1013ORN.pdf (last accessed Feb. 21, 2023).

Table 14.2.2 Annual SC-CO_2 Values Based on 2021 Interim SC-GHG Estimates, 2020–2070 (2020$ per Metric Ton CO_2)

Year	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2020	14	51	76	151
2025	17	56	83	169
2030	19	62	89	187
2035	22	67	96	206
2040	25	73	103	225
2045	28	79	110	242
2050	32	85	116	260
2055	35	89	122	265
2060	38	93	128	275
2065	44	100	135	300
2070	49	108	143	326

DOE multiplied the CO_2 emissions reduction estimated for each year by the SC-CO_2 value for that year for both sets of SC-CO_2. To calculate a present value of the stream of monetary values, DOE discounted the values for both sets of SC-CO_2 using the specific discount rate that had been used to obtain the SC-CO_2 values in each case.

14.2.2 Social Cost of Methane and Nitrous Oxide

The SC-CH_4 and SC-N_2O values used for this final rule are presented using two sets of SC-GHG estimates. One set is the 2023 SC-GHG estimates published by the EPA. Table 14.2.3 shows the updated sets of SC-CH_4 and SC- N_2O estimates in 5-year increments from 2020 to 2080. The full set of annual values used is presented in appendix 14A.

Table 14.2.3 Annual SC-CH_4 and SC-N_2O Values Based on 2023 SC-GHG Estimates, 2020–2080 (2020$ per metric ton)

Emissions Year	SC-CH_4			SC-N_2O		
	Near-term Ramsey Discount Rate			Near-term Ramsey Discount Rate		
	2.5%	2.0%	1.5%	2.5%	2.0%	1.5 %
2020	1,257	1,648	2,305	35,232	54,139	87,284
2025	1,590	2,025	2,737	39,972	60,267	95,210
2030	1,924	2,403	3,169	44,712	66,395	103,137
2035	2,313	2,842	3,673	49,617	72,644	111,085
2040	2,702	3,280	4,177	54,521	78,894	119,032
2045	3,124	3,756	4,718	60,078	85,945	127,916
2050	3,547	4,231	5,260	65,635	92,996	136,799
2055	3,933	4,675	5,774	70,827	99,612	145,196
2060	4,320	5,118	6,289	76,020	106,227	153,594
2065	4,666	5,523	6,767	80,520	112,015	161,048
2070	5,011	5,927	7,244	85,019	117,802	168,503
2075	5,383	6,355	7,745	89,985	123,926	176,053
2080	5,756	6,783	8,246	94,951	130,050	183,602

DOE also presents results using interim SC-CH_4 and SC-N_2O values based on the values developed for the February 2021 SC-GHG TSD. Table 14.2.4 shows the updated sets of SC-CH4 and SC-N_2O estimates from the latest interagency update in 5-year increments from 2020 to 2050. The full set of annual unrounded values used in the calculations is presented in appendix 14A. These estimates include values out to 2070.

Table 14.2.4 Annual SC-CH_4 and SC-N_2O Values Based on 2021 Interim SC-GHG Estimates, 2020–2050 (2020$ per metric ton)

Year	SC-CH_4				SC-N_2O			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile	5% Average	3% Average	2.5 % Average	3% 95th percentile
2020	670	1500	2000	3900	5800	18000	27000	48000
2025	800	1700	2200	4500	6800	21000	30000	54000
2030	940	2000	2500	5200	7800	23000	33000	60000
2035	1100	2200	2800	6000	9000	25000	36000	67000
2040	1300	2500	3100	6700	10000	28000	39000	74000
2045	1500	2800	3500	7500	12000	30000	42000	81000
2050	1700	3100	3800	8200	13000	33000	45000	88000

DOE multiplied the CH_4 and N_2O emissions reduction estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the cases. DOE adjusted the values to 2023$ using the implicit price deflator for GDP from the Bureau of Economic Analysis. To calculate a present value of the stream of monetary values, DOE discounted the values in each of the cases using the specific discount rate that had been used to obtain the SC-CH_4 and SC-N_2O estimates in each case.

14.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

As noted in chapter 13, new or amended energy conservation standards would reduce SO_2 emissions from electricity generation, and NO_x emissions from electricity generation in those States that are not affected by economically binding emissions caps. For each of the considered TSLs, DOE estimated monetized values of NO_x and SO_2 emissions reductions from electricity generation using the latest benefit-per-ton estimates for that sector from the EPA's Benefits Mapping and Analysis Program.[u] DOE used EPA's values for $PM_{2.5}$-related benefits associated with NO_x and SO_2 and for ozone-related benefits associated with NO_x for 2025, 2030, 2035 and 2040, calculated with discount rates of 3 percent and 7 percent. DOE used linear interpolation to define values for the years not given in the 2025 to 2040 period; for years beyond 2040 the values are held constant (rather than extrapolated) to be conservative with the valuation estimate.[v]

The ozone-related benefits associated with NO_x occur only in the ozone season (May to September). EPA data for the past two decades indicate that ozone-season NO_x emissions from electricity generation are slightly less than half of all-year NO_X emissions.[w] Therefore, DOE only applied a corresponding benefit-per-ton value to half of the estimated avoided NOx emissions from potential standards. [x]

EPA provided estimates of benefit-per-ton of NO_X and SO_2 emissions reductions in 40 regions of the continental U.S. DOE combined the EPA benefit-per-ton estimates with regional information on electricity consumption and emissions from *AEO2023* to estimate spatially weighted-average national benefit-per-ton values. Appendix 14B provides methodological details and values that DOE used. DOE multiplied the emissions reduction (in tons) in each year by the associated $/ton values, and then discounted each series using discount rates of 3 percent and 7 percent as appropriate.

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[u] U.S. Environmental Protection Agency. *Estimating the Benefit per Ton of Reducing Directly-Emitted PM2.5, PM2.5 Precursors and Ozone Precursors from 21 Sectors*. https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors

[v] DOE recognizes that there is considerable uncertainty regarding benefit-per-ton values in the period after 2040. Given that EPA's values increase over time, maintaining the 2040 values rather than extrapolating the trends represents a conservative approach, and is preferable to not placing any value on avoided emissions after 2040.

[w] https://www.epa.gov/power-sector/progress-report-emissions-reductions

[x] For the purposes of this analysis, DOE assumes that NO_X emissions associated with electricity savings from ESEMs are spread evenly over the year.

14.4 ESTIMATED BENEFITS

14.4.1 Benefits for Considered TSLs

The tables in this section show the emissions monetization results for each considered TSL. Section 14.2 discusses the estimated SC-GHG values that DOE used. Table 14.4.1 and Table 14.4.2 present the value of CO_2 emissions reduction at each TSL for each of the SC-CO_2 cases. Table 14.4.3 and Table 14.4.4 present the value of the CH_4 emissions reduction at each TSL for each of the SC-CH_4 cases, and Table 14.4.5 and Table 14.4.6 present the value of the N_2O emissions reduction at each TSL for each of the SC-N_2O cases.

DOE also estimated the monetary value of the economic benefits associated with NO_X and SO_2 emissions reductions anticipated to result from the considered TSLs for GIWHs. The dollar-per-ton values that DOE used are discussed in section 14.3. Table 14.4.7 presents the present value for NO_X and SO_2 emissions reduction for each TSL calculated using 7-percent and 3-percent discount rates.

Table 14.4.1 Present Value of CO_2 Emissions Reduction for GIWHs Shipped in 2030-2059 (2023 estimates of SC-GHG)

	SC-CO_2 Case		
TSL	**Near-term Ramsey Discount Rate**		
	2.5%	**2.0%**	**1.5%**
	million 2023$		
1	2,168	3,753	6,773
2	3,526	6,106	11,026
3	5,072	8,793	15,891
4	5,955	10,326	18,667

Table 14.4.2 Present Value of CO_2 Emissions Reduction for GIWHs Shipped in 2030-2059 (2021 interim estimates of SC-GHG)

TSL	**SC-CO_2 Case**			
	Discount Rate and Statistics			
	5% Average	**3% Average**	**2.5% Average**	**3% 95th percentile**
	million 2023$			
1	163	721	1,137	2,182
2	264	1,169	1,845	3,537
3	377	1,672	2,641	5,057
4	441	1,959	3,096	5,926

Table 14.4.3 Present Value of Methane Emissions Reduction for GIWHs Shipped in 2030-2059 (2023 estimates of SC-GHG)

	SC-CH_4 Case		
TSL	**Near-term Ramsey Discount Rate**		
	2.5%	**2.0%**	**1.5%**
	million 2023$		
1	433	600	869
2	704	977	1,415
3	1,014	1,410	2,044
4	1,180	1,641	2,380

Table 14.4.4 Present Value of Methane Emissions Reduction for GIWHs Shipped in 2030-2059 (2021 interim estimates of SC-GHG)

TSL	SC-CH_4 Case			
	Discount Rate and Statistics			
	5% Average	**3% Average**	**2.5% Average**	**3% 95th percentile**
	million 2023$			
1	97	300	422	794
2	157	487	685	1287
3	224	697	981	1844
4	259	809	1139	2140

Table 14.4.5 Present Value of Nitrous Oxide Emissions Reduction for GIWHs Shipped in 2030-2059 (2023 estimates of SC-GHG)

	SC-N_2O Case		
TSL	**Near-term Ramsey Discount Rate**		
	2.5%	**2.0%**	**1.5%**
	million 2023$		
1	1.2	2.0	3.5
2	2.1	3.4	5.7
3	3.0	4.9	8.3
4	3.9	6.5	11.0

Table 14.4.6 Present Value of Nitrous Oxide Emissions Reduction for GIWHs Shipped in 2030-2059 (2021 interim estimates of SC-GHG)

TSL	SC-N_2O Case			
	Discount Rate and Statistics			
	5% Average	3% Average	2.5% Average	3% 95th percentile
	million 2023$			
1	0.12	0.51	0.79	1.36
2	0.20	0.84	1.31	2.24
3	0.29	1.21	1.90	3.23
4	0.38	1.60	2.51	4.28

Table 14.4.7 Present Social Value of Cumulative NO_X and SO_2 Emissions Reduction from Considered Standards for GIWHs

TSL	NO_X		SO_2	
	7% discount rate	3% discount rate	7% discount rate	3% discount rate
	million 2023$		*million 2023$*	
1	554	1,650	0.04	0.22
2	892	2,675	0.9	2.9
3	1,260	3,830	1.9	5.9
4	1,468	4,481	12.9	39.1

14.4.2 Annual and Cumulative Benefits for Selected Standards (TSL 2)

The tables in this section present climate and health benefits estimated for the selected standards. The benefits of reduced CO_2, CH_4, and N_2O emissions are collectively referred to as climate benefits. The benefits of reduced SO_2 and NO_X emissions are collectively referred to as health benefits.

The annual values reflect the benefits from reduced emissions in each year. The associated benefits accrue over very many years in the case of GHG emissions, and over several years in the case of NO_X and SO_2 emissions. The time stream of benefits has been discounted to estimate the benefit-per-ton values for each year, but the total benefits associated with each emissions year are not discounted in these tables. The cumulative present value does reflect discounting at the noted discount rates.

Table 14.4.8 Climate Benefits from GHG Emissions Reduction (CO_2, CH_4, and N_2O) at Selected Standards (TSL 2) for GIWHs Based on 2023 SC-GHG Estimates (million 2023$)

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	**2%**	**1.5%**
2030	10.1	15.7	25.6
2035	66.7	101	163
2040	128	192	302
2045	191	280	432
2050	247	358	545
2055	291	417	628
2060	307	437	650
2065	244	345	509
2070	181	254	371
2075	125	175	253
2080	81.5	113	162
Cumulative Present Value**	4,231	7,087	12,447
Annualized**	229	349	558

* Annual benefits shown are undiscounted values.
** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2080. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.9 Climate Benefits from GHG Emissions Reduction (CO_2, CH_4, and N_2O) at Selected Standards (TSL 2) for GIWH Based on 2021 Interim SC-GHG Estimates (million 2023$)

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th percentile
2030	1.83	5.12	7.19	15.0
2035	12.6	33.6	46.5	99.0
2040	25.1	64.2	87.6	190
2045	38.3	93.9	127	278
2050	50.8	120	160	355
2055	60.6	138	184	397
2060	64.6	144	190	405
2065	59.0	121	157	350
2070	49.0	94.4	121	280
Cumulative Present Value**	421	1,656	2,531	4,827
Annualized**	35	98	137	285

* Annual benefits shown are undiscounted values.
** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2070. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.10 Climate Benefits from Changes in CO_2 Emissions from Selected Standards (TSL 2) for GIWHs Based on 2023 SC-GHG Estimates (million 2023$)

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	2%	1.5%
2030	8.78	14.0	23.4
2031	18.0	28.6	47.6
2032	27.5	43.5	72.3
2033	37.4	58.8	97.2
2034	47.1	74.4	122
2035	57.2	89.8	148
2036	67.5	106	173
2037	77.8	122	198
2038	88.2	137	223
2039	98.7	153	247
2040	109	168	272
2041	119	184	296
2042	130	199	319
2043	140	214	342
2044	151	229	365
2045	160	243	387

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	2%	1.5%
2046	170	258	409
2047	179	272	429
2048	189	285	449
2049	198	298	467
2050	206	309	484
2051	214	321	501
2052	221	331	515
2053	229	341	530
2054	235	350	542
2055	242	358	555
2056	247	367	567
2057	252	375	577
2058	258	382	587
2059	263	388	595
2060	254	374	572
2061	243	358	548
2062	233	342	522
2063	222	326	497
2064	212	310	471
2065	201	294	446
2066	189	277	420
2067	179	261	395
2068	168	245	371
2069	158	230	347
2070	148	215	324
2071	138	200	301
2072	128	187	280
2073	120	173	259
2074	111	160	239
2075	102	148	220
2076	94.4	136	202
2077	86.5	125	185
2078	79.5	114	169
2079	72.8	104	154
2080	66.2	94.9	140
Cumulative Present Value**	3,526	6,106	11,026
Annualized**	191	301	495

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2080. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.11 Climate Benefits from Changes in CO_2 Emissions from Selected Standards (TSL 2) for GIWH Based on 2021 Interim SC-GHG Estimates (million 2023$)

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2030	1.18	3.77	5.46	11.4
2031	2.44	7.69	11.1	23.3
2032	3.77	11.8	16.9	35.7
2033	5.16	15.9	22.8	48.4
2034	6.59	20.1	28.8	61.3
2035	8.06	24.4	34.9	74.5
2036	9.58	28.8	40.9	87.9
2037	11.1	33.1	47.0	101
2038	12.7	37.5	53.0	115
2039	14.3	41.8	59.1	128
2040	15.9	46.2	65.0	142
2041	17.5	50.4	70.9	155
2042	19.2	54.7	76.6	168
2043	20.8	58.9	82.3	181
2044	22.5	63.0	87.8	193
2045	24.1	66.9	93.1	206
2046	25.7	70.9	98.4	218
2047	27.3	74.6	103	229
2048	28.9	78.3	108	240
2049	30.4	81.8	113	251
2050	31.8	85.1	117	261
2051	33.5	87.6	121	268
2052	34.8	90.4	125	275
2053	36.0	93.0	128	281
2054	37.2	95.5	132	286
2055	38.4	97.8	135	293
2056	39.5	99.9	137	298
2057	40.5	102	140	303
2058	41.5	104	142	308
2059	42.4	105	144	312
2060	41.1	102	139	299
2061	40.2	98.0	133	290
2062	39.3	94.2	128	279
2063	38.2	90.3	122	268
2064	37.0	86.3	117	257
2065	35.7	82.2	111	246
2066	34.3	78.1	105	234
2067	32.9	74.0	99.1	223

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2068	31.5	69.9	93.4	211
2069	30.0	65.8	87.8	199
2070	28.5	61.8	82.3	188
Cumulative Present Value**	264	1,169	1,845	3,537
Annualized**	21.9	69.1	99.7	209

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2070. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.12 Climate Benefits from Changes in Methane Emissions from Selected Standards (TSL 2) for GIWHs Based on 2023 SC-GHG Estimates (million 2023$)

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	2%	1.5%
2030	1.33	1.66	2.19
2031	2.77	3.45	4.53
2032	4.33	5.37	7.02
2033	5.98	7.39	9.62
2034	7.71	9.50	12.3
2035	9.51	11.7	15.1
2036	11.4	14.0	18.0
2037	13.3	16.3	20.9
2038	15.3	18.7	23.9
2039	17.3	21.1	26.9
2040	19.4	23.5	29.9
2041	21.5	26.0	33.0
2042	23.6	28.6	36.2
2043	25.8	31.1	39.3
2044	28.0	33.7	42.5
2045	30.1	36.2	45.5
2046	32.4	38.8	48.7
2047	34.4	41.2	51.6
2048	36.6	43.7	54.6
2049	38.6	46.1	57.4
2050	40.5	48.3	60.1
2051	42.4	50.5	62.7
2052	44.2	52.6	65.2
2053	45.9	54.6	67.7
2054	47.6	56.6	70.0

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	**2%**	**1.5%**
2055	49.2	58.4	72.2
2056	50.7	60.2	74.3
2057	52.2	61.9	76.3
2058	53.5	63.5	78.2
2059	54.8	65.0	80.0
2060	53.2	63.1	77.5
2061	51.4	60.9	74.8
2062	49.5	58.6	71.9
2063	47.4	56.2	68.9
2064	45.4	53.7	65.9
2065	43.3	51.2	62.8
2066	41.1	48.7	59.6
2067	39.0	46.2	56.5
2068	36.9	43.6	53.4
2069	34.7	41.1	50.3
2070	32.7	38.6	47.2
2071	30.6	36.2	44.2
2072	28.7	33.9	41.4
2073	26.7	31.6	38.6
2074	24.9	29.4	35.8
2075	23.1	27.3	33.2
2076	21.4	25.2	30.7
2077	19.7	23.3	28.3
2078	18.2	21.4	26.1
2079	16.7	19.7	23.9
2080	15.3	18.0	21.9
Cumulative Present Value**	704	977	1,415
Annualized**	38.0	48.2	63.5

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2080. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.13 Climate Benefits from Changes in Methane Emissions from Selected Standards (TSL 2) for GIWH Based on 2021 Interim SC-GHG Estimates (million 2023$)

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2030	0.65	1.35	1.73	3.58
2031	1.35	2.78	3.56	7.40
2032	2.10	4.30	5.49	11.4
2033	2.89	5.88	7.48	15.7
2034	3.71	7.51	9.54	20.0
2035	4.57	9.18	11.6	24.5
2036	5.45	10.9	13.8	29.1
2037	6.36	12.6	15.9	33.8
2038	7.29	14.4	18.1	38.6
2039	8.23	16.2	20.3	43.4
2040	9.18	18.0	22.5	48.2
2041	10.2	19.8	24.8	53.0
2042	11.2	21.6	27.0	57.8
2043	12.2	23.4	29.1	62.5
2044	13.2	25.2	31.3	67.3
2045	14.2	26.9	33.4	71.9
2046	15.2	28.7	35.5	76.6
2047	16.1	30.3	37.5	80.9
2048	17.1	32.0	39.5	85.4
2049	18.1	33.6	41.4	89.6
2050	18.9	35.0	43.1	93.4
2051	19.7	36.3	44.7	96.1
2052	20.4	37.5	46.0	98.5
2053	21.0	38.5	47.2	101
2054	21.7	39.5	48.4	103
2055	22.2	40.4	49.5	105
2056	22.8	41.3	50.5	106
2057	23.3	42.1	51.4	108
2058	23.8	42.9	52.3	109
2059	24.3	43.6	53.1	110
2060	23.5	42.0	51.1	106
2061	23.7	41.7	50.5	107
2062	23.8	41.2	49.7	107
2063	23.8	40.5	48.7	106
2064	23.6	39.7	47.5	106
2065	23.3	38.7	46.2	104
2066	23.0	37.7	44.8	103
2067	22.5	36.6	43.4	101

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2068	21.9	35.3	41.8	98.1
2069	21.2	34.0	40.1	95.2
2070	20.5	32.5	38.4	92.1
Cumulative Present Value**	157	487	685	1,287
Annualized**	13.0	28.8	37.0	76.1

* Annual benefits shown are undiscounted values.
** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2070. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.14 Climate Benefits from Changes in N_2O Emissions from Selected Standards (TSL 2) for GIWHs Based on 2023 SC-GHG Estimates (million 2023$)

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	2%	1.5%
2030	0.005	0.007	0.011
2031	0.010	0.015	0.023
2032	0.015	0.023	0.035
2033	0.021	0.031	0.047
2034	0.026	0.039	0.059
2035	0.032	0.047	0.072
2036	0.038	0.055	0.084
2037	0.044	0.064	0.097
2038	0.050	0.072	0.110
2039	0.056	0.081	0.122
2040	0.062	0.089	0.135
2041	0.068	0.098	0.147
2042	0.074	0.106	0.160
2043	0.080	0.115	0.172
2044	0.086	0.123	0.184
2045	0.092	0.132	0.196
2046	0.098	0.140	0.208
2047	0.104	0.147	0.218
2048	0.109	0.155	0.229
2049	0.115	0.163	0.240
2050	0.120	0.169	0.249
2051	0.124	0.176	0.258
2052	0.129	0.182	0.267
2053	0.133	0.188	0.275
2054	0.137	0.193	0.283
2055	0.141	0.199	0.290

Emissions Year*	Near-term Ramsey Discount Rate		
	2.5%	2%	1.5%
2056	0.145	0.204	0.296
2057	0.148	0.208	0.303
2058	0.152	0.213	0.308
2059	0.155	0.216	0.313
2060	0.150	0.209	0.302
2061	0.144	0.201	0.290
2062	0.138	0.192	0.277
2063	0.132	0.184	0.264
2064	0.125	0.175	0.251
2065	0.119	0.166	0.238
2066	0.113	0.157	0.225
2067	0.107	0.148	0.213
2068	0.101	0.139	0.200
2069	0.094	0.131	0.187
2070	0.088	0.123	0.175
2071	0.083	0.115	0.164
2072	0.077	0.107	0.152
2073	0.072	0.099	0.141
2074	0.067	0.092	0.131
2075	0.062	0.085	0.121
2076	0.057	0.078	0.111
2077	0.052	0.072	0.102
2078	0.048	0.066	0.093
2079	0.044	0.060	0.085
2080	0.040	0.055	0.078
Cumulative Present Value**	2.05	3.37	5.73
Annualized**	0.11	0.17	0.26

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2080. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.15 Climate Benefits from Changes in N_2O Emissions from Selected Standards (TSL 2) for GIWH Based on 2021 Interim SC-GHG Estimates (million 2023$)

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2030	0.001	0.002	0.004	0.007
2031	0.002	0.005	0.007	0.013
2032	0.003	0.008	0.011	0.021
2033	0.004	0.011	0.015	0.028
2034	0.005	0.013	0.019	0.036
2035	0.006	0.016	0.023	0.043
2036	0.007	0.019	0.027	0.051
2037	0.008	0.022	0.031	0.059
2038	0.009	0.025	0.036	0.067
2039	0.010	0.028	0.040	0.076
2040	0.012	0.031	0.044	0.084
2041	0.013	0.034	0.048	0.092
2042	0.014	0.037	0.052	0.100
2043	0.015	0.040	0.056	0.108
2044	0.017	0.044	0.060	0.116
2045	0.018	0.046	0.064	0.124
2046	0.019	0.049	0.068	0.132
2047	0.020	0.052	0.072	0.139
2048	0.022	0.055	0.076	0.147
2049	0.023	0.058	0.079	0.154
2050	0.024	0.060	0.082	0.161
2051	0.025	0.063	0.086	0.166
2052	0.026	0.065	0.089	0.172
2053	0.027	0.067	0.091	0.178
2054	0.029	0.069	0.094	0.183
2055	0.030	0.071	0.097	0.188
2056	0.031	0.073	0.099	0.193
2057	0.032	0.075	0.101	0.198
2058	0.032	0.077	0.103	0.202
2059	0.033	0.078	0.105	0.206
2060	0.032	0.076	0.102	0.199
2061	0.032	0.073	0.098	0.195
2062	0.032	0.071	0.095	0.190
2063	0.031	0.069	0.091	0.184
2064	0.030	0.066	0.088	0.178
2065	0.029	0.063	0.084	0.172
2066	0.028	0.061	0.080	0.165
2067	0.027	0.058	0.076	0.158

Emissions Year*	Discount Rate and Statistic			
	5% Average	3% Average	2.5% Average	3% 95th Percentile
2068	0.026	0.055	0.072	0.151
2069	0.025	0.052	0.068	0.144
2070	0.024	0.049	0.064	0.137
Cumulative Present Value**	0.202	0.839	1.312	2.240
Annualized**	0.017	0.050	0.071	0.132

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated, for internal consistency, using the same discount rate used to discount the value of damages from future emissions in each SC-GHG case; both include annual values that extend from the compliance year through 2070. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

Table 14.4.16 Health Benefits from Changes in NOx and SO_2 Emissions from Selected Standards (TSL 2) for GIWHs (million 2023$)

Emissions Year*	NOx (as $PM_{2.5}$ and Ozone)		SO_2	
Discount Rate	**7%**	**3%**	**7%**	**3%**
2030	7.79	8.69	0.008	0.009
2031	16.0	17.9	0.016	0.018
2032	24.7	27.5	0.024	0.027
2033	33.8	37.6	0.031	0.034
2034	42.4	47.2	0.038	0.042
2035	51.0	56.8	0.044	0.049
2036	60.4	67.3	0.053	0.059
2037	70.0	78.0	0.062	0.069
2038	81.5	90.8	0.072	0.080
2039	91.3	102	0.083	0.092
2040	101	112	0.092	0.103
2041	108	121	0.102	0.113
2042	116	129	0.111	0.124
2043	124	138	0.122	0.135
2044	131	146	0.134	0.149
2045	137	153	0.144	0.159
2046	145	161	0.155	0.172
2047	150	167	0.162	0.180
2048	156	174	0.174	0.193
2049	161	180	0.175	0.194
2050	164	183	0.182	0.202
2051	168	187	0.187	0.208
2052	171	191	0.192	0.213
2053	174	194	0.196	0.218

Emissions Year*	NOx (as $PM_{2.5}$ and Ozone)		SO_2	
Discount Rate	**7%**	**3%**	**7%**	**3%**
2054	177	197	0.200	0.222
2055	179	200	0.203	0.226
2056	181	202	0.207	0.230
2057	183	204	0.210	0.233
2058	184	205	0.212	0.236
2059	185	207	0.214	0.238
2060	177	197	0.205	0.227
2061	168	187	0.195	0.216
2062	159	177	0.185	0.205
2063	150	168	0.175	0.194
2064	142	158	0.165	0.183
2065	133	148	0.155	0.172
2066	125	139	0.145	0.161
2067	116	130	0.136	0.151
2068	108	121	0.127	0.141
2069	101	112	0.118	0.131
2070	93.4	104	0.109	0.121
2071	86.4	96.3	0.101	0.112
2072	79.7	88.8	0.093	0.104
2073	73.3	81.7	0.086	0.095
2074	67.2	74.9	0.079	0.088
2075	61.5	68.6	0.072	0.080
2076	56.1	62.6	0.066	0.073
2077	51.1	57.0	0.060	0.067
2078	46.4	51.8	0.055	0.061
2079	42.1	46.9	0.050	0.055
2080	38.0	42.4	0.045	0.050
2081	34.3	38.2	0.040	0.045
2082	30.8	34.4	0.036	0.040
2083	27.7	30.8	0.033	0.036
2084	24.8	27.6	0.029	0.033
2085	22.1	24.6	0.026	0.029
2086	19.7	22.0	0.023	0.026
2087	17.5	19.5	0.021	0.023
2088	15.5	17.3	0.018	0.020
2089	13.7	15.3	0.016	0.018
2090	12.1	13.5	0.014	0.016
2091	10.6	11.8	0.013	0.014
2092	9.31	10.4	0.011	0.012
2093	8.14	9.07	0.010	0.011

Emissions Year*	NOx (as $PM_{2.5}$ and Ozone)		SO_2	
Discount Rate	**7%**	**3%**	**7%**	**3%**
2094	7.09	7.91	0.008	0.009
2095	6.17	6.88	0.007	0.008
2096	5.35	5.96	0.006	0.007
2097	4.63	5.16	0.006	0.006
2098	3.99	4.45	0.005	0.005
2099	3.43	3.82	0.004	0.005
2100	2.94	3.28	0.004	0.004
2101	2.51	2.80	0.003	0.003
2102	2.14	2.38	0.003	0.003
2103	1.81	2.02	0.002	0.002
2104	1.53	1.70	0.002	0.002
2105	1.28	1.43	0.002	0.002
2106	1.07	1.20	0.001	0.001
2107	0.89	0.99	0.001	0.001
2108	0.74	0.82	0.001	0.001
2109	0.60	0.67	0.001	0.001
2110	0.49	0.54	0.001	0.001
2111	0.39	0.44	0.000	0.001
2112	0.31	0.34	0.0004	0.0004
2113	0.24	0.27	0.0003	0.0003
2114	0.18	0.20	0.0002	0.0002
2115	0.13	0.14	0.00016	0.00018
2116	0.09	0.10	0.00011	0.00012
2117	0.05	0.06	0.00007	0.00007
2118	0.02	0.03	0.00003	0.00003
Cumulative Present Value**	892	2,675	0.93	2.87
Annualized**	101	158	0.10	0.17

* Annual benefits shown are undiscounted values.

** The cumulative present value and the annualized value are calculated using the discount rate indicated on top of each column, and both include annual values that extend from the compliance year through the year corresponding to the end of the life of units shipped in the last year of the analysis period. The cumulative present value refers to the present year (2024) and the annualized value refers to the cumulative present value annualized over the 30-year analysis period (2030-2059).

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CHAPTER 15. UTILITY IMPACT ANALYSIS

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CHAPTER 15. UTILITY IMPACT ANALYSIS

15.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes several aggregate impacts on electric and gas utilities that DOE projects would result for each trial standard level (TSL).

15.2 ELECTRIC UTILITIES

The electric utility impact analysis is based on output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[a] NEMS is a public domain, multi-sectored, partial equilibrium model of the U.S. energy sector. Each year, DOE/EIA uses NEMS to produce an energy forecast for the United States, the *Annual Energy Outlook (AEO).* The EIA publishes a Reference case, which incorporates all existing energy-related policies at the time of publication, and a variety of side cases which analyze the impact of different policies, energy price and market trends. The current analysis is based on results published for the *AEO 2023*.[2]

DOE's *AEO*-based methodology has a number of advantages:

- The assumptions used in the *AEO* reference case and side cases are fully documented and receive detailed public scrutiny.
- NEMS is updated each year, with each edition of the *AEO*, to reflect changes in energy prices, supply trends, regulations, *etc.*
- The comprehensiveness of NEMS permits the modeling of interactions among the various energy supply and demand sectors.
- Using EIA published reference and side cases to estimate the utility impacts enhances the transparency of DOE's analysis.

The details of the methodology vary based on the number and type of side cases published with each edition of the *AEO*. The approach adopted for this analysis is described in appendix 15A. A more detailed discussion of the general approach is presented in K. Coughlin, "Utility Sector Impacts of Reduced Electricity Demand."[3,4]

This chapter presents the results for consumer gas-fired instantaneous water heaters (GIWHs).

15.2.1 Methodology

DOE estimates the marginal impacts of reduction in energy demand on the energy supply sector. In principle, marginal values should provide a better estimate of the actual impact of

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[a] For more information on NEMS, refer to the U.S. Department of Energy, Energy Information Administration documentation. A useful summary is *National Energy Modeling System: An Overview*.[1]

energy conservation standards. DOE represents these marginal impacts using time series of *impact factors*.

The impact factors are calculated based on output from NEMS for *AEO 2023*. NEMS uses predicted growth in demand for each end use to build up a projection of the total electric system load growth. The system load shapes are converted internally to load duration curves, which are then used to estimate the most cost-effective additions to capacity. When electricity demand deviates from the *AEO* reference case, in general there are three inter-related effects: the annual generation (TWh) from the stock of electric generating capacity changes, the total generation capacity itself (GW) may change, and the mix of capacity types and technologies may change. Technology changes lead to a change in the proportion of fuel consumption to electricity generated (referred to as the heat rate). Each of these effects can vary for different types of end use. The change in total generating capacity is sensitive to the degree to which the end-use is peak coincident, while the capacity mix is sensitive to the hourly load shape associated with the end use. Changes in generation by fuel type lead in turn to changes in total power sector emissions of SO_2, NO_x, Hg, and CO_2.

DOE defined impact factors describing the change in emissions, installed capacity, and fuel consumption per unit reduction of site electricity demand. The impact factors vary by sector and end-use, as well as by year. DOE multiplied the impact factors by the stream of site energy savings calculated in the NIA (chapter 10) to produce estimates of the utility impacts. The utility impact factors are presented in appendix 15A. For GIWHs, DOE used the impact factors for water heating in homes and commercial buildings.

15.2.2 Utility Impact Results

15.2.2.1 Installed Capacity

The figures in this section show the changes in U.S. electricity installed capacity that result for each TSL by major plant type for selected years. The changes have been calculated based on the impact factors for capacity presented in appendix 15A. Units are megawatts of capacity per gigawatt-hour of site electricity use (MW/GWh).[b] Note that a negative number means an increase in capacity under a TSL.

[b] These units are identical to GW/TWh.

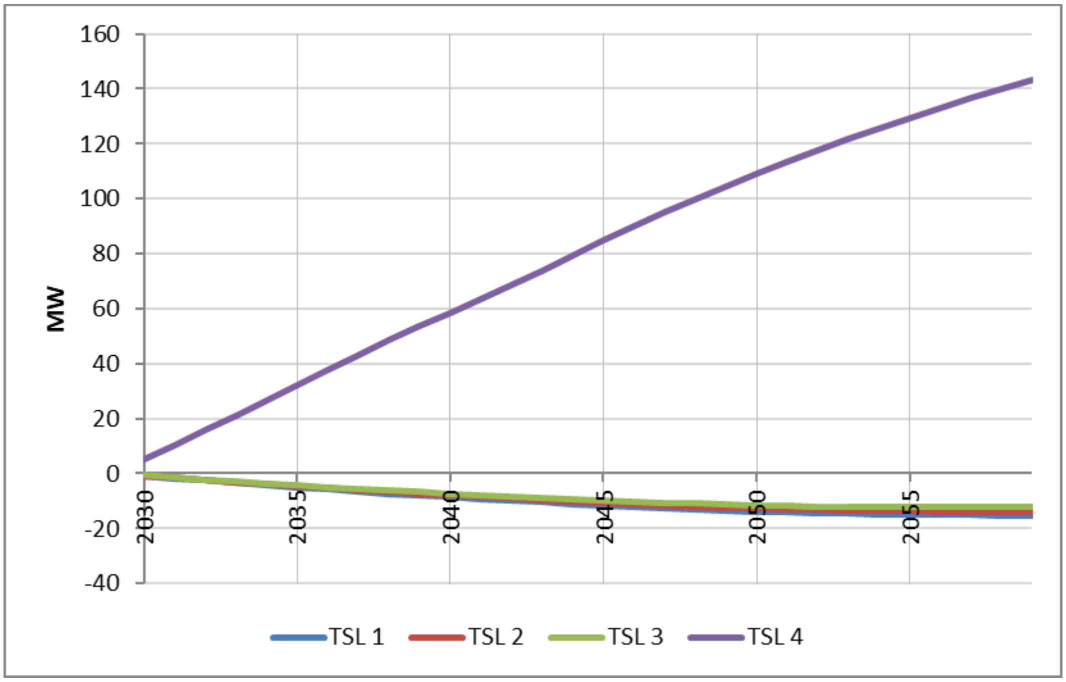

Figure 15.2.1 GIWHs: Total Electric Capacity Reduction

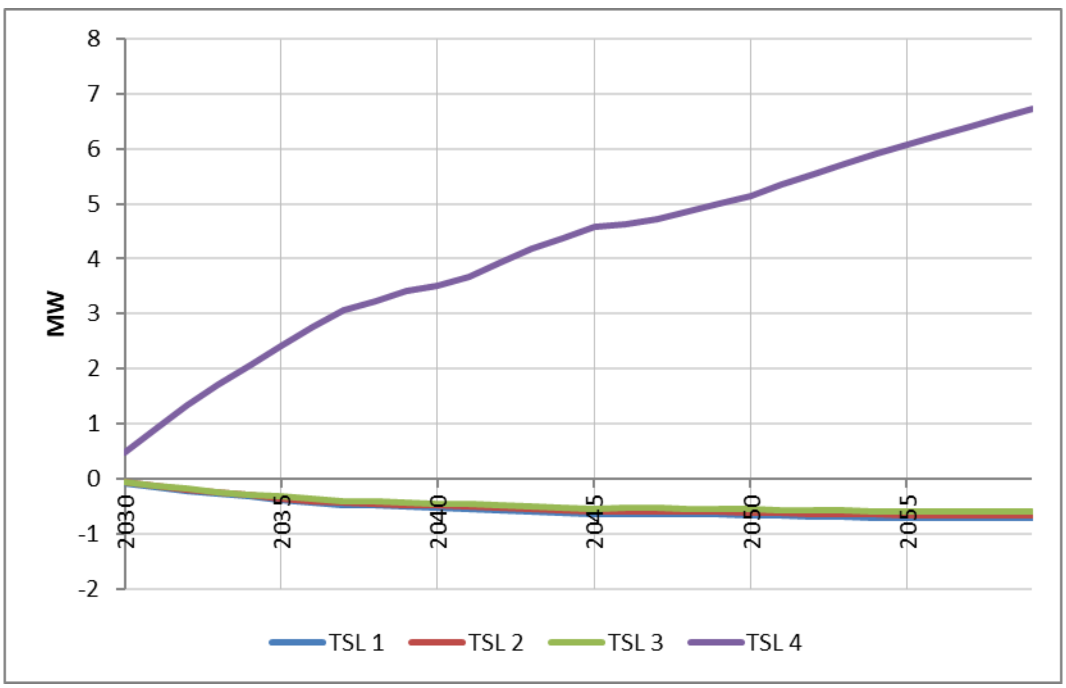

Figure 15.2.2 GIWHs: Coal Capacity Reduction

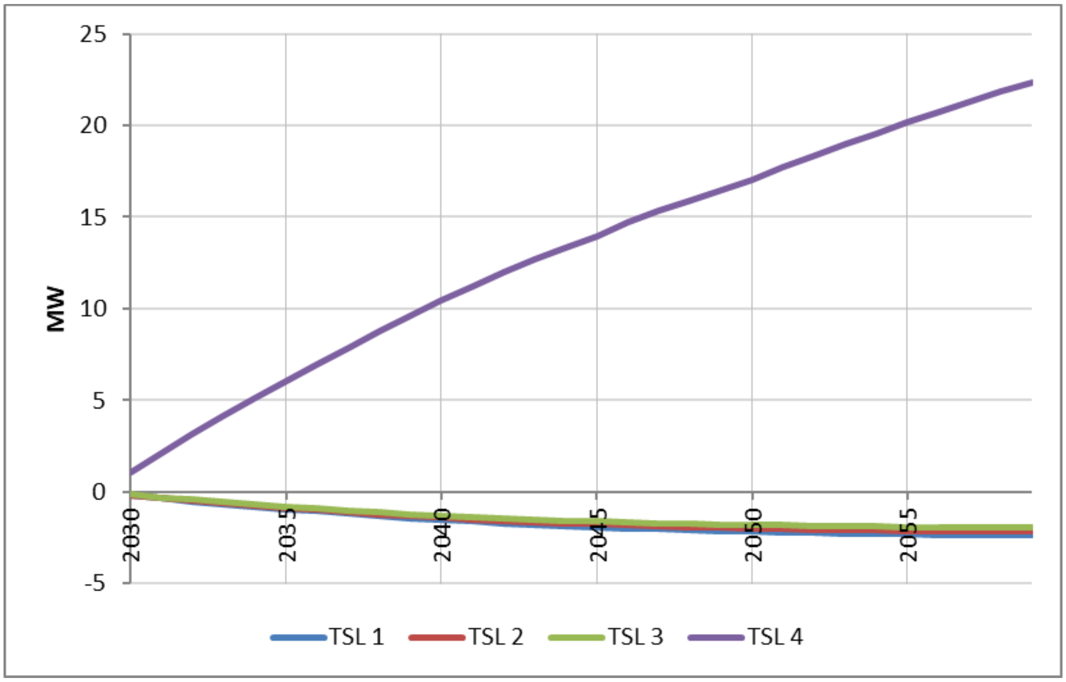

Figure 15.2.3 GIWHs: Gas Combined Cycle Capacity Reduction

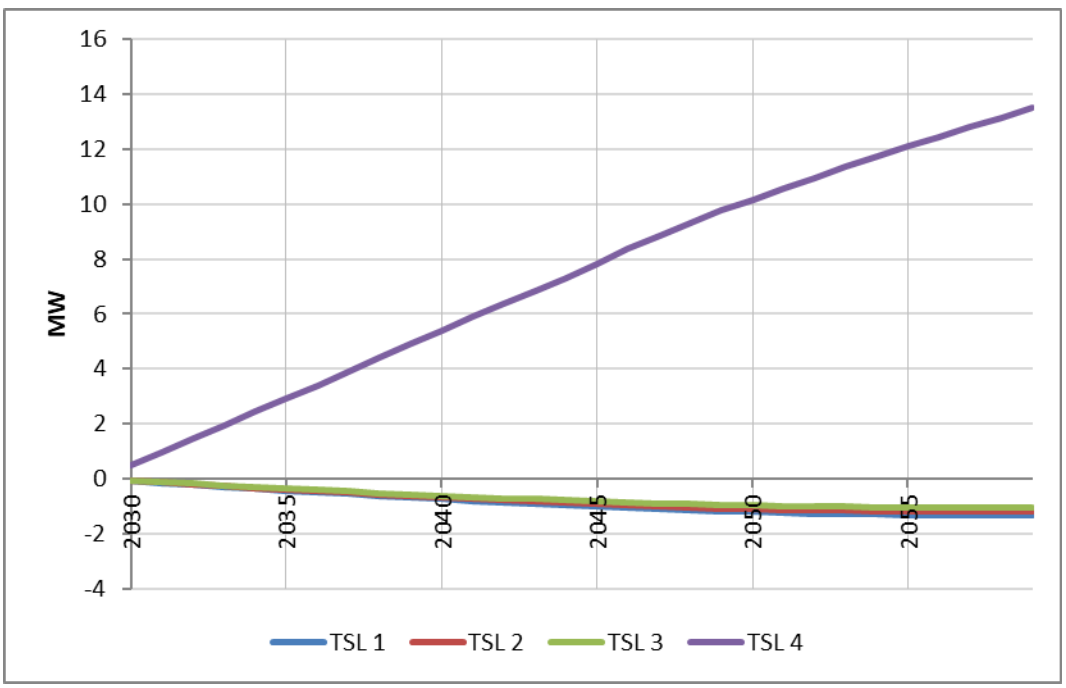

Figure 15.2.4 GIWHs: Peaking Capacity Reduction

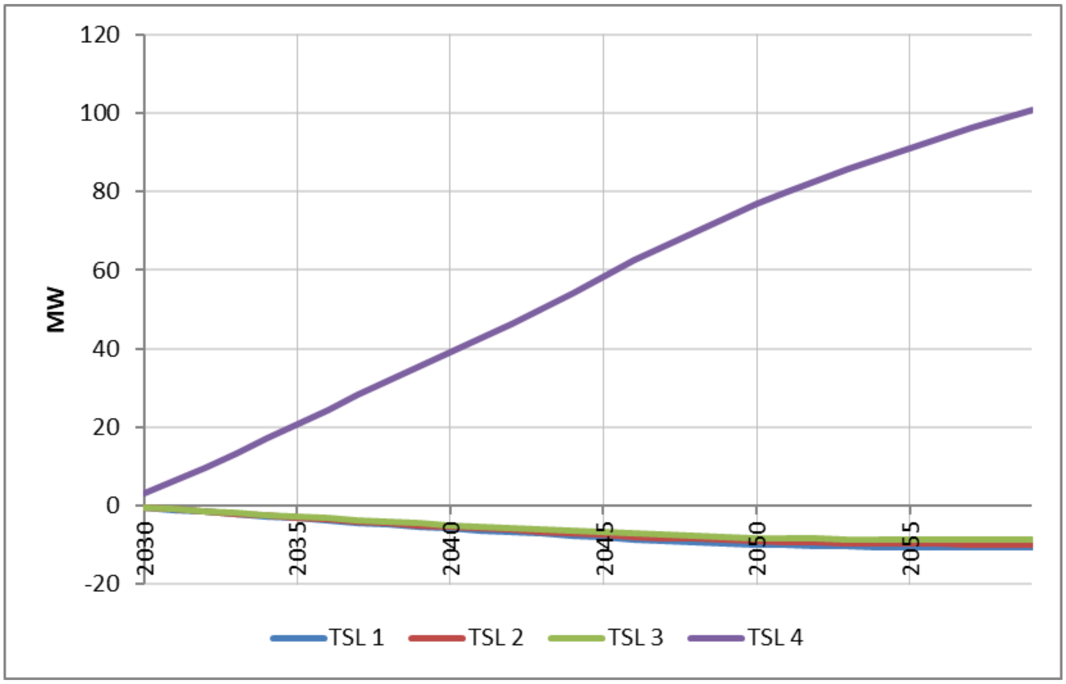

Figure 15.2.5 GIWHs: Renewables Capacity Reduction

15.2.2.2 Electricity Generation

The figures in this section show the annual change in electricity generation that result for each TSL by fuel type. The change by fuel type has been calculated based on factors calculated as described in appendix 15A. Note that a negative number means an increase in generation under a TSL.

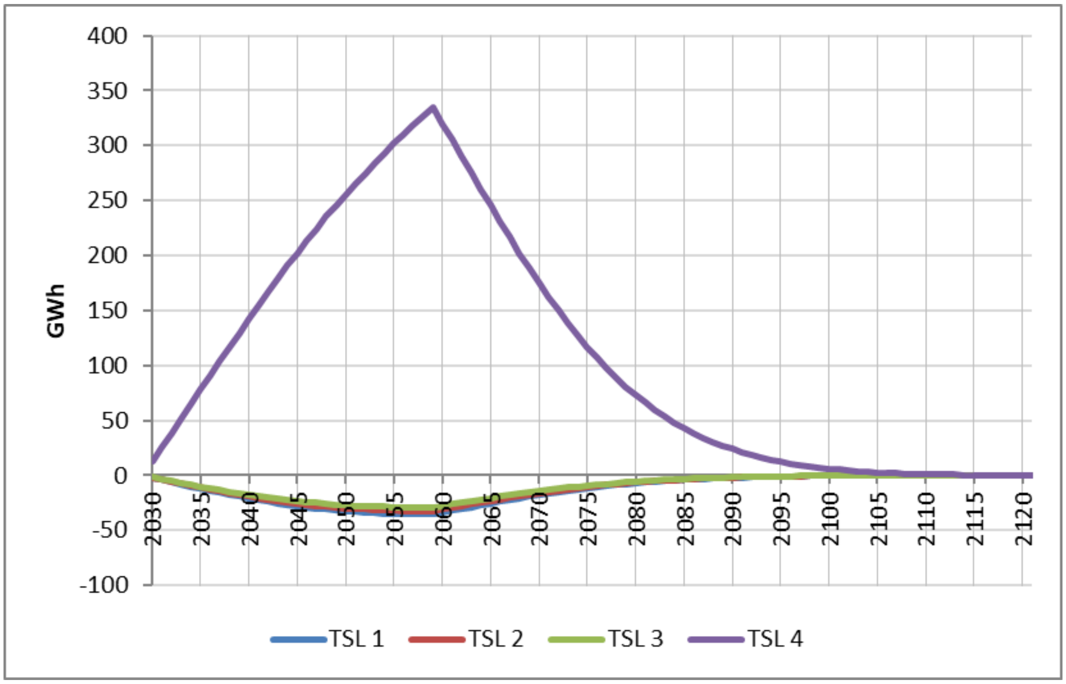

Figure 15.2.6 GIWHs: Total Generation Reduction

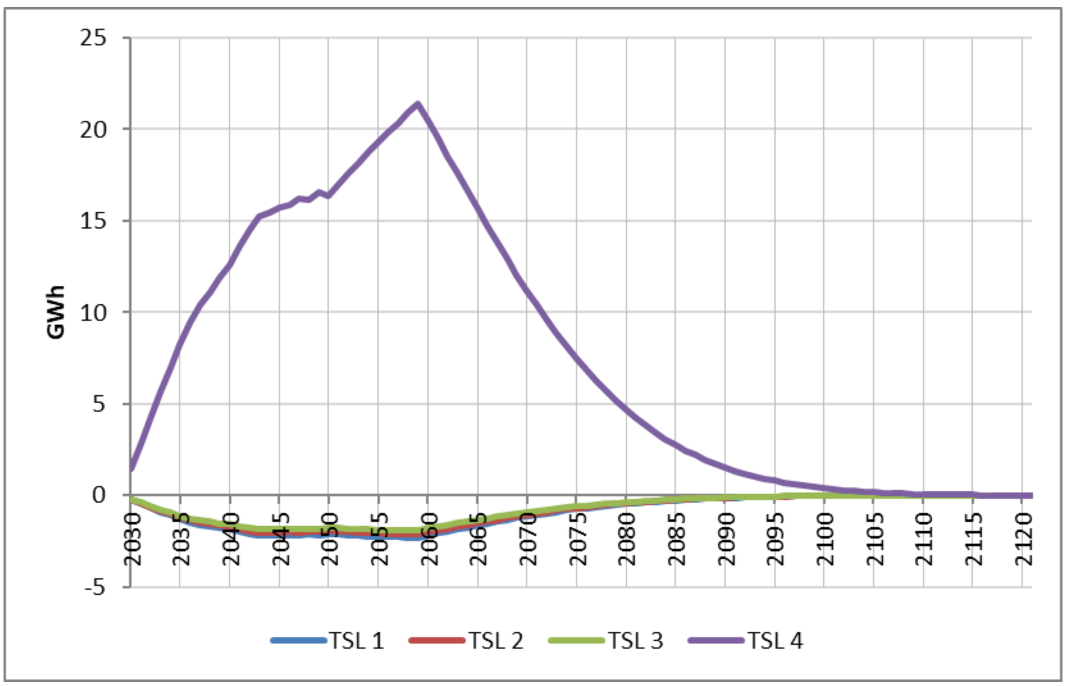

Figure 15.2.7 GIWHs: Coal Generation Reduction

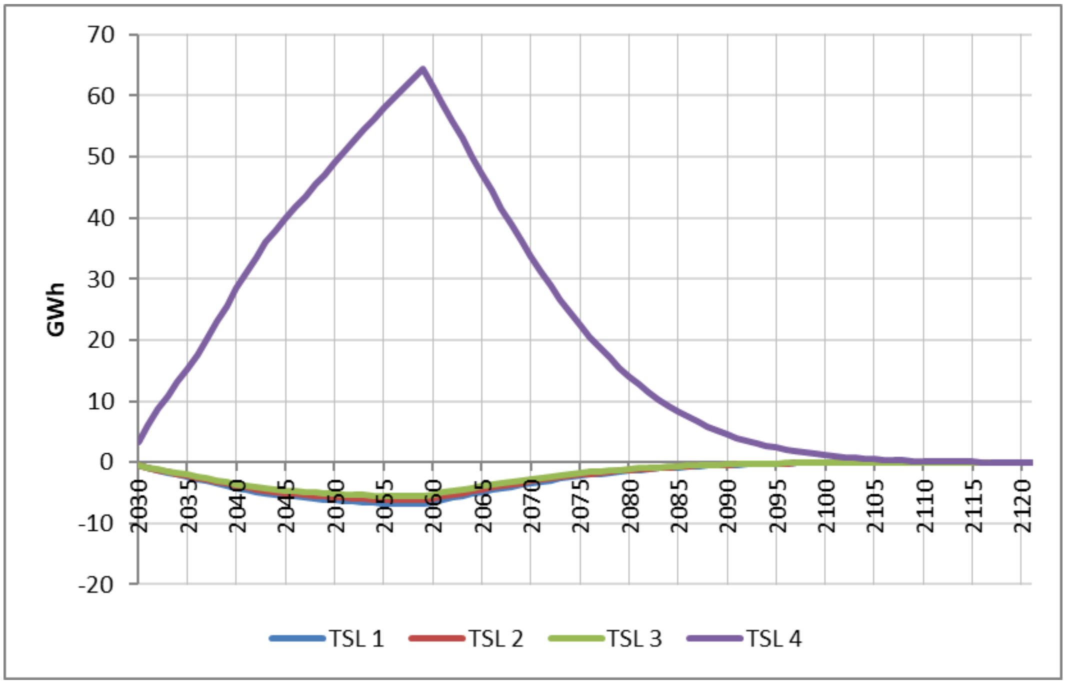

Figure 15.2.8 GIWHs: Gas Combined Cycle Generation Reduction

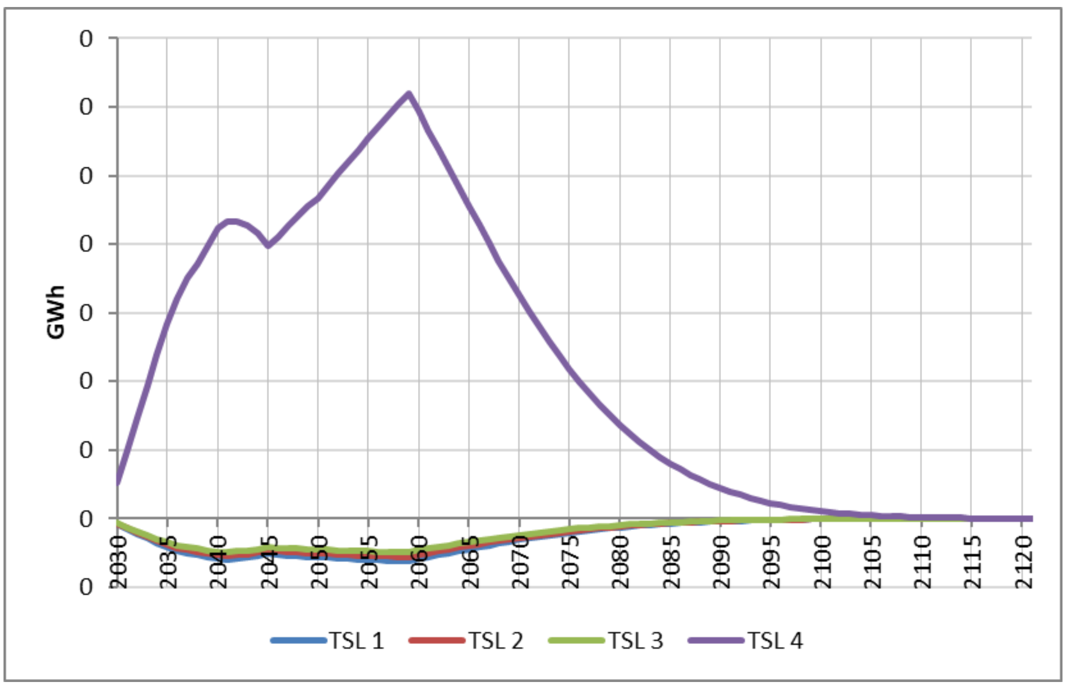

Figure 15.2.9 GIWHs: Oil Generation Reduction

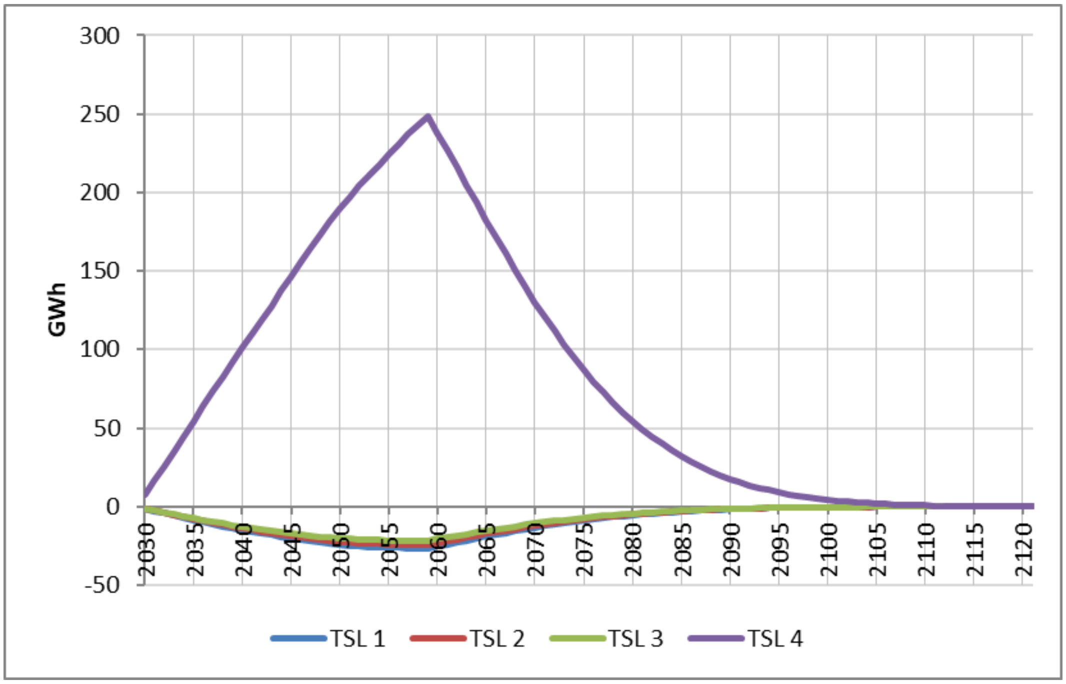

Figure 15.2.10 GIWHs: Renewables Generation Reduction

15.2.2.3 Results Summary

Table 15.2.1 presents a summary of the utility impact results for GIWHs.

Table 15.2.1 GIWHs: Summary of Electric Utility Impact Results

	TSL					
	1	2	3	4	5	6
Installed Capacity Reduction (MW)						
2030	-0.8	-0.8	-0.7	5.0	-0.8	-0.8
2035	-5.0	-4.6	-4.2	32	-5.0	-4.6
2040	-8.6	-7.9	-7.3	59	-8.6	-7.9
2045	-12	-11	-10	85	-12	-11
2050	-14	-13	-12	109	-14	-13
Electricity Generation Reduction (GWh)						
2030	-2.1	-1.9	-1.8	13	-2.1	-1.9
2035	-12	-11	-10	78	-12	-11
2040	-21	-19	-18	142	-21	-19
2045	-28	-26	-23	202	-28	-26
2050	-33	-30	-27	255	-33	-30

Negative values refer to an increase in installed capacity or electricity generation.

15.3 GAS UTILITIES

The gas utility impact analysis considers the projected effect of potential standards on aggregate natural gas delivered to consumers in million cubic feet. Figure 15.3.1 shows the annual change in natural gas delivered to consumers that result for each TSL. For reference, total U.S. natural gas delivered to all consumers was 27,440,492 million cubic feet in 2021.[c]

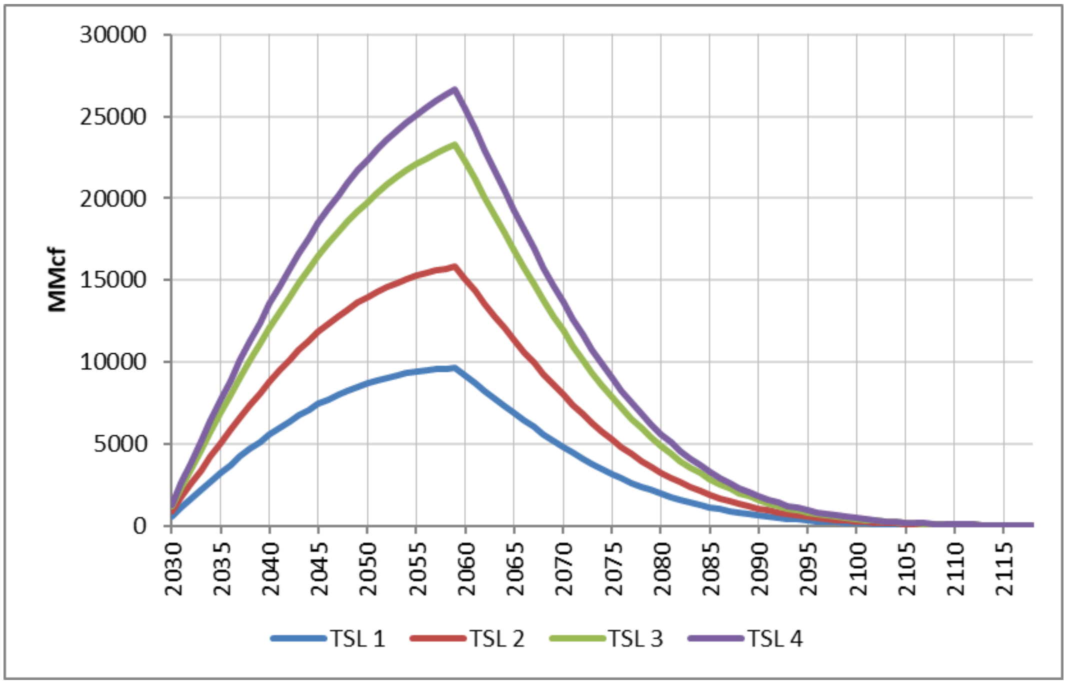

Figure 15.3.1 GIWHs: Total Reduction in Natural Gas Delivered to Consumers

[c] EIA, Natural Gas Consumption by End Use.
https://www.eia.gov/dnav/ng/ng_cons_sum_a_EPG0_vgt_mmcf_a.htm

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

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CHAPTER 16. EMPLOYMENT IMPACT ANALYSIS

16.1 INTRODUCTION

DOE's employment impact analysis for gas-fired instantaneous water heater is designed to estimate national job creation or elimination (i.e., not directly associated with manufacturers subject to an amended standard) resulting from possible standards, due to reallocation of the associated expenditures for purchasing and operating water heaters. DOE quantifies impacts in the short run, and discusses potential long run impacts qualitatively. Job increases or decreases reported in this chapter are separate from the manufacturing sector employment impacts reported in the manufacturer impact analysis (Chapter 12), and reflect the employment impact of efficiency standards on all other sectors of the economy.

16.2 ASSUMPTIONS

DOE expects energy conservation standards to decrease energy consumption, and therefore to reduce energy expenditures. The savings in energy expenditures may be spent by the consumer on new investments, goods and services, or not at all (e.g., spent later by a household or because a firm does not consequently change its output as a result of lower energy costs). The standards may also increase the purchase price of products and thus expenditures on equipment, including the retail price plus sales tax, and change installation and maintenance costs.

Using the ImSET input/output model of the U.S. economy, this analysis estimated the short-term effect, which are those effects in first few years after the initial compliance date, of these expenditure changes on employment. DOE intends this analysis to quantify these employment impacts of these expenditure changes. It evaluated employment impacts at manufacturers' facilities in the manufacturer impact analysis (see Chapter 12).

DOE notes that ImSET is not a general equilibrium forecasting model, and understands the uncertainties involved in projecting employment impacts, especially changes in the later years of the analysis.[1] ImSET does not account for how behavior will both change prices and respond to changing prices. Instead, ImSET is based on assuming input shares in each sector remain fixed. As such, the employment effects predicted by ImSET would over-estimate the magnitude of actual change in national employment over the long run for this rule. Since input/output models do not allow prices to bring markets into equilibrium, they are best used for short-run analysis. DOE therefore includes a qualitative discussion of how labor markets are likely to respond in the longer term at the end of this chapter. In future rulemakings, DOE may consider the use of other modeling approaches for examining long run employment impacts.

16.3 METHODOLOGY

The Department based its analysis on an input/output model of the U.S. economy that estimates the effects of standards on major sectors of the economy related to buildings and the net impact of standards on jobs. The Pacific Northwest National Laboratory developed the model, ImSET 4 (Impact of Sector Energy Technologies)[1] as a successor to ImBuild,[2] a special-purpose version of the IMPLAN[3] national input/output model. ImSET estimates the employment effects of building energy technologies. None of the native inputs to the model, such as the benchmark I-O table, described in the ImSET documentation[1] have been revised for this rule. The model uses the Bureau of Economic Analysis (BEA) 2007 benchmark I-O table.

In an input/output model, the level of employment in an economy is determined by the relationships between different sectors of the economy and the spending flows among them. Different sectors have different levels of labor intensity, thus changes in the level of spending (e.g., due to the effects of an efficiency standard) in one sector of the economy will affect flows in other sectors, which affects the overall national level of employment.

ImSET uses a 187-sector model of the national economy to predict the economic effects of residential and commercial buildings technologies. ImSET inputs estimates of initial investments, energy savings, and economic activity associated with spending the savings resulting from standards (e.g., changes in final demand in personal consumption, business investment and spending, and government spending). It provides overall estimates of the change in output, measured by the total value of produced goods or services, for each sector. The model uses estimates of employment and wage income per dollar of output for each sector to calculate changes on national employment.

Energy-efficiency technology primarily affects the U.S. economy along three spending pathways. First, general expenditures are diverted to sectors that manufacture, install, and maintain energy-efficient products. The increased cost of products leads to higher employment in the product manufacturing sectors, and lower employment in other economic sectors as expenditures on goods and services other than water heaters declines. Second, for commercial firm and residents that purchase equipment subject to the standard, their spending is redirected from energy (and potentially water) inputs toward firms that supply other production inputs. Third, utility sector expenditures attributable to the change in energy demand are released for use in other sectors of the economy.[a] When consumers use less energy or water, utilities experience relative reductions in demand which leads to reductions in utility sector investment and employment.

DOE also notes that the employment impacts estimated with ImSET for the entire economy differ from the employment impacts in the water heater manufacturing sector estimated in Chapter 12 using the Government Regulatory Impact Model (GRIM). The methodologies used and the sectors analyzed in the ImSET and GRIM models are different.

16.4 SHORT-TERM RESULTS

The results in this section refer to impacts of water heater standards relative to the baseline (“no-new-standards” case). DOE presents the summary impact.

[a] The reduction in the use of inputs by the utility sector due to the reduction in energy demand a result of the second pathway is estimated in ImSET for the purposes of this analysis. The analysis in Chapter 15 is not used as an input to ImSET.

Conceptually, one can consider the impact of the rule in its first year on three aggregate sectors, the water heater manufacturing sector, the energy generation sector, and all other sectors (as mentioned above ImSET's calculations are made at a much more disaggregate level). By raising energy efficiency, the rule generally requires more inputs to produce water heaters; these increased inputs may include changes in employment in this sector. At the same time, the improvements in energy efficiency reduce consumer expenditures on energy, freeing up income to be spent in other sectors, potentially increasing employment therein. The reduction in energy demand causes a reduction in employment in that sector. Finally, based on the net impact of increased expenditures on water heaters and reduced expenditures on energy, consumer expenditures on everything else are either positively or negatively affected, increasing or reducing jobs in each sector accordingly. The model also captures any indirect jobs created or lost by changes in consumption due to changes in employment (e.g., as more workers are hired they consume more goods, which generates more employment; the converse is true for workers laid off).

Table 16.4.1 presents the modeled annual net employment impact from the rule in 2030, rounded to the nearest hundred jobs (i.e., the estimated difference in the annual number of jobs compared to the case of no new standard). Approximately 20% of water heaters are domestically produced, with the remaining 80% imported. The net employment impact estimate is sensitive to assumptions regarding the return to the U.S. economy of money spent on imported products. The two scenarios bounding the ranges presented in Table 16.4.1 represent situations in which none of the money spent on imported water heaters returns to the U.S. economy and all of the money spent on imported water heaters returns to the U.S. economy. The U.S. trade deficit in recent years suggests that between 50% and 75% of the money spent on imported products is likely to return, and therefore short-term impacts would fall within the ranges presented below.

Table 16.4.1 Net National Short-term Change in Employment (1000s of Jobs)

Trial Standard Level	2030	2035
TSL 1	0.0 to 0.6	0.0 to 0.6
TSL 2	0.0 to 0.6	0.0 to 0.7
TSL 3	0.0 to 0.8	0.0 to 0.8
TSL 4	0.0 to 1.5	0.0 to 1.6

Note: For each year, the range represents the potential change in employment under the assumptions that 0% of import spending returns to the U.S. economy (low end) and 100% of import spending returns to the U.S. economy (high end).

For context, the Congressional Budget Office projects that over the relevant time period, the unemployment rate will be close to "full employment."[4] When an economy is at full employment any short-run effects on net employment are likely to be transitory as workers change jobs, rather than enter or exit longer-term employment. The ImSET model projections, assuming no price or wage effects until 2035, are included in the second column of Table 16.4.1.

16.5 LONG-TERM RESULTS

Over the long term DOE expects the energy savings to consumers to increasingly dominate the increase in product costs, resulting in increased aggregate savings to consumers. As a result, DOE expects demand for electricity to decline over time, reducing energy expenses to consumers, allowing demand for other goods to increase. Since the electricity generation sector is relatively capital intensive compared to the consumer goods sector, the net effect will be an increase in labor demand and a shift in employment away from energy towards consumer goods. Increased demand for labor will increase the equilibrium price of labor (i.e., wages). Note that in long-run equilibrium it is possible that there is no net effect on total employment since wages adjust to bring the labor market into equilibrium, as discussed at end of previous section. Nonetheless, even to the extent that markets are slow to adjust, DOE anticipates that net labor market impacts will in general be negligible over time due to the small magnitude of the short-term effects presented in Table 16.4.1.

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

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CHAPTER 17. REGULATORY IMPACT ANALYSIS

17.1 INTRODUCTION

The Administrator of the Office of Information and Regulatory Affairs (OIRA) in the OMB has determined that the regulatory action in this document is a significant regulatory action within the scope of section 3(f)(1) of Executive Order (E.O.) 12866. Regulatory Planning and Review. 58 FR 51735 (October 4, 1993), as amended by E.O. 14094. Modernizing Regulatory Review. 88 FR 21879 (April 11, 2023). For such actions, E.O. 12866 requires Federal agencies to provide "an assessment, including the underlying analysis, of costs and benefits of potentially effective and reasonably feasible alternatives to the planned regulation, identified by the agencies or the public (including improving the current regulation and reasonably viable non-regulatory actions), and an explanation why the planned regulatory action is preferable to the identified potential alternatives." 58 FR 51735, 51741.

To conduct this analysis, DOE used an integrated National Impact Analysis (NIA)-RIA model built on a modified[a] version of the NIA model discussed in chapter 10. DOE identified five non-regulatory policy alternatives that possibly could provide incentives for the same energy efficiency levels as the ones in the selected trial standard levels (TSLs) for the consumer gas-fired instantaneous water heaters (GIWHs) that are the subject of this rulemaking. The non-regulatory policy alternatives are listed in Table 17.1.1, which also includes the "no new regulatory action" alternative. DOE evaluated each alternative in terms of its ability to achieve significant energy savings at a reasonable cost, and compared the effectiveness of each to the effectiveness of the selected standards for the GIWH product class covered by this RIA.[b]

Table 17.1.1 Non-Regulatory Alternatives to National Standards

No New Regulatory Action
Consumer Rebates
Consumer Tax Credits
Manufacturer Tax Credits
Voluntary Energy Efficiency Targets
Bulk Government Purchases

Sections 17.2 and 17.3 discuss the analysis of five selected policies listed in Table 17.1.1 (excluding the alternative of "No New Regulatory Action"). Section 17.4 presents the results of the policy alternatives.

[a] For this RIA, DOE developed an alternative NIA model where shipments in the policy case do not account for any consumer-choice decision making. DOE believes that the national benefits from standards calculated this way are more comparable to the benefits from the alternative policies.
[b] This RIA covers GIWHs shipped to the residential sector only, as it makes up approximately 91% of GIWH shipments.

17.2 NON-REGULATORY POLICIES

This section describes the method DOE used to analyze the energy savings and cost effectiveness of the non-regulatory policy alternatives for GIWHs. This section also describes the assumptions underlying the analysis.

17.2.1 Methodology

DOE used its integrated NIA-RIA spreadsheet model to calculate the national energy savings (NES) and net present value (NPV) associated with each non-regulatory policy alternative. Chapter 10 of this technical support document (TSD) describes the NIA spreadsheet model. Appendix 17A discusses the NIA-RIA integrated model approach.

DOE quantified the effect of each alternative on the purchase of equipment that meets the efficiency levels corresponding to each TSL. After establishing the quantitative assumptions underlying each alternative, DOE appropriately revised inputs to the NIA-RIA spreadsheet model. The primary model inputs revised were market shares of equipment meeting the target efficiency levels set for each TSL. The shipments of equipment for any given year reflect a shipment distribution across efficiency levels. DOE assumed, for each TSL, that new energy efficiency standards would affect 100 percent of the shipments of products that did not meet the TSL target levels in the no-new-standards case, whereas the non-regulatory policies would affect a smaller percentage of those shipments. DOE made certain assumptions about the percentage of shipments affected by each alternative policy. DOE used those percentages to calculate the shipment-weighted average energy consumption and costs of GIWHs attributable to each policy alternative.

Increasing the efficiency of a product often increases its average installed cost. However, operating costs generally decrease because energy consumption declines. DOE therefore calculated an NPV for each non-regulatory alternative in the same way it did for the selected standards. In some policy scenarios, increases in total installed cost are mitigated by government rebates or tax credits. Because government expenditures on tax credits and rebates would be covered to a significant extent by income taxes paid by consumers in the aggregate, DOE did not include rebates or tax credits as a consumer benefit when calculating national NPV. DOE's analysis also excluded any administrative costs for the non-regulatory policies; including such costs would decrease the NPVs slightly.

The following are key measures for evaluating the impact of each alternative.

- National Energy Savings (NES), given in quadrillion Btus (quads), describes the cumulative national energy saved over the lifetime of equipment purchased during the 30-year analysis period starting in the effective date of the policy (2030-2059).
- Net Present Value (NPV), represents the value of net monetary savings in 2024, expressed in 2023$, from equipment purchased during the 30-year analysis period starting in the effective date of the policy (2030-2059). DOE calculated the NPV as the difference between the present values of installed equipment cost and operating expenditures in the no-new-standards case and the present values of those costs in

each policy case. DOE calculated operating expenses (including energy costs) for the life of the product.

17.2.2 Assumptions Regarding Non-Regulatory Policies

The effects of non-regulatory policies are by nature uncertain because they depend on program implementation, marketing efforts, and on consumers' response to a program. Because the projected effects depend on assumptions regarding the rate of consumer participation, they are subject to more uncertainty than are the impacts of mandatory standards, which DOE assumes will be met with full compliance. To increase the robustness of the analysis, DOE conducted a literature review regarding each non-regulatory policy to gather information on similar incentive programs that have been implemented in the United States. By studying experiences with the various types of programs, DOE sought to make credible assumptions regarding potential market impacts. Section 17.3 presents the sources DOE relied on in developing assumptions about each alternative policy and reports DOE's conclusions as they affected the assumptions that underlie the modeling of each alternative policy.

Each non-regulatory policy that DOE considered would improve the average efficiency of new GIWHs relative to their no-new-standards case efficiency scenario (which involves no new regulatory action). The analysis considered that each alternative policy would induce consumers to purchase units having the same technology as required by standards (the target efficiency level, referred to as the "target level" throughout the RIA), according to the minimum energy efficiency set for each TSL. As opposed to the standards case, however, the policy cases may not lead to 100 percent market penetration of units that meet the target level.

Table 17.2.1 shows the minimum energy efficiency of the GIWHs at each TSL.

Table 17.2.1 Minimum Energy Efficiency by TSL (UEF)

TSL 1	**TSL 2**	TSL 3	TSL 4
0.89	**0.93**	0.95	0.96

DOE assumed that the effects of non-regulatory policies would last from the effective date of standards—2030—through the end of the analysis period, which is 2059.

17.2.3 Policy Interactions

DOE calculated the effects of each non-regulatory policy separately from those of the other policies. In practice, some policies are most effective when implemented in combination, such as voluntary efficiency targets implemented with consumer rebates or tax credits. However, DOE attempted to make conservative assumptions to avoid double-counting policy impacts. The resulting policy impacts are therefore not additive, and the combined effect of several or all policies cannot be inferred from summing their results.

Section 17.4 presents graphs that show the market penetration estimated under each non-regulatory policy for GIWHs.

17.3 NON-REGULATORY POLICY ASSUMPTIONS

The following subsections describe DOE's analysis of the impacts of the five non-regulatory policy alternatives to the standards selected for GIWHs. (Because the alternative of "No New Regulatory Action" has no energy or economic impacts, essentially representing the NIA no-new-standards case, DOE did not perform any additional analysis for that alternative.) DOE developed estimates of the market penetration of more efficient products both with and without each of the non-regulatory policy alternatives. The analysis accounts only for the impacts of the non-regulatory policy alternatives on consumers' decision to purchase energy efficient GIWHs. No considerations are made on the potential impacts of the alternatives to standards on manufacturers or government.

17.3.1 No New Regulatory Action

The case in which no new regulatory action is taken with regard to the energy efficiency of GIWHs constitutes the no-new-standards case, as described in chapter 10, National Impact Analysis. The no-new-standards case, which exhibits some gains in efficiency, provides the basis of comparison for all other policies. By definition, no new regulatory action yields zero NES and an NPV of zero dollars.

17.3.2 Consumer Rebates

DOE considered the scenario in which the Federal government would provide financial incentives in the form of rebates to consumers for purchasing energy-efficient equipment. This policy provides a consumer rebate for purchasing GIWHs that operate at the same efficiency level as stipulated in each TSL.

17.3.2.1 Methodology

DOE based its evaluation methodology for consumer rebates on a comprehensive study of California's potential for achieving energy efficiency. The study, performed by XENERGY, Inc.,[c] summarized experiences with various utility rebate programs.[1] XENERGY's analytical method utilized graphs, or penetration curves, that estimate the market penetration of a technology based on its benefit/cost (B/C) ratio. DOE consulted with experts and reviewed other methods of estimating the effect of consumer rebate programs on the market penetration of efficient technologies. The other methods, developed after the referenced XENERGY report was published,[2, 3] used different approaches: other economic parameters (e.g., payback period), expert surveys, or model calibration based on specific utility program data rather than multi-utility data. Some models in use by energy efficiency program evaluation experts were so client-specific that generic relationships between economic parameters and consumer response could not be established. DOE decided that the most appropriate available method for this RIA was the XENERGY approach of penetration curves based on B/C ratio, which incorporates lifetime operating cost savings.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

XENERGY's model estimates market impacts induced by financial incentives based on the premise that two types of information diffusion drive the adoption of new technologies. *Internal sources* of information encourage consumers to purchase new equipment primarily through word-of-mouth from early adopters. *External sources* affect consumer purchase decisions through marketing efforts and information from outside the consumer group. Appendix 17A contains additional details on internal and external information diffusion.

XENERGY's model equation accounts for the influences of both internal and external sources of information by superimposing the two components. Combining the two mechanisms for information diffusion, XENERGY's model generates a set of penetration (or implementation) curves for a policy measure. XENERGY calibrated the curves based on participation data from utility rebate programs. The curves illustrate the increased penetration (i.e., increased market share) of efficient equipment driven by consumer response to changes in B/C ratio induced by rebate programs. The penetration curves depict various diffusion patterns based on perceived market barriers (from no-barriers to extremely-high-barriers) to consumer purchase of high-efficiency equipment. DOE adjusted the XENERGY former penetration curves based on expert advice founded on more recent utility program experience.

DOE modeled the effects of a consumer rebate policy for GIWHs by determining, for each TSL, the increase in market penetration of equipment meeting the target level relative to its market penetration in the no-new-standards case. It used the interpolation method presented in Blum et al (2011)[4] to create a customized penetration curve based on relationships between actual no-new-standards case market penetrations and actual B/C ratios. To inform its estimate of B/C ratios provided by a rebate program DOE assumed that a rebate program would cover half of the installed cost of efficient GIWH, and used this data to calibrate the customized penetration curve it developed for the product class covered by this RIA so it can best reflect the market barrier levels that consumer rebates for GIWHs would face. Section 17.3.2.2 shows the resulting interpolated curve used in the analysis.

17.3.2.2 Analysis

DOE estimated the effect of increasing the B/C ratio of GIWHs via a rebate that would pay half of the increased installed cost of units that meet the target efficiency levels compared to units meeting the baseline efficiency level.[d] Based on such assumption, DOE estimated, for each TSL, a rebate value for the product class covered by this RIA which it applied in the calculation of the B/C ratio of GIWHs under the effect of consumer rebates. DOE assumed that rebates would remain in effect at the same level throughout the analysis period (2030-2059).

DOE first calculated the B/C ratio of a GIWH without a rebate using the difference in total installed costs (C) and lifetime operating cost savings[e] (B) between a unit meeting the target level and a baseline unit. It then calculated the B/C ratio given a rebate for the unit meeting the target efficiency level. Because the rebate reduced the incremental cost, the unit receiving the

[d] The baseline technology is defined in the engineering analysis, chapter 5, as the technology that represents the basic characteristics of GIWHs. A baseline unit typically is one that just meets current Federal energy conservation standards and provides basic consumer utility.
[e] The cash flow of the operating cost savings is discounted to the purchase year using a 7 percent discount rate.

rebate had a larger B/C ratio. Table 17.3.1 shows the effect of consumer rebates for each TSL on the B/C ratio of GIWHs shipped in the first year of the analysis period.

Table 17.3.1 Benefit/Cost Ratios Without and With Rebates

	TSL 1	**TSL 2**	TSL 3	TSL 4
B/C Ratio without Rebate	1.2	**1.8**	1.9	1.6
Rebate Amount (2023$)	95.81	**102.05**	108.99	149.97
B/C Ratio with Rebate	2.5	**3.6**	3.9	3.1
Estimated Market Barriers*	Low-Mod	**No-to-Low**	Low-Mod	Low-Mod

*Low-Mod: Low-to-Moderate market barriers.

DOE used the B/C ratio along with the customized penetration curve shown in Figure 17.3.1 to estimate the percentage of consumers who would purchase GIWHs that meet the target level both with and without a rebate incentive. Table 17.3.1 indicates the estimated level of market barriers corresponding to the penetration curve DOE calculated to represent the market behavior for GIWHs at the selected TSL.

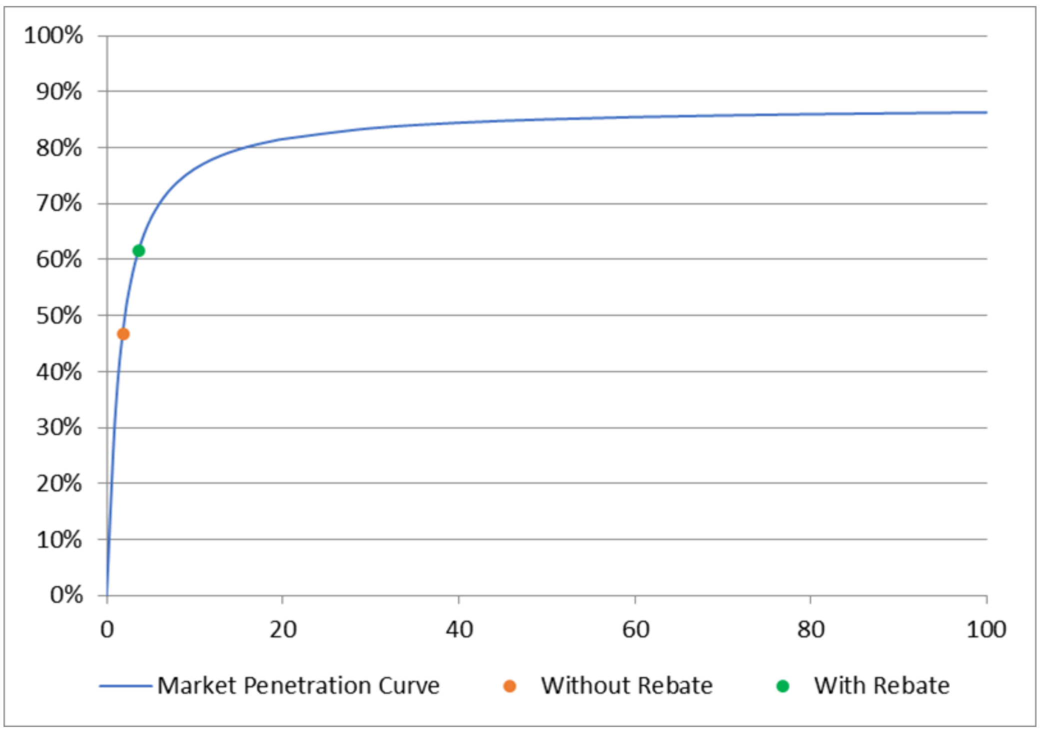

Figure 17.3.1 Market Penetration Curve for GIWHs (TSL 2)[f]

DOE next estimated the percent increase represented by the change in penetration rate shown on the corresponding penetration curve. It then added this percent increase to the market share of units that meet the target level in the no-new-standards case to obtain the market share of units that meet the target level in the rebate policy case.

[f] The chart shows how the market penetration (in the *y* axis) increases as the B/C ratio (in the *x* axis) increases.

Table 17.3.2 summarizes DOE's assumptions for GIWHs regarding the market penetration of products in 2030 that meet the target level at each TSL given a consumer rebate.

Table 17.3.2 Market Penetrations in 2030 Attributable to Consumer Rebates

	TSL 1	**TSL 2**	TSL 3	TSL 4
Base-Case Market Share	7.6%	**46.7%**	7.3%	8.4%
Policy Case Market Share	20.7%	**61.6%**	20.9%	22.4%
Increased Market Share	13.1%	**14.9%**	13.6%	14.0%

DOE used the resulting annual increases in market shares as inputs to represent the rebate policy case scenario in its NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole analysis period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer rebates for GIWHs.

17.3.3 Consumer Tax Credits

DOE estimated the effects of tax credits on consumer purchases based on its previous analysis of consumer participation in tax credits. DOE supported its approach using data from Oregon State's tax credit program for energy-efficient appliances. DOE also incorporated previous research that disaggregated the effect of rebates and tax credits into a *direct price effect*, which derives from the savings in purchase price, and an *announcement effect*, which is independent of the amount of the incentive.[5,6] The announcement effect derives from the credibility that a technology receives from being included in an incentive program, as well as changes in product marketing and modifications in markup and pricing. DOE assumed that the rebate and consumer tax credit policies would encompass both direct price effects and announcement effects, and that half the increase in market penetration associated with either policy would be due to the direct price effect and half to the announcement effect.

In estimating the effects of a tax credit on purchases of consumer products that meet new efficiency standards, DOE assumed the amount of the tax credit would be the same as the corresponding rebate amount discussed above.

DOE estimated that fewer consumers would participate in a tax credit program than would take advantage of a rebate. Research has shown that the delay required for a consumer to receive a tax credit, plus the added time and cost in preparing the tax return, make a tax credit incentive less effective than a rebate received at the time of purchase. Based on previous analyses, DOE assumed that only 60 percent of the consumers who would take advantage of a rebate would take advantage of a tax credit.[7]

In preparing its assumptions to estimate the effects of tax credits on consumer purchases of GIWHs, DOE also reviewed other tax credit programs that have been offered at both the Federal and State levels for energy-efficient appliances.

The Energy Policy Act of 2005 (EPACT 2005) included Federal tax credits for consumers who purchase energy-efficient products.[8] Those tax credits were in effect in 2006 and 2007, expired in 2008, were reinstated for 2009–2010 by the American Recovery and Reinvestment Act of 2009 (ARRA), extended by Congress for 2011 with some modifications, and expired at the end of 2011.[9,10] The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[11] DOE reviewed Internal Revenue Service data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. However, DOE did not find data specific enough to GIWHs to warrant adjusting its analysis method for the Consumer Tax Credits policy case.[g] Appendix 17A contains more information on Federal consumer tax credits.

DOE also reviewed its previous analysis of Oregon's tax credits for clothes washers to provide support for its assumptions.[12] In that previous analysis, DOE compared the market shares of ultra-high efficiency (UHE) residential clothes washers in Oregon, which offered both State tax credits and utility rebates, with those in Washington State, which offered only utility rebates during the same period. Based on this analysis, DOE estimated that in Oregon the impact of tax credits was 62 percent of the impact of rebates for UHE clothes washers having equivalent efficiency. This finding supports its original assumption that participation in a tax credit program would be about 60 percent of participation in a rebate program. Additional discussion of State tax credits for Oregon and other states is in appendix 17A.

DOE applied the assumed 60 percent participation described above to the increase in penetration rates estimated for the rebate policy to estimate penetration rates attributable to consumer tax credits. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curve it developed for GIWHs (See Figure 17.3.1).

Table 17.3.3 summarizes DOE's assumptions for GIWHs regarding the market penetration of products in 2030 that meet the target level at each TSL given a consumer tax credit.

Table 17.3.3 Market Penetrations in 2030 Attributable to Consumer Tax Credits

	TSL 1	**TSL 2**	TSL 3	TSL 4
Base-Case Market Share	7.6%	**46.7%**	7.3%	8.4%
Policy Case Market Share	15.4%	**55.6%**	15.4%	16.8%
Increased Market Share	7.8%	**8.9%**	8.1%	8.4%

The increased market shares attributable to consumer tax credits shown in Table 17.3.3 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole analysis period. Section 17.4 presents the resulting market penetration trends for the policy case of consumer tax credits for GIWHs that meet the efficiency level for the selected TSL. Because the increase in market penetration for consumer tax credits is proportional to the increase in market penetration DOE calculated for consumer rebates, they follow similar increasing trends over the analysis period.

[g] The Inflation Reduction Act (2022) provides for tax credits for the purchase of some energy-efficient products, but there are no data yet to examine their impact.

17.3.4 Manufacturer Tax Credits

To analyze the potential effects of a policy that offers tax credits to manufacturers that produce GIWHs that meet the target efficiency level at each TSL, DOE assumed that a manufacturer tax credit would lower the consumer's purchase cost by an amount equivalent to that provided by the consumer rebates or tax credits described above. DOE further assumed that manufacturers would pass on some of their reduced costs to consumers, causing a direct price effect. DOE assumed that no announcement effect would occur, because the program would not be visible to consumers.[h] Because the direct price effect is approximately equivalent to the announcement effect,[5] DOE estimated that a manufacturer tax credit would induce half the number of consumers assumed to take advantage of a consumer tax credit to purchase more efficient products. Thus, the assumed participation rate is equal to 30 percent of the number of consumers who would participate in a rebate program.

DOE attempted to investigate manufacturer response to the Energy Efficient Appliance Credits for manufacturers mandated by EPACT 2005.[8] Those manufacturer tax credits have been in effect for dishwashers, clothes washers and refrigerators produced beginning in 2009. DOE was unable to locate data from the Internal Revenue Service or other sources on manufacturer response to the Federal credits. Appendix 17A presents details on Federal manufacturer tax credits.

DOE applied the assumption of 30 percent participation to the increase in penetration rates predicted for the rebate policy to estimate the effects of a manufacturer tax credit policy. In doing so, DOE incorporated the assumptions for consumer response to financial incentives from the customized penetration curve it developed for GIWHs. (See Figure 17.3.1).

Table 17.3.4 summarizes DOE's assumptions for GIWHs regarding the market penetration of products in 2030 that meet the target level at each TSL given a manufacturer tax credit.

Table 17.3.4 Market Penetrations in 2030 Attributable to Manufacturer Tax Credits

	TSL 1	**TSL 2**	TSL 3	TSL 4
Base-Case Market Share	7.6%	**46.7%**	7.3%	8.4%
Policy Case Market Share	11.5%	**51.1%**	11.4%	12.6%
Increased Market Share	3.9%	**4.5%**	4.1%	4.2%

The increased market shares attributable to a manufacturer tax credit shown in Table 17.3.4 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole analysis period. Section 17.4 presents the resulting market penetration trends for the policy case of manufacturer tax credits for GIWHs. Because the increase in market penetration for manufacturer tax credits is proportional to the increase in

[h] Note that this is a conservative assumption, since it is possible that manufacturers or utility/agency efficiency programs might promote the models for which manufacturers increase production due to the tax credits, which in turn might induce some announcement effect. However, DOE found no data on such programs on which to base an estimate of the magnitude of this possible announcement effect on consumer behavior.

market penetration DOE calculated for consumer rebates, they follow similar increasing trends over the analysis period.

17.3.5 Voluntary Energy Efficiency Targets

DOE assumed that voluntary energy efficiency targets would lead manufacturers of GIWHs to gradually stop producing units that operate below the efficiency level set for each TSL. DOE assumed that the impetus for phasing out production of low-efficiency units would be a program with impacts similar to those of the ENERGY STAR labeling program conducted by the Environmental Protection Agency (EPA) and DOE in conjunction with industry partners. The ENERGY STAR program specifies the minimum energy efficiencies that various products must have to receive the ENERGY STAR label. ENERGY STAR encourages consumers to purchase efficient products via marketing that promotes consumer label recognition, various incentive programs that adopt the ENERGY STAR specifications, and manufacturers' promotion of their qualifying appliances. ENERGY STAR projects market penetration of compliant appliances and estimates the percentage of sales of compliant appliances that are attributable to the ENERGY STAR program.

Researchers have analyzed the ENERGY STAR program's effects on sales of several consumer products. Program efforts generally involve a combination of information dissemination and utility or agency rebates. The analyses have been based on State-specific data on percentages of shipments of various appliances that meet ENERGY STAR specifications. The analyses generally have concluded that the market penetration of ENERGY STAR-qualifying appliances is higher in regions or States where ancillary promotional programs have been active.[13, 14]

DOE believes that informational incentive programs – like ENERGY STAR, or any other labeling program sponsored by industry or other organizations – are likely to reduce the market barriers to more efficient products over time. During the rebate analysis, when assessing the B/C ratio and market penetration in the no-new-standards case for GIWHs, DOE observed market barriers to adoption of GIWHs that are more efficient than baseline GIWHs. DOE estimates that voluntary energy efficiency targets could reduce these barriers over 10 years. DOE simulates such reduction by reducing the market barrier score it assigns to the product class at each TSL. Lower market barriers are related to market penetration curves with higher adoption levels. Therefore, reducing the market barrier score of a product class at a certain TSL, as a result of the program, leads to an increased adoption of the efficient GIWHs. Table 17.3.5 presents the levels of market barriers DOE estimated for GIWHs in the no-new-standards case and in the policy case of voluntary energy efficiency targets. DOE followed the methodology presented by Blum et al (2011)[4] to evaluate the effects that such a reduction in market barriers would have on the market penetration of efficient GIWHs.[i] The methodology relies on interpolated market penetration curves to calculate – given a B/C ratio – how the market penetration of more efficient units increases as the market barrier level to those units decreases.

[i] For the calculation of B/C ratios DOE discounted the cash flow of the operating cost savings to the purchase year using a 7 percent discount rate.

Table 17.3.5 Market Barriers Changes Attributable to Voluntary Energy Efficiency Targets (TSL 2)

No-new-standards Case	Voluntary Energy Efficiency Targets
No-to-Low	No

Table 17.3.6 summarizes DOE's assumptions for GIWHs regarding the market penetration of products in 2030 that meet the target level at each TSL given voluntary energy efficiency targets. Table 17.3.7 expands on Table 17.3.6 to include, for the selected TSL, DOE's assumptions regarding the market penetration of units in selected years.

Table 17.3.6 Market Penetrations in 2030 Attributable to Voluntary Energy Efficiency Targets

	TSL 1	**TSL 2**	TSL 3	TSL 4
Base-Case Market Share	7.6%	**46.7%**	7.3%	8.4%
Policy Case Market Share	9.8%	**48.3%**	12.0%	11.6%
Increased Market Share	2.2%	**1.6%**	4.7%	3.1%

Table 17.3.7 Market Penetrations in Selected Years Attributable to Voluntary Energy Efficiency Targets for TSL 2

	2030	**2039**	**2059**
Base-Case Market Share	46.7%	49.7%	56.3%
Policy Case Market Share	48.3%	62.8%	66.2%
Increased Market Share	1.6%	13.1%	9.8%

The increased market shares attributable to voluntary energy efficiency targets shown in Table 17.3.6 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole analysis period. Section 17.4 presents the resulting market penetration trends for the policy case of voluntary energy efficiency targets for GIWHs that meet the efficiency level for the selected TSL. Because of the decrease in the market barriers level over the first 10 years of the analysis period, the market penetration of more efficient GIWHs significantly increases over that period.

17.3.6 Bulk Government Purchases

Bulk government purchases can lead to Federal, State, and local governments purchasing large quantities of products that meet a certain, target efficiency level. Combining the market demands of multiple public sectors can provide a market signal to manufacturers and vendors that some of their largest customers seek products that meet an efficiency target at favorable prices. Such a program also can induce "market pull," whereby manufacturers and vendors would achieve economies of scale for high efficiency products.

Most of the previous bulk government purchase (procurement) initiatives at the Federal, State, and municipal levels have not tracked data on number of purchases or degree of compliance with procurement specifications. In many cases, procurement programs are decentralized, being part of larger State or regional initiatives. DOE based its assumptions regarding the effects of this policy on studies the Federal Energy Management Program (FEMP) performed regarding the savings potential of its procurement specifications for appliances and other products. FEMP, however, does not track purchasing data, because of the complex range of purchasing systems, large number of vendors, and so on. States, counties, and municipalities have demonstrated increasing interest and activity in "green purchasing." Although many of the programs target office equipment, the growing infrastructure for developing and applying efficient purchasing specifications indicates that bulk government purchase programs are feasible.

DOE assumed that government agencies would administer bulk purchasing programs for GIWHs. At the federal level, this type of program could be similar to the current FEMP procurement guidelines for residential water heaters, which refer to the ENERGY STAR requirements for residential water heaters.[j] DOE reviewed its own previous research on the potential for market transformation through bulk government purchases. Its major study analyzed several scenarios based on the assumption that 20 percent of Federal equipment purchases in 2000 already incorporated energy efficiency requirements based on FEMP guidelines. One scenario in the DOE report showed energy efficient purchasing ramping up during 10 years from 20 percent to 80 percent of all Federal purchases.[15] Based on this study, DOE estimated that a bulk government purchase program instituted within a 10-year period would result in at least 80 percent of government-purchased GIWHs meeting the target efficiency level.

DOE assumed that bulk government purchases would affect a subset of housing units for which government agencies purchased or influenced the purchase of GIWHs. This subset would consist primarily of public housing and housing on military bases. According to the 2009 Residential Energy Consumption Survey (RECS 2009), about 3.0 percent of all U.S. households with tankless gas water heaters are housing units in a public housing authority.[16] DOE therefore estimated that 3.0 percent of the U.S. housing units with tankless gas water heaters constitute the market to which this policy would apply.

DOE estimated that starting in 2030, each year of a bulk government purchase policy would result in an increasing percent of shipments of government-purchased units beyond the no-new-standards case that would meet the target efficiency level. DOE estimated that within 10 years (by 2039) bulk government purchasing programs would result in 80 percent[k] of the market for GIWHs used in publicly owned housing meeting the target level. DOE modeled the bulk government purchase program assuming that the market share for GIWHs achieved in 2039 would be at least maintained throughout the rest of the analysis period.

Table 17.3.8 summarizes DOE's assumptions for GIWHs regarding the market penetration of products in 2030 that meet the target level at each TSL given bulk government purchases.

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[j] https://www.energy.gov/eere/femp/purchasing-energy-efficient-residential-water-heaters

[k] The 80 percent target to be achieved within 10 years may not be reached, as it is constrained by the market share below the target level in the no-new-standards case scenario.

Table 17.3.8 Market Penetrations in 2030 Attributable to Bulk Government Purchases

	TSL 1	**TSL 2**	TSL 3	TSL 4
Base-Case Market Share	7.6%	**46.7%**	7.3%	8.4%
Policy Case Market Share	7.7%	**46.8%**	7.5%	8.7%
Increased Market Share	0.1%	**0.1%**	0.2%	0.2%

The increased market shares attributable to bulk government purchases shown in Table 17.3.8 were used as inputs in the NIA-RIA model. Appendix 17A shows the annual market share increases due to this policy for the whole analysis period. Section 17.4 presents the resulting market penetration trends for the policy case of bulk government purchases for GIWHs. Market penetration slightly increases over the first 10 years of the analysis period and follows the no-new-standards case market penetration trend for the rest of the analysis period.

17.4 IMPACTS OF NON-REGULATORY ALTERNATIVES

Figure 17.4.1 shows the effects of each non-regulatory policy alternative on the market penetration of more efficient GIWHs. Relative to the no-new-standards case, the alternative policy cases increase the market shares that meet the target level. Recall the selected standards (not shown in the figures) would result in a 100-percent market penetration of products that meet the more efficient technology.

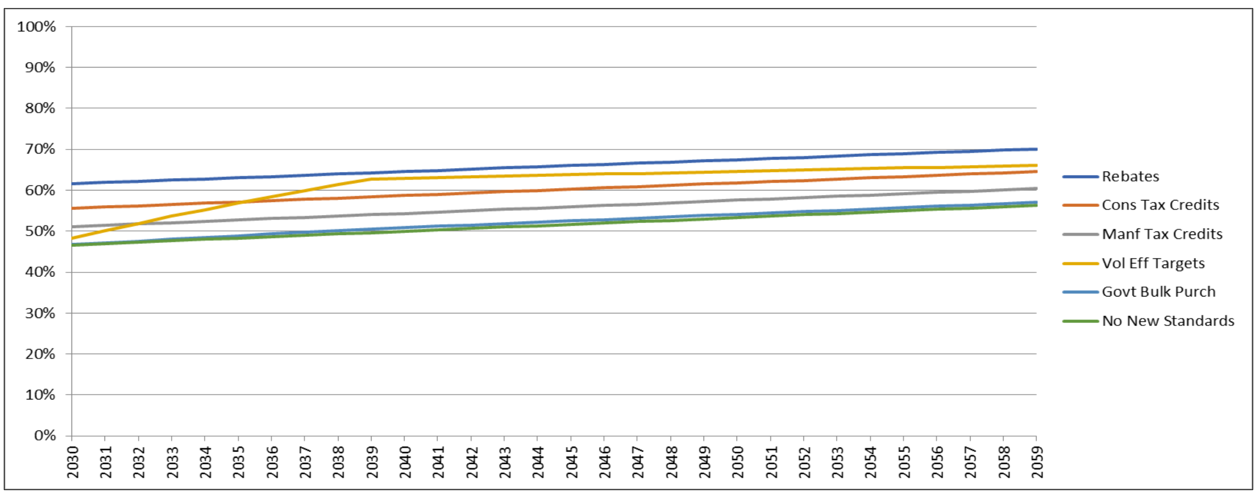

Figure 17.4.1 Market Penetration of Efficient GIWHs (TSL 2)

Table 17.4.1 shows the national energy savings and net present value for the five non-regulatory policy alternatives analyzed in detail for GIWHs. The target level for each policy corresponds to the same efficient technology selected for standards at TSL 2. The case in which no regulatory action is taken with regard to GIWHs constitutes the no-new-standards case (or "No New Regulatory Action" scenario), in which NES and NPV are zero by definition. For comparison, the tables include the impacts of the selected standards calculated as described in footnote 'a'. Energy savings are given in quadrillion British thermal units (quads) of primary energy savings.[1] The NPVs shown in Table 17.4.1 are based on two discount rates, 7 percent and 3 percent. Under both discount rates, the selected standards carry a considerably higher NPV than any non-regulatory alternative.

The policy with the highest projected cumulative energy savings is consumer rebates. Savings from manufacturer tax credits and consumer tax credits range from 11 percent to 22 percent of the savings from selected standards calculated as described in footnote 'a'. Bulk government purchases have the lowest cumulative energy savings. Overall, the energy-saving benefits from the alternative policies range from 0.3 percent to 40 percent of the benefits from the selected standards calculated as described in footnote 'a'.

Table 17.4.1 Impacts of Non-Regulatory Policy Alternatives (TSL 2)

Policy Alternative	**Energy Savings*** *Quads*		**Net Present Value*** *million 2023$*	
			7% Disc Rate	**3% Disc Rate**
Consumer Rebates	0.22	39.7%**	355	1,127
Consumer Tax Credits	0.12	21.7%	213	676
Manufacturer Tax Credits	0.06	10.9%	106	338
Voluntary Energy Efficiency Targets	0.05	8.2%	45	265
Bulk Government Purchases	0.002	0.3%	3	10
Selected Standards***	0.56	100.0%	892	3,112

* For products shipped 2030-2059.
** The percentages show how the energy savings from each policy alternative compare to the (primary) energy savings from the selected standards (represented in the table as 100%) when the latter is calculated as described in footnote 'a'.
*** Calculated as described in footnote 'a'.

[1] For the alternative policies whose market penetration depends on B/C ratio, the energy savings in Table 17.4.1 correspond to the case where the cash flow of the operating cost savings was discounted to the purchase year using a 7 percent discount rate.

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APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

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APPENDIX 6A. DETAILED DATA FOR PRODUCT PRICE MARKUPS

6A.1 INTRODUCTION

This appendix provides further details on the retailer, distributor, and builder markups and markups validation presented in chapter 6, Markups to Determine Product Cost. The Department of Energy (DOE) presents a breakdown of revenues and expenses (previously presented in chapter 6 in an aggregated form). DOE identified expenses which scale with direct "labor" costs (such as payroll) and "all costs" (such as advertising). The sum of all expenses that scale with "all costs" is the non-labor-scaling costs (NLSC) used for incremental markup calculations in chapter 6. DOE also presents the by-state sales, payroll, sub-contract, and cost of materials data used to estimate the baseline and incremental builder markups presented in chapter 6.

To gain insight into the consumer water heater distribution channels, DOE conducted a literature review and requested an experienced consultant who specializes in the consumer water heater field, to prepare a report about water heater distribution channels.

6A.2 DETAILED WHOLESALER COST DATA

Table 6A.2.1 shows the breakdown of operating expenses for the hardware and plumbing and heating equipment and supplies merchant wholesale sector using the 2017 Annual Wholesale Trade Survey.[1]

Table 6A.2.1 Disaggregated Costs and Expenses for Wholesalers

	Amount ($1,000,000)
Sales	140,474
Cost of Goods Sold (CGS)	100,101
Gross Margin (GM)	41,373
Labor & Occupancy Expenses ("Fixed")	
Annual payroll	15,441
Employer costs for fringe benefit	3,589
Contract labor costs including temporary help	405
Purchased utilities, total	404
Purchased Repairs and Maintenance to Machinery and Equipment	269
Purchased Repairs and Maintenance to Buildings, Structures, and Offices	197
Purchased communication services	348
Lease and Rental Payments for Machinery, Equipment, and Other Tangible Items	302
Lease and Rental Payments for Land, Buildings, Structures, Store Space, and Offices	1,683
Subtotal:	22,635
Other Operating Expenses & Profit ("Variable")	
Expensed equipment	122
Purchases of other materials, parts, and supplies (not for resale)	444
Cost of purchased packaging and containers	305
Cost of purchased transportation, shipping and warehousing services	1,777
Cost of purchased professional and technical services	568
Cost of purchased advertising and promotional services	973
Cost of purchased software	137
Cost of data processing and other purchased computer services	154
Depreciation and amortization charges	1,217
Commission expenses	527
Taxes and license fees (mostly income taxes)	394
Other operating expenses	2,586
Net profit before tax (Operating profit)	8,534
Subtotal:	17,738
Incremental Markup = (CGS+Total Other Operating Expenses and Profit)/CGS	**1.177**

Source: U.S. Census, 2017 Annual Wholesale Trade Survey.[1]

6A.3 DETAILED PLUMBING CONTRACTOR DATA

Chapter 6 provides mechanical contractor revenues and costs in aggregated form by 'Cost of Goods Sold' and 'Gross Margin'. A further disaggregated breakdown of costs used to scale the incremental markup are shown in Table 6A.3.1 by both dollar value and percentage terms from the 2017 Economic Census.[2] In Table 6A.3.1, only the categories in the 'Scaling' column that are scaled with both the baseline and incremental markups are marked when there is an incremental change in product costs.

Table 6A.3.1 Plumbing Contractor Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**145,663,613**	**70.64**	
Total payroll, construction workers wages	55,924,117	27.12	
Cost of materials, components, and supplies	66,809,886	32.40	
Cost of construction work subcontracted out to others	15,843,400	7.68	
Cost of purchased lands	26,092	0.01	
Total cost of selected power, fuels, and lubricants	4,480,245	2.17	
Purchased professional and technical services	1,323,472	0.64	
Rental costs of machinery and equipment	1,062,676	0.52	
Refuse removal (including hazardous waste) services	193,725	0.09	
Gross Margin	**60,544,603**	**29.36**	
Payroll Expenses	**24,436,263**	**11.85**	**Baseline**
Total payroll, other employees' wages	17,749,793	8.61	
Total fringe benefits	5,623,693	2.73	
Temporary staff and leased employee expenses	1,062,777	0.52	
Occupancy Expenses	**2,988,327**	**1.45**	**Baseline**
Rental costs of buildings	1,413,799	0.69	
Communication services	932,999	0.45	
Cost of repair to machinery and equipment	641,529	0.31	
Other Operating Expenses	**15,064,680**	**7.31**	**Baseline & Incremental**
Data processing and other purchased computer services	222,424	0.11	
Expensed computer hardware and other equipment	444,416	0.22	
Expensed purchases of software	250,992	0.12	
Advertising and promotion services	1,061,264	0.51	
All other expenses	9,288,684	4.50	
Taxes and license fees	1,058,118	0.51	
Total depreciation ($1,000)	2,738,782	1.33	
Net Profit Before Income Taxes	**18,055,333**	**8.76**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Plumbing, Heating, and Air-Conditioning Contractors: 2017. Sector 23: 238220. Construction: Geographic Area Series. Detailed Statistics for Establishments: 2017.[2]

6A.4 DETAILED GENERAL CONTRACTOR COST DATA

Based on U.S. Department of Census data, chapter 6 shows both residential building and commercial building general contractor revenues and costs in aggregated form. Table 6A.4.1 shows the complete breakdown of costs and expenses of residential building contractor provided by the U.S. Department of Census.[3] Table 6A.4.2 shows the similar analysis for commercial building contractors.[4]

Table 6A.4.1 Residential General Contractor Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**258,374,767**	**75.55**	
Total payroll, construction workers wages	22,643,659	6.62	
Cost of materials, components, and supplies	116,014,196	33.92	
Cost of construction work subcontracted out to others	97,748,912	28.58	
Cost of purchased lands	12,408,527	3.63	
Total cost of selected power, fuels, and lubricants	6,371,037	1.86	
Purchased professional and technical services	807,656	0.24	
Rental costs of machinery and equipment	1,833,753	0.54	
Refuse removal (including hazardous waste) services	547,027	0.16	
Gross Margin	**83,635,761**	**24.45**	
Payroll Expenses	**23,189,001**	**6.78**	**Baseline**
Total payroll, other employees' wages	18,243,976	5.33	
Total fringe benefits	3,357,643	0.98	
Temporary staff and leased employee expenses	1,587,382	0.46	
Occupancy Expenses	**3,413,413**	**1.00**	**Baseline**
Rental costs of buildings	1,440,086	0.42	
Communication services	1,194,127	0.35	
Cost of repair to machinery and equipment	779,200	0.23	
Other Operating Expenses	**18,063,273**	**5.28**	**Baseline & Incremental**
Data processing and other purchased computer services	314,847	0.09	
Expensed computer hardware and other equipment	508,902	0.15	
Expensed purchases of software	373,420	0.11	
Advertising and promotion services	1,976,729	0.58	
All other expenses	11,162,785	3.26	
Taxes and license fees	1,580,517	0.46	
Total depreciation ($1,000)	2,146,073	0.63	
Net Profit Before Income Taxes	**38,970,074**	**11.39**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Residential Building Construction. Sector 23, EC0723I1: 236115 through 236118. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2017.[3]

Table 6A.4.2 Commercial General Contractor Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**343,317,381**	**79.29**	
Total payroll, construction workers wages	29,438,318	6.80	
Cost of materials, components, and supplies	118,310,102	27.32	
Cost of construction work subcontracted out to others	184,272,890	42.56	
Cost of purchased lands	106,526	0.02	
Total cost of selected power, fuels, and lubricants	7,778,246	1.80	
Purchased professional and technical services	1,483,597	0.34	
Rental costs of machinery and equipment	1,697,510	0.39	
Refuse removal (including hazardous waste) services	230,192	0.05	
Gross Margin	**89,692,056**	**20.71**	
Payroll Expenses	**27,040,957**	**6.24**	**Baseline**
Total payroll, other employees' wages	20,515,276	4.74	
Total fringe benefits	5,483,998	1.27	
Temporary staff and leased employee expenses	1,041,683	0.24	
Occupancy Expenses	**2,368,100**	**0.55**	**Baseline**
Rental costs of buildings	1,113,219	0.26	
Communication services	644,100	0.15	
Cost of repair to machinery and equipment	610,781	0.14	
Other Operating Expenses	**14,310,829**	**3.30**	**Baseline & Incremental**
Data processing and other purchased computer services	281,555	0.07	
Expensed computer hardware and other equipment	461,023	0.11	
Expensed purchases of software	323,275	0.07	
Advertising and promotion services	531,679	0.12	
All other expenses	9,323,826	2.15	
Taxes and license fees	867,178	0.20	
Total depreciation ($1,000)	2,522,293	0.58	
Net Profit Before Income Taxes	**45,972,170**	**10.62**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Residential Building Construction. Sector 23, EC0723I1: 236220 (Commercial Building Construction. Construction, Industry Series, Preliminary Detailed Statistics for Establishments: 2017.[4]

6A.5 DETAILED MOBILE HOME MANUFACTURING COST DATA

Based on U.S. Department of Census data, as shown in chapter 6, *Markups for Mobile Home Manufacturers* shows mobile home manufacturer revenues and costs in aggregated form. Table 6A.5.1 in this appendix shows the complete breakdown of costs and expenses provided by the 2017 Economic Census.[5]

Table 6A.5.1 Mobile Home Manufacturer Expenses and Markups

Item	Dollar Value *$1,000*	Percentage %	Scaling
Total Cost of Equipment Sales	**3,316,060**	**77.64**	
Total payroll, construction workers wages	784,830	18.37	
Total selected costs	2,507,410	58.70	
Rental costs of machinery and equipment	5,674	0.13	
Purchased professional and technical services	10,073	0.24	
Refuse removal (including hazardous waste) services	8,073	0.19	
Gross Margin	**955,247**	**22.36**	
Payroll Expenses	**292,831**	**6.86**	**Baseline**
Total payroll, other employees' wages	213,855	5.01	
Total fringe benefits	51,903	1.22	
Temporary staff and leased employee expenses	27,073	0.63	
Occupancy Expenses	**40,704**	**0.95**	**Baseline**
Rental costs of buildings	16,165	0.38	
Communication services	4,405	0.10	
Cost of repair to machinery and equipment	20,134	0.47	
Other Operating Expenses	**207,857**	**4.87**	**Baseline & Incremental**
Data processing and other purchased computer	993	0.02	
Expensed computer hardware and other equipment	11,289	0.26	
Expensed purchases of software	1,259	0.03	
Advertising and promotion services	12,638	0.30	
All other expenses	112,484	2.63	
Taxes and license fees	13,486	0.32	
Total depreciation	55,708	1.30	
Net Profit Before Income Taxes	**413,855**	**9.69**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. Manufactured Home (Mobile Home) Manufacturing. Sector 31: 321991. Manufacturing: Industry Series: Preliminary Detailed Statistics for Establishments: 2017.[5]

6A.6 DETAILED MOBILE HOME DEALER COST DATA

Based on U.S. Census data, chapter 6 shows mobile home dealer revenues and costs in the new construction market in aggregated form. Table 6A.6.1 in this appendix shows the complete breakdown of costs and expenses provided by the 2017 Economic Census.[6]

Table 6A.6.1 Mobile Home Dealer Expenses and Markups

Item	Dollar Value $1,000	Percentage %	Scaling
Total Cost of Equipment Sales	**35,249,999**	**67.53**	
Total payroll, construction workers wages	11,401,326	21.84	
Cost of materials, components, and supplies	16,818,176	32.22	
Cost of construction work subcontracted out to others	3,690,671	7.07	
Cost of purchased lands	11,534	0.02	
Total cost of selected power, fuels, and lubricants	2,034,296	3.90	
Purchased professional and technical services	918,450	1.76	
Rental costs of machinery and equipment	310,064	0.59	
Refuse removal (including hazardous waste) services	65,482	0.13	
Gross Margin	**16,948,186**	**32.47**	
Payroll Expenses	**5,285,213**	**10.13**	**Baseline**
Total payroll, other employees wages	4,061,911	7.78	
Total fringe benefits	984,219	1.89	
Temporary staff and leased employee expenses	239,083	0.46	
Occupancy Expenses	**1,185,303**	**2.27**	**Baseline**
Rental costs of buildings	355,098	0.68	
Communication services	190,296	0.36	
Cost of repair to machinery and equipment	639,909	1.23	
Other Operating Expenses	**4,991,109**	**9.56**	**Baseline & Incremental**
Data processing and other purchased computer services	42,644	0.08	
Expensed computer hardware and other equipment	84,824	0.16	
Expensed purchases of software	39,115	0.07	
Advertising and promotion services	189,427	0.36	
All other expenses	2,791,443	5.35	
Taxes and license fees	323,953	0.62	
Total depreciation ($1,000)	1,519,703	2.91	
Net Profit Before Income Taxes	**5,486,561**	**10.51**	**Baseline & Incremental**

Source: U.S. Census Bureau. 2017. All Other Specialty Trade Contractor. Sector 23: 238990. Construction, Industry Series, General Summary: Detailed Statistics for Establishments: 2017.[6]

6A.7 DISTRIBUTION CHANNEL LITERATURE REVIEW

To gain insight into the consumer water heater distribution channels, DOE conducted a literature review about consumer water heater markups and distribution channels (Table 6A.7.1).

Table 6A.7.1 Literature Review References

Source	Note
LBNL (2000)[7]	Water Heater Retail Price Database (1997 - 1999).
DOE (2004)[8]	Provides market share of national accounts.
ORNL(2005)[9]	Provides assessment of consumer values and the supply-chain market for the Integrated Water Heater/Dehumidifier.
NEEA (2006)[10]	Provides distribution channel fractions based on stakeholder interviews.
AO Smith (2008)[11]	Provides information about manufacturer representatives.
EPA (2009, 2010)[12,13]	Includes updated historical data.
DOE (2010)[14,15]	Provides 2010 and 2001 rulemaking methodology and historical data.
The ACH&R News (2012)[16]	Highlights increased used of the web and e-commerce.
The ACH&R News (2015)[17]	Highlights increased efforts of online distribution.
DOE (2016)[18]	Includes commercial WH distribution channels.
CEE (2018)[19]	Most recent CEE report. Provides data on distribution channels.
Biz Times (2018)[20]	56% of all water heater sales in the U.S. go through wholesale distribution channels.
Digital Commerce (2020)[21]	Bradford White balances ecommerce and product integrity
Clear Seas (2020)[22]	Proprietary purchased data. DOE has access to 2006 to 2020 data. It provides distribution fractions from the contractor perspective.
CDS Consulting (2021)[23]	Provides data on distribution channel split and market participants markups.
Plumbing Perspective (2021)[24]	Provides information about advantageous of wholesalers for contractors.
BRG (2023)[25]	Provides distribution fractions. Accounts for whole market including commercial and other product types.
Digital Commerce (2023)[26]	Highlights increased efforts of online distribution.
AO Smith (2022)[27]	Provides overall retail vs. distributor fraction.

For consumer water heaters, the main market participants in the distribution chain are: (1) manufacturers; (2) manufacturer's representatives; (3) plumbing wholesalers or distributors; (4) buying groups; (5) retailers; (6) online retailers; (7) plumbing contractors; (8) HVAC specialist; (9) Whole home energy efficiency performance contractors/raters; (10) remodelers; (11) builders/developers; (12) utilities (primarily for grid-enabled water heaters); (13) manufactured home manufacturer; and (14) manufactured home dealer/retailer. Manufacturer representatives are mostly connecting manufacturers and wholesalers in water heater distribution channel for new construction application.[11,28] Across various resources, wholesalers or distributors are reported to be taking anywhere from 49% to 56% of the overall market,[10,12,20,29] which is also validated by a customized report prepared for DOE by CDS Consulting.[23] Retailers dominate most of the remaining portion of the market with a smaller percentage of the water heaters going straightly from manufacturers to the buyer level.[22,25]

At the buyer level, customers can be categorized into two types: (1) Professional Customers, including contractors, remodelers, and builders who will markup the water heater when servicing at cost to the end consumers, and (2) Private Customers. Literature review shows that most sources believe that professional customers are taking a dominant percentage in the overall market. For example, EPA estimates that 57% at the buyer level are professional customers,[12] while according to a more recent market research done by BRG a higher market share of 81% for professional customers is estimated showing the direction in which the evolving market goes.[25] To further disaggregate the market share of professional customers, according to an EPA study, 86% of the water heaters goes to contractors while 4%, 2%, and 8% goes to builders, remodelers, and property owners respectively.[12]

In this analysis, DOE considered (1) manufacturers; (2) wholesalers; (3) retailers; (4) plumbing contractors; (5) builders; (6) manufactured home manufacturer; and (7) manufactured home dealer/retailer as the main market participants for its markup analysis. DOE considered separate distribution channels by market sectors (residential and commercial applications) and market segments (new construction and replacement/new owner). Note that a significant fraction of consumer water heaters are purchased to be installed in small to mid-size commercial buildings that have low hot water needs and where 180ºF water isn't required by code. For example, retail stores with restrooms, convenience store/gas stations, strip malls with businesses having restrooms or small break kitchens, etc.[23] Mainly for consumer water heaters in commercial applications, DOE considers an additional market participant: National account[a], through which the wholesalers sell to the customers in both replacement and new construction markets. Based on manufacturer input, customers purchased 50% through small mechanical contractors, 32.5% through large mechanical contractors, and 17.5% through national accounts.[8] Another study shows that national account takes about 15% for instantaneous water heaters[b] while wholesalers and retailers constituting the rest.[22]

DOE has done market research on the role of a buying group in instantaneous water heater distribution but did not include it *per se* for the purpose of its markup analysis. A buying group is a coalition of companies within a shared category who leverage their collective purchasing power to negotiate price reductions from manufacturers. For instantaneous water heaters, the main types of buying groups involve small regional distributors (buying groups for distributors) and plumbing/hardware stores (retailer buying groups).[23] In this analysis, DOE applied wholesaler markup and retailer markup for the two types of buying group, respectively.

DOE also took into consideration the following trends in the market: (1) online distribution: consumers purchase products through online retailers, and (2) rising big-box home centers. Study shows that it is estimated that about 22% of instantaneous water heaters are through big-box home centers and 9% are through internet.[22] Some big-box or other retail purchases lead to do-it-yourself (DIY) installation. One source shows the percentage of consumer DIY installation in the overall market being about 26%,[12] and 12.7% from another more recent source.[25]

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[a] More information can be found at: www.rheem.com/national-accounts/ and www.hotwater.com/where-to-buy/national-accounts/.
[b] This data includes water heaters that are directly from manufacturers.

6A.8 CONSULTANT REPORT (CDS CONSULTING)

The following is the markup and distribution channel report prepared by CDS Consulting,[c] for Lawrence Berkeley National Laboratory (LBNL) on October 19, 2021.

6A.8.1 Introduction

This report is based on a request from LBNL to provide markup and distribution channel information for water heater types based on my 40+ year experience in the water heater industry and recent research. This report looks at the consumer water heaters using DOE's designated product classes (as shown in Table 6A.8.1).

Table 6A.8.1 Consumer Water Heater Product Classes

Product Class	Nominal Input	Rated Storage Volume
Tabletop Water Heater	≤ 12 kW	≥ 20 gal and ≤ 50 gal
Instantaneous Gas-fired Water Heater	> 50,000 Btu/h and < 200,000 Btu/h	< 2 gal
	≤ 200,000 Btu/h	≥ 2 gal
	≤ 50,000 Btu/h	All
Instantaneous Electric Water Heater	≤ 12 kW	< 2 gal
		≥ 2 gal
Instantaneous Oil-fired Water Heater	≤ 210,000 Btu/h	All

6A.8.2 Market Participants

The following are the market participants in the water heater market. For each market participant, roles in the distribution channel and major companies associated are introduced. Note that not all of them have significant presence in the market.

- **Manufacturers** - Design, certification and supply of products. Major manufacturers are Bradford-White, A. O. Smith, Rheem. Bock, Bosch, Rinnai, Takagi, Stiebel Eltron, Ariston, Valliant, Eemax, Navien, Noritz, Titan, Viessmann and others are significantly smaller manufacturers.

- **Manufacturer's representative** - Serve a major role in the selling function for manufacturers. The majority of the major manufacturer's wholesale trade is done through representatives. The representatives are commissioned by the manufacturers, which is typically included in the manufacturer markup. The commission varies as to whether they inventory the products or simply make sales calls and ship direct from the manufacturer to the wholesaler. Most of them inventory the products and ship the products to the

[c] Drew Smith is founder of CDS Consulting and has more than 40 years of experience in the consumer water heater industry (including sixteen years in sales and marketing and nineteen years in engineering design and development). He was previously Director of Residential Engineering and Product Safety, Certification and Standards at A.O. Smith until 2007 and previously Vice President of Product Development and Research at State Industries until 2001.

wholesalers. Generally, representatives only carry one line of water heaters and are very brand dedicated. Some of them are Added Sales, Rep South, A6 Sales, TM Sales, Harry Warren and Assoc., RC Sales, and Hugh Cunningham Sales.

- **Plumbing wholesalers and distributors** - These companies are the primary way the contractors get products throughout the US. They perform a vital role in keeping the contractor supplied with the products they need and take up about 50 to 60 percent of the overall market. They warehouse the products, have a sales force calling on contractors, a city sales desk and quite often a sales showroom. Some of them are Ferguson, Winsupply, Hughes Supply, Watsco, Johnstone, R E Michel, Morrison, HD Supply, Hajoca, and Sid Harvey.

- **Buying group** - A buying group is an affiliation of individually owned businesses that, through a third party organization, pools their orders for individual products to gain buying quantity and better pricing. The orders are processed to the group company who then combines the orders by product or category and places orders with manufacturers. Some of them are Do It Best, Castle, Emery Waterhouse, and Handy Hardware. The buying group third party charges a fee for the service and handles the transactions with the supplier.

- **Retailers** - Most retailers are sold direct from manufacturers or through Sales Rep organizations. The "big box" stores maintain an inventory of branded water heaters and are shipped directly from the manufacturer to their stores or they have regional warehouses which supply their stores. Retailers sell to anyone walking through their door and take up 40 to 50 percent of the market. The larger retailers maintain a list of installing contractors who will give the customers a quote and do the installation. Some contractors will buy from Retailers but in some cases they prefer wholesalers who can provide all the products and supplies they need and offer discounts and services that the retailers don't provide such as payment terms, delivery, easy warranty claims, quantity incentives, etc. Some of the retailers are Home Depot, Lowes, Ace Hardware, Sears, Menards, Do it Best, Handy Andy, and True Value.

- **Online retailers** - Not as common before for traditional water heater manufacturers, but the tankless water heaters brought more interest for online retailers. In general, internet sales are not a preferable distribution channel (primarily because of liability and pricing). There is a mix of companies that advertise water heaters on the internet. Some are internet only organizations and others are retailers with sites on the internet. Some provide a list of installers but experience has been that these listings are obsolete or if active, the installer wants to come to your house to quote a turnkey job. Most of the direct sellers offer instantaneous or small point of use water heaters without any reference to installers. The challenge to the consumer is paying for a product "sight unseen" when shipped from someone they don't know and having to arrange their own installer. This is a *small* segment of instantaneous sales. Some of them are Supplyhouse.com, Amazon.com, Overstock.com, ecomfort.com, AFSupply.com, eBay.com, consumersplumbing.com, and Acwholesalers.com.

- **Contractors (plumbing contractors)** - Plumbing contractors supply and install about half of all water heaters sold. They also install about 25% of the water heaters purchased from retailers by home and property owners. They are the point of contact with the end user. Many municipal codes require water heaters to be installed by a licensed plumber and a permit be acquired for the job. Obviously, the contractor is held responsible for the safety and conformance of the job to the manufacturer's instructions and all code requirements. There are over 170,000 plumbing contractors in the US. Some of the larger ones are Atlas, Chesapeake, J A Croson, Garrett's, TD Industries, New York Plumbing and Heating, Roto Rooter, Dallas Plumbing and Air, and Brothers Plumbing Heating and Electrical.

- **HVAC specialists** - Many companies listed as water heater contractors are also HVAC contractors. These perform the same function as plumbing contractors and they share the importance of safe, code conforming installers. Some of them are New York Plumbing and Heating, Dallas Plumbing and Air, Beacon Plumbing Heating and Electrical, and Brothers Plumbing Heating and Electrical.

- **Whole home energy efficiency performance contractors, raters** - This segment is very complex in form. Many Home Energy Raters work with Plumbing and HVAC contractors to make improvements in the building envelope. Because of the licensing involved in the trade areas of water heating, piping, HVAC equipment and duct work, insulation, windows, doors and such, this category is hard to define. The market segment serviced by this category is difficult to define. The best reference for companies in this category would be Utility Companies who often have associations with these specialists.

- **Remodelers** - This group ordinarily sub-contracts plumbing and water heater installation, especially where codes require permits and licensed installers. With this said, where no codes require permits and/or licensed plumbers, a remodeling contractor may buy and install water heaters. This is a small segment of the overall market.

- **Builders/Developers** - These use plumbing contractors for the purchase and installation of water heaters. Very large tract builders may purchase the water heater along with appliances from a distributor but in the vast majority of cases, the plumber quoting the entire plumbing job for the house includes the water heater along with piping, lavatories, faucets, tubs, sinks and other plumbing items. A little over million water heaters are installed in this category every year. Some of the builders are D.R. Horton, Lennar, PulteGroup, CalAtlantic, Toll Brothers, KB Homes, Taylor Morrison, and Shea Homes.

- **Utilities (primarily for grid-enabled water heaters)** - This is a very small segment of the water heater market and the actual equipment requirements vary from one utility to another. Inconsistency of equipment specifications is a counter to growth in this segment. Most of the major water heater manufacturers have "pilot" programs with utilities. However, the general consensus is that until large amounts of single design "Grid Water Heaters" can be manufactured down an assembly line at reasonable cost, this program will not foster water heater manufacturer involvement. Hence, the market opportunity may develop faster with Utility "add on" equipment to the exterior of the water heater. There are efforts to "commonize" control equipment to entice water heater manufacturers' involvement in these programs. Some active utilities today are Mosaic Power, Arizona Public Service, Portland General Electric.

- **Manufactured home manufacturer** - Water heaters installed in new manufactured homes are purchased directly from the water heater manufacturer. In many cases there may be a water heater manufacturer's representative company acting as an agent (sometimes with water heater inventory) between the water heater manufacturer and the home manufacturer. The water heaters are installed by the home manufacturer on their assembly line. The water heater volume in this segment is about 90,000 units per year. Large manufacturers are Champion, Clayton, Fleetwood, Silvercrest, Cavco, Palm Harbor, Live Oak, Fairmont, Adventure, Commodore, and O'Hara.

- **Manufactured home dealer** - Most dealers are either owned by the home manufacturer or are franchised with the home manufacturer. However, there are many independent dealers that sell more than one manufactured brand. These dealers (of either type) are the intermediary seller of the mobile home to the consumer. They sell and receive payment, accommodate financing, transport and set up the home and in many cases give the buyer references for land purchase or lease. The dealers are responsible for warranty coverage on the home and in most cases will arrange an in-warranty water heater replacement. There are manufactured home service companies which specialize in warehousing unique parts and provide service for manufactured home owners. These companies also sell water heaters for replacement and they get water heaters uniquely designed for manufactured homes from the same water heater manufacturer's representatives as the home manufacturers. These service companies also buy non-manufactured home specific water heaters from wholesalers and retailers. Mobile Home manufacturers install specific water heaters designed for Mobile Home use. Whereas, other types of manufactured housing can use standard home type water heaters. Large independent dealers are Independent Homes Inc., Freedom Homes, Mobile Homes Direct, Schroeder's All American Homes, and Wood's Mobile Homes. Refer to the list of manufacturers above for owned or franchised dealers.

6A.8.3 Distribution Channels

The typical (main) distribution channels and the market shares for residential water heaters are shown in Table 6A.8.2. Contractor will tend to purchase from wholesalers since they get more discounts (the more they buy the more the discount), but because of product availability some might turn to retailers. For new construction, 80% or more cases are plumbing contractors being subcontracted by builders. The plumbing contractor will do the whole plumbing job for the site. The builder may buy the water heater as part of a builder package, but this seldom occurs. The plumbing contractor usually has the water heater as part of the total plumbing job. In the table, "builder" includes tract builder, custom builder, and general contractor. Tract builder is volume builder, with lower markup. Contractors have more work through tract builders, but with reduced markup. For mobile home replacements, it is estimated that 70% will go through mobile home dealers while 30% go through service companies or plumbing contractors.

Table 6A.8.2 Summary of Distribution Channels by Market Share

Distribution Channel	Market Share
Replacement/New Owner (includes manufactured home)	**80%**
1. Manufacturer ⇒ Wholesaler/Dealer ⇒ Plumbing Contractor ⇒ Consumer	*52%*
2. Manufacturer ⇒ Retailer ⇒ Consumer	*47%*
3. Manufacturer ⇒ Buying Group ⇒ Retailer ⇒ Consumer	*1%*
New Construction (not including manufactured home)	**11%**
4. Manufacturer ⇒ Wholesaler/Dealer ⇒ Plumbing Contractor ⇒ "builder" ⇒ Consumer	
New Construction (manufactured home only)	**1%**
5. Manufacturer ⇒ Manufactured Home Builder ⇒ MH Dealer ⇒ Consumer	
Replacement/New Owner (manufactured home only)	**1%**
6. Manufacturer ⇒ Manufactured Home Dealer/Service Company/Plumbing Contractor ⇒ Consumer (mostly for MH GSWHs, some for MH ESWHs)	
Commercial Applications Only	**5%**
7. Manufacturer ⇒ National Account ⇒ Plumbing Contractor/Installer ⇒ Consumer (Mainly multi-family applications)	
Replacement/New Owner (online retail**)**	**<1%**
8. Manufacturer ⇒ Internet ⇒ Consumer	

Table 6A.8.3 shows the typical distributions channels by product class (including the main distribution channels for residential water heaters sold in commercial applications).

Table 6A.8.3 Summary of Distribution Channels by Product Class

Product Classes	1	2	3	4	5	6	7	8
Tabletop Electric	Y	Y						
Grid Electric	Y			Y			Y	
Instantaneous Gas	Y	Y	Y	Y			Y	Y
Instantaneous Electric	Y	Y	Y				Y	Y
Instantaneous Oil	Y	Y		Y			Y	

Note:
1. Manufacturer – Wholesaler/Dealer – Contractor – Consumer
2. Manufacturer – Retailer – Consumer
3. Manufacturer – Buying Group – Retailer – Consumer
4. Manufacturer – Wholesaler/Dealer – Contractor – Builder – Consumer
5. Manufacturer – Mobile Home Builder – Mobile Home Dealer – Consumer
6. Manufacturer – Mobile Home Dealer/Service Company/Contractor – Consumer
7. Manufacturer – National Account – Contractor/Installer – Consumer (Mainly multi-family applications)
8. Manufacturer – Internet – Consumer

In the future, a bigger role in internet sales for equipment prices can be expected. This will exert increased pressure on contractors and retailers for sharp equipment prices. However, labor is seldom listed on the internet. Thus, any reduction in stated equipment prices may be compensated for in raised labor and material prices for a quote or finished job. Some Instantaneous products will see sales growth on the internet as this is their mainstream form of advertising.

However, it is not expected that online sales will make up a significant portion of total sales in the future. Some instantaneous manufacturers, particularly electric, do sell on the internet but the complexity of installation is left to the buyer or the buyer's installer and this limits serious growth. Instantaneous sales on the internet by major manufacturers is somewhat limited because the manufacturer has a vested interest in the quality of the installation of their equipment. Once the product is sold on the internet, the manufacturer loses connection to the installation.

In terms of installation of the equipment, the self-installation (Do-it-Yourself) market is a significant portion for this equipment. The complexity of new venting, electrical supply and larger gas lines for high efficiency gas instantaneous and the higher amperage requiring new wiring in instantaneous electric, limits DIY installation of these products.

6A.8.4 Markup Values for Plumbing Contractors

The plumbing contractor's markup on the water heater equipment is dependent on the type of sale. Emergency replacements generate higher markups than tract home complete plumbing jobs or negotiated contracts with maintenance companies. Generally, the contractor will want markups as high as possible but they are aware that many homeowners surf the internet for prices on water heaters. So, they could move profit from equipment to installation materials and/or labor. Emergency sales generate water heater markups in the 45 to 50% range. Other sales are more moderate in the 25 to 35% range.

Table 6A.8.4 summary of ways plumbing contractors' markup their equipment.

Table 6A.8.4 Summary of Markup Values

Markup Description	Markup Value	Frequency
Use the same markup as all other costs such as labor	Markup around 30-60%	80% of sales
Do not Markup equipment cost, only markup labor cost	Markup around 0%	5% of sales (Very seldom), primarily to get the job from a competitor.
Markup to cover mainly profit, handling, transportation	Markup around 10-15%	15% of sales, not often, usually in slow season, to compete for a job that includes a water heater, contracted builder business.

Typically, wholesalers, retailers, contractors (plumbers) adjust their markup values between low-efficiency models and high-efficiency models. The entire market channel marks up "premium" (including added features, longer warranties, and premium aesthetics) or higher efficiency water heaters more than the base or minimum efficiency models. This is very traditional in this business and not uncommon in many other efficiency mandated products. The "good, better, best" market approach involves added cost for manufacturers in areas such as better grade tank or heat exchanger materials, better trim and finishing, improved heat transfer, better electric heating elements, electronics, better ignition systems, better anodic protection of metals, larger overall product and related packaging with commensurate higher freight cost, extended warranties, and with product complexities comes more service support. All this and other added costs generate the desire for more markup percentage in the "better" and "best" products. Each member in the distribution chain "tacks on" their desired increase in markup for these better featured products.

Contractors have been adjusting markups as new products are introduced and the economy fluctuates. They adjust their markup up or down to satisfy their bottom line to stay in business. During the current pandemic, many homeowners don't want workers in their house unless there is an emergency, like water heater leaking, HVAC system not working, etc. That means contractors have to be really competitive to stay in business.

6A.8.5 Estimates of Water Heater Shipments by Market Segment

Table 6A.8.5 shows the estimated shipments based on my years of experience by market segment (replacement, new construction, and new owners) in a typical year.

Table 6A.8.5 Estimated Fraction of Shipments by Market Segment

Product Class	Estimated Fraction of Shipments (%)		
	Replacements	New Owner	New Construction
Tabletop Water Heater	98	1	1
Instantaneous Gas-fired Water Heater	45	20	35
Instantaneous Electric Water Heater*	30	50	20
Instantaneous Oil-fired Water Heater	85	5	10

*The numbers for Instantaneous Electric Water Heater include models ≤ 12 kW.

General trend is that tabletop creeping down, instantaneous gas creeping up, instantaneous electric static, and instantaneous oil-fired creeping down, and grid enabled water heaters creeping up. Major shifts don't occur from one year to next. There are very few new gas lines being laid, nationally. Nuclear power is stagnate, wind and solar are growing slowly in geographical zones. Major shifts regionally are not anticipated.

Instantaneous Gas replacement is growing because of space constraints installing large storage replacement water heaters. It can be an expensive changeover if new gas lines are necessary.

Table 6A.8.6 shows my estimated fraction of residential water heaters in commercial applications (such as multi-family buildings owned by property management companies) by product class.

Table 6A.8.6 Estimated Fraction of Shipments by Residential/Commercial Applications

Product Class	Estimated Fraction of Shipments	
	Residential	**Commercial**
Tabletop Water Heater	99	1
Instantaneous Gas-fired Water Heater	80	20
Instantaneous Electric Water Heater	30	70
Instantaneous Oil-fired Water Heater	90	10

The commercial building types and/or commercial applications are primarily those installations that have low volume hot water needs and where 180ºF water isn't required by code. For example, retail stores with restrooms, convenience store/gas stations, strip malls with businesses having restrooms or small break kitchens (especially where electric or gas utilities are paid by the occupying business), hair studios, auto mechanic garages, tire stores, florists. Note, most manufacturers reduce the warranty period on commercial installations of residential water heaters. And having several residential units may incur much more maintenance and service than a single commercial water heater.

A commercial building application would use a residential water heater instead of a commercial water heater (e.g., using multiple small residential water heaters instead of a larger commercial water heater), because it offers the ability to add water heating to electric or gas bills that is individually billed to the tenant. No code or requirement for 180ºF water or NSF certification. Also, residential water heaters are less expensive to buy and install. They are suitable for cases of low hot water demand.

Estimation is that about 15 percent or less of commercial water heaters (residential duty commercial water heaters) are used in residential applications.

These fractions, as shown in Table 6A.8.6, seem not to change significantly by region or over time. It is more defined by the original plan of the building and seems to continue, as designed, in time. Generally, which product class is more commonly used in commercial application depends on the fuel available in the building. Electricity is usually more easily available and gas may not be available or the necessary routing for a vent system.

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APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

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APPENDIX 6B. INCREMENTAL MARKUPS: THEORY AND EVIDENCE

6B.1 INTRODUCTION

Since 2004, the U.S. Department of Energy (DOE) has applied the incremental markup approach to estimate the increase in final product price of high-efficiency products as a function of the increase in manufacturing cost.[1] In this appendix we calculate the change in final consumer prices due to minimum efficiency standards, focusing on a standard economic model of the air-conditioning and heating equipment (ACHE) wholesale industry. The model examines the relationship between the marginal cost to distribute and sell equipment and the final consumer price in this industry. The model predicts that the impact of a standard on the final consumer price is conditioned by its impact on marginal distribution costs. For example, if a standard raises the marginal cost to distribute and sell equipment a small amount, the model predicts that the standard will raise the final consumer price a small amount as well. Statistical analysis suggest that standards do not increase the amount of labor needed to distribute equipment the same employees needed to sell lower efficiency equipment can sell high efficiency equipment. Labor is a large component of the total marginal cost to distribute and sell air-conditioning and heating equipment. We infer from this, that standards have a relatively small impact on ACHE marginal distribution and sale costs. Thus, our model predicts that a standard will have a relatively small impact on final ACHE consumer prices. Our statistical analysis of U.S. Census Bureau wholesale revenue tends to confirm this model prediction. Generalizing, we find that the ratio of manufacturer price to final consumer price prior to a standard tends to exceed the ratio of the change in manufacturer price to the change in final consumer price resulting from a standard. The appendix expands our analysis through a typical distribution chain for commercial and residential air-conditioning and heating equipment. Under this approach, DOE applies a lower markup than the average markup to the incremental cost of higher-efficiency products, relative to the baseline product. The approach is described in detail in chapter 6.

DOE's incremental markup approach is based on the widely accepted economic view that prices closely reflect marginal costs in competitive markets and in those with some degree of concentration. Evaluating 2023 industry data in IBISWorld suggests that most of the industries relevant to heating, ventilation, and air conditioning (HVAC) wholesalers and contractors are considered to have low market concentration, high and increasing market competition and low to medium barriers to entry (see Table 6B.1.1).[2]

Table 6B.1.1 Competitive Environment of HVAC Sectors

Sector	Industry Concentration	Competition	Barriers to Entry
Home builders	Low	High and increasing	Low and steady
Commercial building construction	Low	High and steady	Medium and steady
Heating & air-conditioning contractors	Low	High and increasing	Medium and steady
Heating & air-conditioning wholesaling	Low	High and steady	Medium and increasing

Examining gross margin and price data in HVAC wholesale industry over time, DOE finds that both gross margins and prices did not demonstrate any persistent trend; thus, this set of historical data has no bearing on firm markup behavior under product price increases, such as may occur as a result of standards.

To investigate markup behavior under product price increases, DOE evaluated time series gross margin data from three industries with rapidly changing input prices – the LCD television retail market, the U.S. oil and gasoline market, and the U.S. housing market. Additionally, DOE conducted an in-depth interview with an HVAC consultant who represents many individual contractors in the industry.

6B.2 MARGIN TRENDS UNDER PRICE VOLATILITY

Heating, Air-Conditioning and Refrigeration Distributors International (HARDI) published annual profit report with aggregated financial and operating data of its participating firms in HVAC wholesale industry.[3] DOE evaluated the percent gross margins[a] and sales revenue per shipment received (as a proxy for average HVAC wholesale prices) reported from 1999 to 2012 for typical HARDI distributors.[b] As shown in Figure 6B.2.1, average HVAC wholesaler prices have experienced some fluctuations during this period of time, but the overall wholesale price trend is relatively stable, with a price increase of four percent from 1999 to 2012.

However, the existence of constant percent margin over time is not sufficient to identify an industry's markup practice without considering the underlying input price changes during the same period. If the prices have been relatively constant, the incremental markup approach will arrive at the same result as applying constant margin. In fact, the average HVAC wholesale prices have been relatively stable over time;[c] hence, the historically constant percent margins do not necessarily imply a constant percent margin in the future, especially in the case of increased input prices due to standards (Figure 6B.2.1).

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[a] Percent gross margin is defined as gross margin in percentage of sales revenue.
[b] The typical distributors are the firms with median financial results among all participating firms.
[c] In 2005 the HVAC market experienced a brief 15-percent price rise. The HVAC price increase may be attributed to the 2006 Central Air-Conditioner and Heat Pump Standard. Percent gross margins declined slightly at this time.

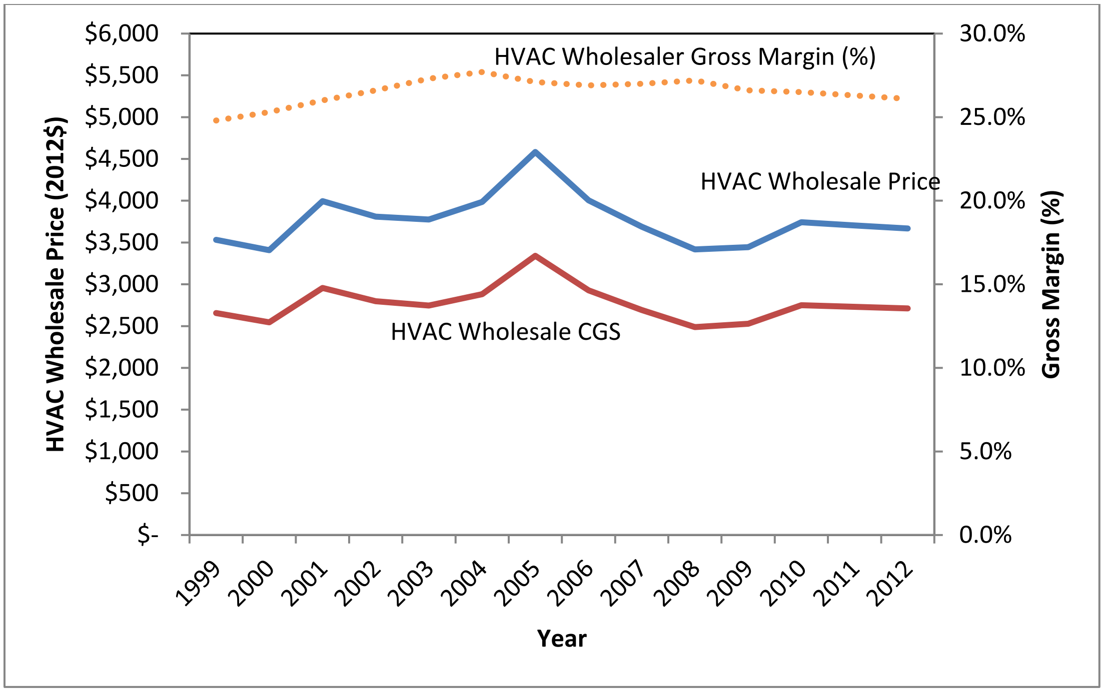

Figure 6B.2.1 HVAC Wholesale Prices, Cost of Goods Sold and Gross Margins

As historical data in HVAC wholesale markets cannot be used to address the question of margins under a price shock, DOE looked to other publicly available data for markets of a single product that have experienced noticeable price changes, evaluating the prevalence of fixed percent gross margins.

To replicate the theorized conditions of efficiency standard implementation, DOE would ideally analyze a household durable that has experienced a consistent rise in price, such as may occur as a result of standards. The LCD television retail market, on the other hand, is a market with a consistently downward price trend since 2007. The material costs and retail prices of LCD televisions have both dropped substantially over this period. At the same time, average retailer gross margins have decreased from 25 percent in 2007 to only 6 percent in late 2014. Under the change in input price (i.e., cost of goods sold (CGS)), retailers did not maintain constant percent gross margins (Figure 6B.2.2).[d]

[d] LCD television data from DisplaySearch, a market research company affiliated with NPD Group.

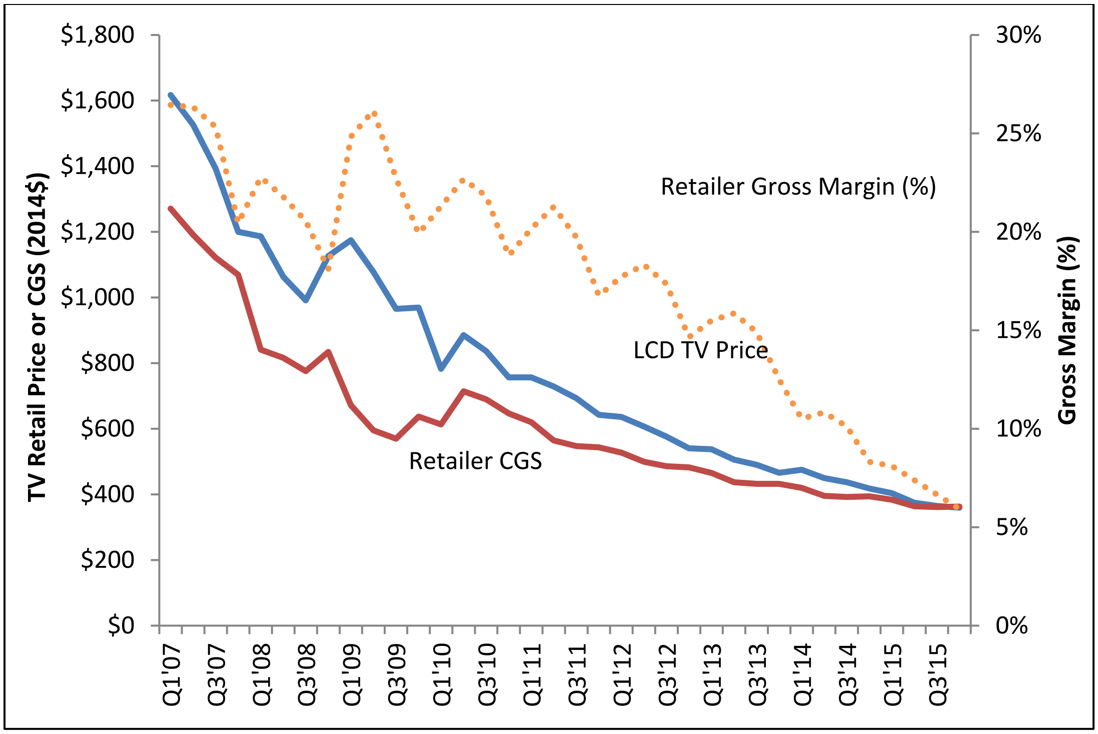

Figure 6B.2.2 LCD TV Prices, Cost of Goods Sold and Gross Margins

DOE also analyzed margin behavior in markets with upward price trends to test the prevalence of fixed percent gross margins. U.S. imported crude oil prices rose by $2.50 per gallon from 1995 to 2008, but the percent retail gross margins have decreased during the same period of time (Figure 6B.2.3).[4,5]

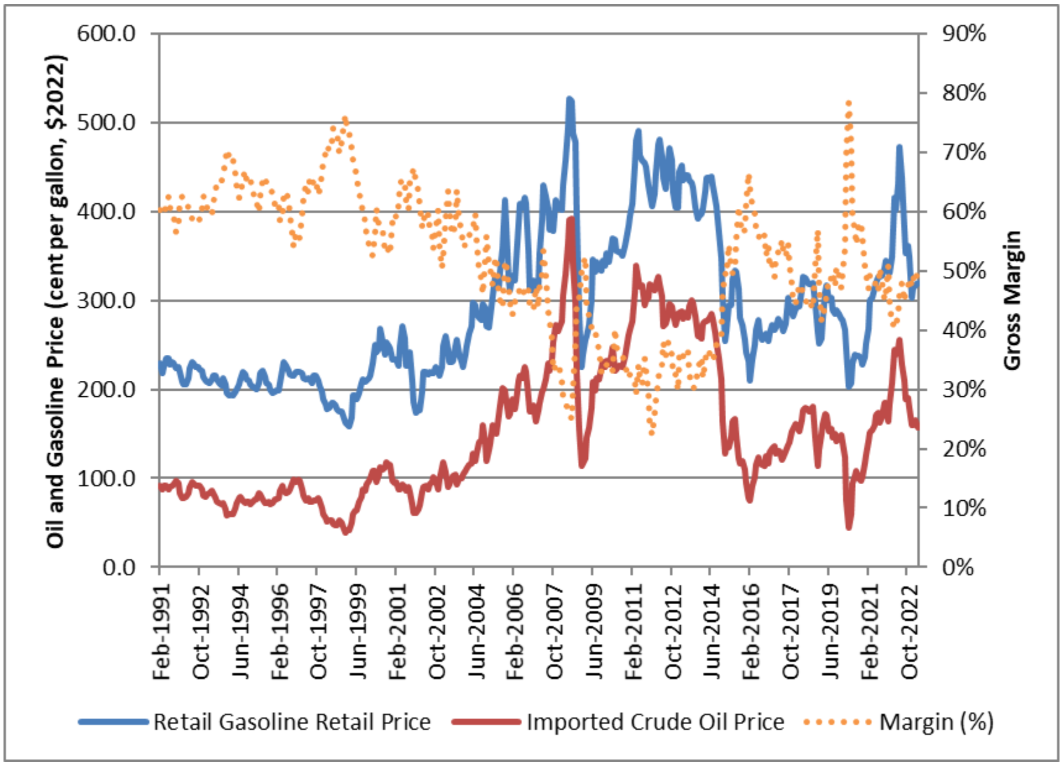

Figure 6B.2.3 Oil and Gasoline Price, Gross Margin

The U.S. inflation-adjusted median home sales prices and the costs of selling, measured by home sales price minus agent's commission fee, have increased substantially from 1991 to 2005. The percent gross margin in the housing market (i.e., commission rate), however, has declined by 15 percent over this period.[e] (Figure 6B.2.4)[7,8,9,10,11] Similar pattern was found during the period from 2011 to 2018. In short, fixed percent gross margins are not observed in this market with increasing costs.

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[e] Federal Trade Commission and the U.S. Department of Justice published a report, titled "Competition in the Real Estate Brokerage Industry", which provides extensive literature review on the topic of housing prices and brokerage commission fee, and the empirical evidences are consistent with our findings.[6]

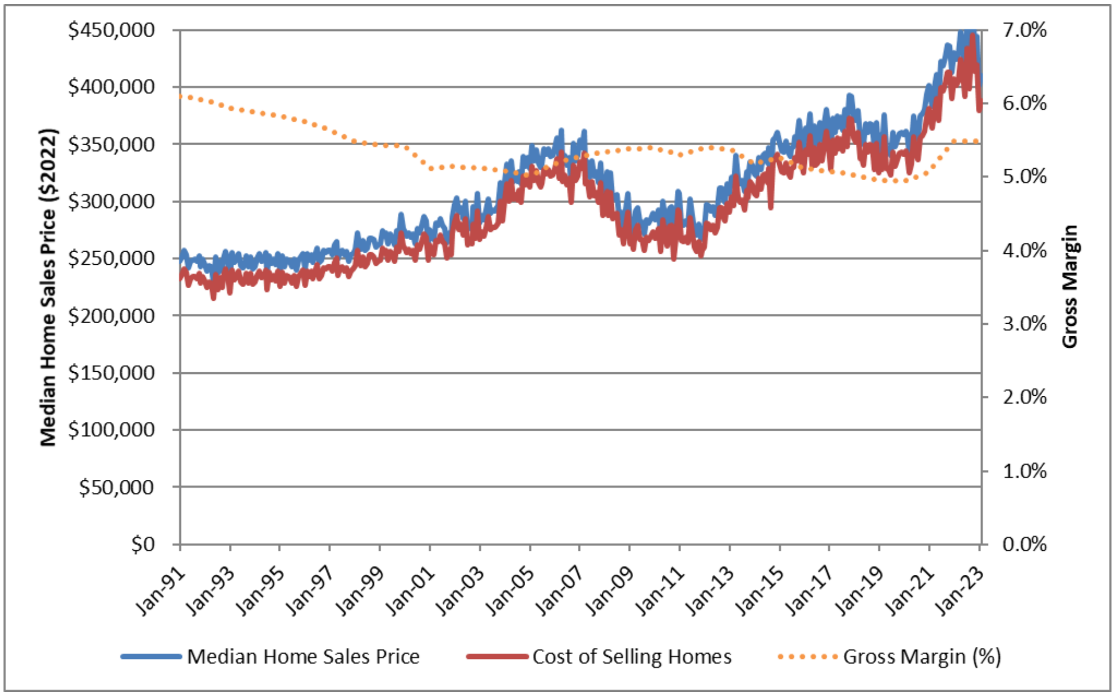

Figure 6B.2.4 House Sales Price, Costs of Selling Homes, and Realtor Commission (%)

After examining price and gross margin data in various markets, the results indicate that prices could go up or down in different circumstances, but in no case are percent gross margins observed to remain fixed over time. Hence, DOE does not expect that firms can sustain on applying constant markups on incremental costs of more efficient products after standards.

6B.3 SUMMARY OF CONSULTANT INTERVIEW

To gain insight into contractor markup determination, DOE interviewed an experienced consultant who specializes in the HVAC contracting field (see consultant interview in section 6B.4).[f] Because the incremental markup is applied in a very specific analytical situation where the input cost increases due to the standard while other costs remain the same, it was necessary to carefully craft the interview to accurately convey the concept. The list of key questions asked of the consultant includes the following points:

1. *Assuming the HVAC equipment price increases while the other costs remain constant (no change in labor, material, and operating costs), are contractors still able to keep the same markup over time as before?*
2. *Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?*

[f] Michael Stone is co-founder of Construction Programs & Results, Inc. (www.markupandprofit.com), has more than five decades of experience in the building and remodeling industry, and is the author of Markup and Profit; A Contractor's Guide (1998), Profitable Sales: A Contractor's Guide (2007), and, Markup and Profit; A Contractor's Guide Revisited (2012).

3. *If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?*

The consultant responded as follows:

1. *Initially, contractors will attempt to use the same markup after the increase in input cost occurs, but, assuming there is no increase in other costs, "they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated."*
2. *Any increase in profit following an input cost increase is likely to be short-lived. "There are too many pressures on contractors to lower their prices for various reasons… We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago."*
3. *Contractor profit margins and markups are typically reevaluated every three to six months; this limits the timeframe in which higher-than-sustainable profits are likely to persist.*

The consultant's responses provide real-world evidence indicating that HVAC contractors aim to maintain fixed percent markups, but market pressures force them to reevaluate and adjust markups over time to stay competitive. This empirical phenomenon reinforces the underlying theory and assumptions inherent in the incremental markup approach used in DOE's post-standard price projections. While the consultant speaks specifically to the practices of HVAC contractors, his descriptions of firm response to cost increase over time in a competitive environment can be logically extended to wholesalers and retailers as well. DOE concludes that the combined evidence of changing percent gross margins across industries with cost changes and the support of the industry consultant justify the use of the incremental markup approach.

6B.4 CONSULTANT INTERVIEW REPORT

In this section, the original responses from consultant regarding markup practice in construction industry is presented as a supplementary material supporting the use of incremental markup when estimating the consumer product price of more efficient products.

To: Lawrence Berkeley National Laboratory
From: Michael Stone, Construction Programs & Results, Inc.
Date: January 26, 2015
Re: Supplementary questions on contractor markups

After a new energy efficiency standard is in place, the equipment prices generally go up as less efficient (cheaper) ones are eliminated on the market by new standard. The questions below are intended to help us understand the impact of increased equipment prices on contractors' markup practices and profitability. That is, how contractors react to this change in equipment price while the other costs remain constant.

(1) Assuming the equipment price increases while the other costs remain constant (no change in labor, material and operating costs), are contractors still able to keep the same markup over time as before?

Michael Stone (Michael): *Yes and no. The contractors will attempt to use the same markup over time, but, assuming no increase in other costs, they'll eventually either have to lower their markup based on market pressures, or they'll choose to lower their markup when it's reviewed and recalculated.*

Keep in mind the numbers and our answer assume a "pure" company; one that currently only installs the lower efficiency units and that in the future will only install the higher efficiency units. They don't perform any other service work or install any other equipment. Those companies don't exist in real life. So it's most likely that on individual sales, if under pressure, the contractor might choose to reduce their markup because they recognize the equipment price increase without other related cost increases. The markup change will happen when the company's finances are reviewed, and the equipment cost increase will be only one factor in the adjustment.

(2) Keeping a fixed markup when the equipment price goes up implies that the contractor's profitability would increase, assuming no other cost changes. Is this increase in profitability viable over time?

Michael: *Probably not. There are too many pressures on contractors to lower their prices for various reasons. Unless building owners suddenly have more money to spend and consider the work on their building valuable enough to pay what it's worth, profitability will stay the same.*

We'll guess this isn't the first time over the past 40 years that equipment prices have increased because of regulatory changes rather than inflationary or commodity price increases. Construction today is not a more profitable industry than it was decades ago.

(3) If contractors would have to adjust their markup in this situation due to competition, how long does it take for them to revisit their markup values and adjust the firm's profitability to a competitive level?

Michael: *Generally speaking, 3-6 months.*

(4) For commercial contractors, is the market as competitive as for residential contractors? Is there a significant difference in their ability to maintain a fixed markup between commercial and residential contractors? If so, please elaborate the differences.

Michael: *There are so many variations in how commercial contractors operate, and the market is considerably different than residential. But it is as competitive.*
Many of them get jobs because of their connections. They do a lot of marketing and schmoozing, promoting themselves to buyers. This enables them to get jobs easier. If they have long-time relationships with general contractors who are primarily concerned with getting a job well-built with few problems, they can have an easier time maintaining a fixed markup. If they have long-time relationships with general contractors who are more concerned about getting the job built at the lowest possible price, they might choose to cut their price to get jobs.
Others get jobs by competing to be the lowest price. If they have relationships and can influence the bid process, they might have a bid that's written with them in mind, making it easier for them to be low bid and still maintain a reasonable markup on the job. Other contractors just shoot to be the lowest bid and have a tough time being profitable (ie, no, they don't maintain a fixed markup).

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APPENDIX 7A. HOUSEHOLD AND BUILDING VARIABLES

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APPENDIX 7A. HOUSEHOLD AND BUILDING VARIABLES

7A.1 INTRODUCTION

U.S. Department of Energy (DOE) created a database containing a subset of the records and variables from DOE's Energy Information Administration (EIA)'s 2020 Residential Energy Consumption Survey (RECS 2020)[1] and DOE's Energy Information Administration (EIA)'s 2018 Commercial Building Energy Consumption Survey (CBECS 2018)[2] using Microsoft ACCESS. DOE used this RECS 2020 subset in the life-cycle cost (LCC) analysis of the gas-fired instantaneous water heaters rulemaking. This appendix explains the variable name abbreviations and provides definitions of the variable values.

The RECS consists of two parts:

- Web and mail survey forms sent to households to collect detailed information on household energy characteristics including physical characteristics of the home and energy use behaviors
- Data from energy suppliers to these homes to estimate energy costs and usage for heating, cooling, appliances and other end uses

For the entire RECS 2020 dataset, refer to: www.eia.gov/consumption/residential/data/2020/index.php?view=microdata.

For the entire CBECS 2018 dataset, refer to: www.eia.gov/consumption/commercial/data/2018/index.php?view=microdata.

DOE derived water heater samples for Gas-fired Instantaneous Water Heaters (GIWHs).

7A.2 RESIDENTIAL SAMPLE DETERMINATION USING RECS DATA

RECS 2020 includes energy-related data from nearly 18,500 housing units that represent almost 123.5 million occupied households. RECS 2020 includes information such as the household or building owner demographics, fuel types used, energy consumption and expenditures, and other relevant data. DOE used RECS 2020 to establish a sample of households that use gas-fired instantaneous water heaters (see Table 7A.2.1).

The subset of RECS 2020 records used in the analysis met the following criteria:

- A water heater served as the primary or secondary source of heated water.
- The water heater used one of two heating fuels (gas or propane).
- The RECS 2020 record included use of a tankless water heater.

- The water heater’s energy consumption was greater than zero.

The RECS 2020 weighting indicates how commonly each household configuration occurs in the general population. Table 7A.2.1 shows the RECS sample weights and criteria for replacement and new construction samples. DOE accounted for the projected growth of the number of gas-fired instantaneous water heaters by 2030 based on shipments analysis and made some adjustments to EIA’s weightings for each RECS 2020 household in order to create the gas-fired instantaneous water heater weights of shipment in 2030. The gas-fired instantaneous water heater sample weights are also adjusted to account for:

1. Households sharing a gas-fired instantaneous water heater with another housing unit: RECS 2020-reported weight is decreased by the number of units sharing a gas-fired instantaneous water heater. Multi-family unit (2-4 units and 5 or more units) is assumed to share a gas-fired instantaneous water heater with another and 4 other housing units, respectively, if the water heater is reported to be shared;
2. Households with multiple gas-fired instantaneous water heaters: RECS 2020-reported weight is increased by the number of gas-fired instantaneous water heaters in a household (assumed to be two maximum) for households listed in RECS 2020 with a primary and secondary gas-fired instantaneous water heater of the same fuel;
3. RECS 2020 does not distinguish between water heating for a boiler (e.g., using an indirect tank or a combi-boiler) or water heaters. For water heaters, with a same fuel boiler and water heating, DOE assumed that 45% use a boiler, so the weight is decreased by 45%.
4. For the new construction sample, DOE used only households built after 2000.

Table 7A.2.1 Selection of RECS 2020 Records for Gas-fired Instantaneous Water Heaters in Replacement and New Construction Applications

Product Class	Algorithm*	No. of Records	RECS 2020 No. of U.S. Households Represented *(million)*	DOE 2030 No. of U.S. Shipments Represented *(million)*
Replacement				
GIWH	(WHEATSIZ = 4 AND FUELH2O = 1 or 2)	807	4.9	0.454
New Construction				
GIWH	(WHEATSIZ = 4 AND FUELH2O = 1 or 2), while YEARMADERANGE >= 7	307	1.6	0.421

* RECS 2020 variable definitions: WHEATSIZ = Main water heater size (4 = tankless); FUELH2O = Fuel used by main water heater (1 = Natural Gas; 2 = Propane; YEARMADERANGE = Range when housing unit was built (7 = 2000 to 2009; 8 = 2010 to 2015, 9 = 2016 to 2020).

Table 7A.2.2 shows the final sample weight by state for replacement and new construction, respectively.

Table 7A.2.2 Gas-fired Instantaneous Water Heater Sample Weights for Replacement and New Construction by State for Residential Applications

States	GIWH, %	
	Repl.	NC
Alabama	1.05	1.99
Alaska	0.41	0.44
Arizona	2.65	2.61
Arkansas	0.43	0.00
California	21.17	14.44
Colorado	2.41	2.49
Connecticut	1.13	1.12
Delaware	0.64	1.20
District of Columbia	0.07	0.08
Florida	4.68	4.56
Georgia	2.62	3.02
Hawaii	0.28	0.16
Idaho	0.52	0.90
Illinois	1.57	0.75
Indiana	1.48	0.58
Iowa	0.72	0.45
Kansas	0.67	0.56
Kentucky	0.35	0.08
Louisiana	1.51	2.04
Maine	0.97	1.18
Maryland	0.97	0.74
Massachusetts	3.10	2.06
Michigan	2.76	0.00
Minnesota	1.44	0.27
Mississippi	1.35	1.82
Missouri	0.89	1.02
Montana	0.94	1.38
Nebraska	0.19	0.53
Nevada	1.24	2.50
New Hampshire	0.64	0.60
New Jersey	2.92	0.75
New Mexico	0.54	0.65
New York	3.90	1.79
North Carolina	3.30	4.67
North Dakota	0.14	0.06
Ohio	2.62	1.14
Oklahoma	0.91	1.93
Oregon	1.07	0.84
Pennsylvania	2.08	0.64
Rhode Island	0.40	0.21
South Carolina	2.60	3.84
South Dakota	0.35	0.75
Tennessee	2.03	3.32
Texas	9.84	21.41

States	GIWH, %	
	Repl.	NC
Utah	1.09	1.94
Vermont	0.35	0.17
Virginia	2.65	3.18
Washington	2.90	2.74
West Virginia	0.08	0.00
Wisconsin	0.99	0.00
Wyoming	0.39	0.37

7A.3 COMMERCIAL SAMPLE DETERMINATION USING CBECS DATA

DOE's calculation of the annual energy use of gas-fired instantaneous water heaters in commercial applications relied on data from the Commercial Building Energy Consumption Survey 2018 (CBECS 2018),[2] which was conducted by DOE's Energy Information Administration (EIA). CBECS 2018 includes energy-related data from more than 6,436 commercial buildings that represent almost 5.9 million buildings in 2018. DOE used CBECS 2018 to establish a sample of households that use gas-fired instantaneous water heaters.

The subset of CEBECS 2018 records used to study gas-fired instantaneous water heaters met the following criteria.

- A "point-of-use" water heater served as the primary or secondary source of heated water.
- The water heater used one of two heating fuels (gas or propane).
- The water heater's energy consumption was greater than 500 and less than 200,000 kBtu.

The CBECS 2018 weighting indicates how commonly each building configuration occurs in the general population. Table 7A.3.1 shows the CBECS sample weights and criteria for replacement and new construction samples. DOE made some adjustments to EIA's weightings for each CBECS 2018 building in order to create the gas-fired instantaneous water heater sample weights in 2030. The gas-fired instantaneous water heater sample weights are adjusted to account for:

1. DOE assumed that buildings did not share a gas-fired instantaneous water heater with another building;
2. Buildings with multiple gas-fired instantaneous water heaters: CBECS 2018-reported weight is increased by the number of gas-fired instantaneous water heaters in a building;
3. For gas-fired instantaneous water heaters, DOE did not have shipments by state to match to CEBCS 2018 weights, so DOE did *not* adjust the sample weights by state based on shipments data;

4. DOE accounted for the projected growth of the number of gas-fired instantaneous water heaters by 2030 based on shipments analysis, see chapter 9;
5. For the new construction sample, DOE used only buildings built after 1990.

Table 7A.3.1 Selection of CBECS 2018 Records for Gas-fired Instantaneous Water Heaters in Replacement and New Construction Applications

Product Class	Algorithm	No. of Records	CBECS 2018 No. of U.S. Buildings Represented *(million)*	DOE 2030 No. of U.S. Shipments Represented *(million)*
Replacement				
GIWH	WTHTEQ = 2 or 3 AND NGWATR = 1 or PRWATR = 1 AND 500 < NGWTBTU < 200,000	542	0.3	0.117
New Construction				
GIWH	(WTHTEQ = 2 or 3 AND NGWATR = 1 or PRWATR = 1 AND 500 < NGWTBTU < 200,000), while YEARCON >=7	262	0.1	0.011

* CBECS 2018 variable definitions: WTHTEQ = Water heating equipment (1=Centralized water heaters; 2=Point-of-use water heaters; 3=Both types); NGWATR = Natural gas used for water heating (1 = Yes; 2 = No); PRWATR = Propane used for water heating (1 = Yes; 2 = No); YEARCON = Year of construction category (7 = 1990 to 1999, 8 = 2000 to 2012; 9 = 2013 to 2018).

Table 7A.3.2 shows the final sample weight by state and market segment.

Table 7A.3.2 Gas-fired Instantaneous Water Heaters Sample Weights by Replacement and New Construction and State for Commercial Applications

States	GIWH, %	
	Repl.	**NC**
Alabama	0.17	0.21
Alaska	0.44	0.09
Arizona	0.08	0.10
Arkansas	5.15	4.26
California	18.53	17.66
Colorado	0.73	0.71
Connecticut	0.93	0.26
Delaware	0.20	0.48
District of Columbia	0.83	1.95
Florida	8.67	11.18
Georgia	2.39	3.11
Hawaii	2.07	2.62
Idaho	0.07	0.05
Illinois	3.99	6.29
Indiana	3.48	1.13

States	GIWH, %	
	Repl.	NC
Iowa	0.94	1.08
Kansas	0.37	0.37
Kentucky	2.25	4.23
Louisiana	2.12	1.55
Maine	1.11	2.16
Maryland	0.91	0.96
Massachusetts	1.68	0.02
Michigan	2.90	2.69
Minnesota	1.58	0.95
Mississippi	1.28	0.12
Missouri	0.26	0.57
Montana	0.60	1.42
Nebraska	0.43	0.00
Nevada	0.05	0.11
New Hampshire	0.21	0.00
New Jersey	3.38	2.20
New Mexico	0.51	0.92
New York	3.18	3.95
North Carolina	1.54	0.19
North Dakota	0.01	0.00
Ohio	3.64	3.60
Oklahoma	0.15	0.08
Oregon	1.01	0.48
Pennsylvania	1.30	1.19
Rhode Island	0.51	0.00
South Carolina	1.06	1.13
South Dakota	0.12	0.27
Tennessee	2.73	0.63
Texas	9.18	8.99
Utah	0.79	1.85
Vermont	0.37	0.00
Virginia	0.82	1.75
Washington	0.96	1.67
West Virginia	1.65	3.65
Wisconsin	2.47	1.10
Wyoming	0.20	0.01

7A.4 RECS 2020 DATABASE VARIABLE RESPONSE CODES

Table 7A.4.1 lists the variables use in the analysis.

Table 7A.4.1 List of RECS 2020 Variables Used for Water Heaters

Variable	Description
Location Variables	
REGIONC	Census region
DIVISION	Census division
CDD65	Cooling degree days in 2020, base temperature 65F
HDD65	Heating degree days in 2020, base temperature 65F
Household Characteristics Variables	
DOEID	Unique identifier for each respondent
NWEIGHT	Final sample weight
TYPEHUQ	Type of housing unit
YEARMADERANGE	Range when housing unit was built
FUELH2O	Fuel used by main water heater
WHEATSIZ	Main water heater size
WHEATAGE	Main water heater age
NHSLDMEM	Number of household members
NUMADULT2	Number of household members age 65 or older
ELPAY	Who pays for electrical
NGPAY	Who pays for natural gas
LPGPAY	Who pays for propane
FOPAY	Who pays for fuel oil
CELLAR	Housing unit over a basement
CRAWL	Housing unit over a crawlspace
TEMPHOME	Winter temperature when someone is home during the day
TEMPGONE	Winter temperature when no one is home during the day
TEMPNITE	Winter temperature at night
KOWNRENT	Own or rent
ATTIC	Attic above the housing unit
BTUNGWTH	Natural gas usage for water heating, main and secondary, in thousand Btu, 2020
BTULPWTH	Propane usage for water heating, main and secondary, in thousand Btu, 2020
BTUFOWTH	Fuel oil/kerosene usage for water heating, main and secondary, in thousand Btu, 2020
BTUELWTH	Electricity usage for water heating, main and secondary, in thousand Btu, 2020
H2OAPT	Water heating equipment serves multiple housing units in building
H2OMAIN	Location of main water heating equipment in single-family home
FUELH2O2	Fuel used by secondary water heater

Variable	Description
EQUIPM	Main space heating equipment type
FUELHEAT	Main space heating fuel
ACEQUIPM_PUB	Main air conditioning equipment type - public file variable
GWT	Annual average ground water temperature (F) for 2020
TEMPHOMEAC	Summer temperature when someone is home during the day
TEMPGONEAC	Summer temperature when no one is home during the day
TEMPNITEAC	Summer temperature at night
MONEYPY	Annual gross household income for the last year
STORIES	Number of stories in a single-family home
HIGHCEIL	High ceilings
WALLTYPE	Major outside wall material
TOTSQFT_EN	Total square footage (used for publication)
KWH	Total electricity use, in kilowatt hours, 2020, including self-generation of solar power
DOLLAREL	Total electricity cost, in dollars, 2020
BTUNG	Total natural gas use, in thousand Btu, 2020
DOLLARNG	Total natural gas cost, in dollars, 2020
BTULP	Total propane use, in thousand Btu, 2020
DOLLARLP	Total propane cost, in dollars, 2020
BTUFO	Total fuel oil/kerosene use, in thousand Btu, 2020
DOLLARFO	Total fuel oil/kerosene cost, in dollars, 2020
STATE_NAME	State Name
WEATHERLOCATIONCODE*	Added to link to weather data

* Not part of RECS 2020 variables.

Table 7A.4.2 provides the response codes for the RECS 2020 variables.

Table 7A.4.2 Definitions of RECS 2020 Variables Used in Life-Cycle Cost Analysis

Variable	Response	
REGIONC		Northeast Midwest South West
DIVISION		New England Middle Atlantic East North Central West North Central South Atlantic East South Central West South Central Mountain North Mountain South Pacific

Variable		Response
CDD65		Cooling degree days in 2020, base temperature 65F; Derived from the weighted temperatures of nearby weather stations
HDD65		Heating degree days in 2020, base temperature 65F; Derived from the weighted temperatures of nearby weather stations
DOEID	100001-118496	Unique identifier for each respondent
NWEIGHT	437.9-29279.1	
TYPEHUQ	1	Mobile home
	2	Single-family detached house
	3	Single-family attached house
	4	Apartment in a building with 2 to 4 units
	5	Apartment in a building with 5 or more units
YEARMADERANGE	1	Before 1950
	2	1950 to 1959
	3	1960 to 1969
	4	1970 to 1979
	5	1980 to 1989
	6	1990 to 1999
	7	2000 to 2009
	8	2010 to 2015
	9	2016-2020
FUELH2O	1	Natural gas from underground pipes
	2	Propane (bottled gas)
	3	Fuel oil/kerosene
	5	Electricity
	7	Wood (cordwood or pellets)
	8	Solar thermal
	99	Some other fuel
WHEATSIZ	1	Small storage tank (30 gallons or less)
	2	Medium storage tank (31 to 49 gallons)
	3	Large storage tank (50 gallons or more)
	4	Tankless or on-demand
	-2	Not applicable
WHEATAGE	1	Less than 2 years old
	2	2 to 4 years old
	3	5 to 9 years old
	41	10 to 14 years old
	42	15 to 19 years old
	5	20 years or older
	-2	Not applicable
NHSLDMEM	1-7	Number of household members
NUMADULT2	0-6	Number of household members age 65 or older

Variable	Response	
ELPAY	1 2 3 99	Household is responsible for paying for all used in this home All used in this home is included in the rent or condo fee Some is paid by the household, some is included in the rent or condo fee Paid for some other way
NGPAY	1 2 3 99 -2	Household is responsible for paying for all used in this home All used in this home is included in the rent or condo fee Some is paid by the household, some is included in the rent or condo fee Paid for some other way Not applicable
LPGPAY	1 2 3 99 -2	Household is responsible for paying for all used in this home All used in this home is included in the rent or condo fee Some is paid by the household, some is included in the rent or condo fee Paid for some other way Not applicable
FOPAY	1 2 3 99 -2	Household is responsible for paying for all used in this home All used in this home is included in the rent or condo fee Some is paid by the household, some is included in the rent or condo fee Paid for some other way Not applicable
CELLAR	1 0 -2	Yes No Not applicable
CRAWL	1 0 -2	Yes No Not applicable
TEMPHOME	50 - 90 -2	Winter temperature when someone is home during the day Not applicable
TEMPGONE	50 - 90 -2	Winter temperature when no one is home during the day Not applicable
TEMPNITE	50 - 90 -2	Winter temperature at night Not applicable

Variable	Response	
KOWNRENT	1 2 3	Own Rent Occupy without payment of rent
ATTIC	1 0 -2	Yes No Not applicable
BTUNGWTH	0- 125687.15	Calibrated usage for water heating, main and secondary, in thousand Btu, 2020
BTULPWTH	0- 45679.06	Calibrated usage for water heating, main and secondary, in thousand Btu, 2020
BTUFOWTH	0- 51331.07	Calibrated usage for water heating, main and secondary, in thousand Btu, 2020
BTUELWTH	0- 88113.06	Calibrated usage for water heating, main and secondary, in thousand Btu, 2020
H2OAPT	1 0 -2	Yes No Not applicable
H2OMAIN	1 2 3 4 99 -2	Main living space Basement Garage Outside Other Not applicable
FUELH2O2	1 2 3 5 7 8 99 -2	Natural gas from underground pipes Propane (bottled gas) Fuel oil/kerosene Electricity Wood (cordwood or pellets) Solar thermal Some other fuel Not applicable
EQUIPM	2 3 4 5 7 8 10 13 99 -2	Steam or hot water system with radiators or pipes Central furnace Central heat pump Built-in electric units installed in walls, ceilings, baseboards, or floors Built-in room heater burning gas or oil Wood or pellet stove Portable electric heaters Ductless heat pump, also known as “mini-split” Other Not applicable

Variable	Response	
FUELHEAT	1 2 3 5 7 99 -2	Natural gas from underground pipes Propane (bottled gas) Fuel oil/kerosene Electricity Wood (cordwood or pellets) Other Not applicable
ACEQUIPM_PUB	1 3 4 5 6 -2	Central air conditioner (including central heat pump) Ductless heat pump, also known as a "mini-split" Window or wall air conditioner Portable air conditioner Evaporative or swamp cooler Not applicable
GWT	32.1 - 80.8	Annual average ground water temperature (F) for 2020
TEMPHOMEAC	50-90 -2	Summer thermostat setting or temperature in home when someone is home during the day Not applicable
TEMPGONEAC	50-90 -2	Summer thermostat setting or temperature in home when no one is home during the day Not applicable
TEMPNITEAC	50-90 -2	Summer thermostat setting or temperature in home at night Not applicable
MONEYPY	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	Less than $5,000 $5,000 - $7,499 $7,500 - $9,999 $10,000 - $12,499 $12,500 - $14,999 $15,000 - $19,999 $20,000 - $24,999 $25,000 - $29,999 $30,000 - $34,999 $35,000 - $39,999 $40,000 - $49,999 $50,000 - $59,999 $60,000 - $74,999 $75,000 - $99,999 $100,000 - $149,999 $150,000 or more

Variable	Response	
STORIES	1 2 3 4 5 -2	One story Two stories Three stories Four or more stories Split-level Not applicable
HIGHCEIL	1 0 -2	Yes No Not applicable
WALLTYPE	1 2 3 4 5 6 7 99	Brick Wood Siding (aluminum, fiber cement, vinyl, or steel) Stucco Shingle (composition) Stone Concrete block Other
TOTSQFT_EN	200-15000	Total energy-consuming area (square footage) of the housing unit. Includes all main living areas; all basements; heated, cooled, or finished attics; and heating or cooled garages. For single-family housing units this is derived using the respondent-reported square footage (SQFTEST) and adjusted using the "include" variables (e.g., SQFTINCB), where applicable. For apartments and mobile homes this is the respondent-reported square footage. A derived variable rounded to the nearest 10
KWH	42-184102	Total use, in kilowatthours, 2020, including self-generation of solar power
DOLLAREL	-890-15681	Total cost, in dollars, 2020
BTUNG	0-1134709	Total use, in thousand Btu, 2020
DOLLARNG	0-8155	Total cost, in dollars, 2020
BTULP	0-364216	Total use, in thousand Btu, 2020
DOLLARLP	0-6622	Total cost, in dollars, 2020
BTUFO	0-426269	Total use, in thousand Btu, 2020
DOLLARFO	0-7004	Total cost, in dollars, 2020
STATE_NAME	1-51	States and District of Columbia in alphabetical order
WEATHERLOCATIONCODE*		Added to link to weather data

* Not part of RECS 2020 variables.

7A.5 CBECS 2018 DATABASE VARIABLE RESPONSE CODES

Table 7A.5.1 lists the variables used in the analysis.

Table 7A.5.1 List of CBECS 2018 Variables Used for Water Heaters in Commercial Application

Variable	Description
Location Variables	
REGION	Census region
CENDIV	Census division
HDD65	Heating degree days (base 65)
CDD65	Cooling degree days (base 65)
Household Characteristics Variables	
YRCONC	Year of construction category
SQFT	Square footage
PBA	Principal building activity
OWNTYPE	Derived variable: Building owner
WTHTEQ	Water heating equipment
BOOSTWT	Water heating equipment
MAINHT	Derived variable: Main heating equipment
Boiler	Derived variable: Boilers used for heating
BOILER_EL	Boilers fueled by electricity
BOILER_NG	Boilers fueled by natural gas
BOILER_PR	Boilers fueled by propane
BOILER_FK	Boilers fueled by fuel oil
NGHT1	Natural gas used for main heating
NGHT2	Natural gas used for secondary heating
PRHT1	Propane used for main heating
PRHT2	Propane used for secondary heating
ELHT1	Electricity used for main heating
ELHT2	Electricity used for secondary heating
FKHT1	Fuel oil used for main heating
FKHT2	Fuel oil used for secondary heating
NWMNHT	Main heating replaced
ELWATR	Electricity used for water heating
NGWATR	Natural gas used for water heating
FKWATR	Fuel oil used for water heating
NGHTBTU	Modeled variable: Natural gas heating use (thous Btu)
LPHTBTU*	Derived.
FKHTBTU	Modeled variable: Fuel oil heating use (thous Btu)
ELHTBTU	Modeled variable: Electricity heating use (thous Btu)
NGWTBTU	Modeled variable: Natural gas water heating use (thous Btu)
LPWTBTU*	Derived.
FKWTBTU	Modeled variable: Fuel oil water heating use (thous Btu)

Variable	Description
ELWTBTU	Modeled variable: Electricity water heating use (thous Btu)
ELCNS	Building/energy supplier variable: Annual electricity consumption (kWh)
NGCNS	Building/energy supplier variable: Annual natural gas consumption (ccf)
FKCNS	Building/energy supplier variable: Annual fuel oil consumption (gallons)
ELBTU	Building/energy supplier variable: Annual electricity consumption (thous Btu)
NGBTU	Building/energy supplier variable: Annual natural gas consumption (thous Btu)
FKBTU	Building/energy supplier variable: Annual fuel oil consumption (thous Btu)
ELEXP	Building/energy supplier variable: Annual electricity expenditures ($)
NGEXP	Building/energy supplier variable: Annual natural gas expenditures ($)
FKEXP	Building/energy supplier variable: Annual fuel oil expenditures ($)

* Not part of CBECS 2018 variables.

Table 7A.5.2 provides the response codes for all CBECS 2018 variables used in the water heater analysis.

Table 7A.5.2 Definitions of CBECS 2018 Variables Used in Life-Cycle Cost Analysis

Variable	Response Codes
Location Variables	
REGION	1=Northeast 2=Midwest 3=South 4=West
CENDIV	1=New England 2=Middle Atlantic 3=East North Central 4=West North Central 5=South Atlantic 6=East South Central 7=West South Central 8=Mountain 9=Pacific
HDD65	402 – 10,790
CDD65	10 – 5,643
Household Characteristics Variables	
YRCONC	2=Before 1946 3=1946 to 1959 4=1960 to 1969 5=1970 to 1979 6=1980 to 1989

Variable	Response Codes
	7=1990 to 1999 8=2000 to 2012 9=2013 to 2018
SQFT	1,001 – 2,100,000
PBA	1=Vacant 2=Office 4=Laboratory 5=Nonrefrigerated warehouse 6=Food sales 7=Public order and safety 8=Outpatient health care 11=Refrigerated warehouse 12=Religious worship 13=Public assembly 14=Education 15=Food service 16=Inpatient health care 17=Nursing 18=Lodging 23=Strip shopping center 24=Enclosed mall 25=Retail other than mall 26=Service 91=Other
OWNTYPE	1=Real estate investment trust (REIT) 2=Other public or private corporation, partnership, LLC, or LLP 3=Individual owner(s) 4=Religious organization 5=Non-profit organization (other than religious or government) 6=Private academic institution 7=Other 8=Federal government 9=State government 10=Local government 97=Withheld to protect confidentiality
WTHTEQ	1=Centralized water heaters 2="Point-of-use" water heaters 3=Both types Missing=Not applicable
BOOSTWT	1=Yes 2=No Missing=Not applicable
MAINHT	1=Electric furnace 2=Electric packaged unit 3=Electric boiler 4=Electric heat pump 5=Electric space heater

Variable	Response Codes
	6=Electric fireplace 7=Electric duct reheat 8=Other electric heating equipment 9=Natural gas furnace 10=Natural gas packaged unit 11=Natural gas boiler 12=Natural gas heat pump 13=Natural gas space heater 14=Natural gas fireplace 15=Other natural gas heating equipment 16=Fuel oil furnace 17=Fuel oil boiler 18=Fuel oil space heater 19=Other fuel oil heating equipment 20=Propane furnace 21=Propane packaged unit 22=Propane boiler 23=Propane heat pump 24=Propane space heater 25=Propane fireplace 26=Other propane heating equipment 27=District steam heating system 28=District hot water heating system 29=Wood furnace 30=Wood space heater 31=Wood fireplace 32=Other wood heating equipment 33=Coal furnace 34=Coal boiler 35=Other coal heating equipment 36=Solar thermal heating 37=Other source furnace 38=Other source packaged unit 39=Other source boiler 40=Other source space heater 41=Other source fireplace 42=Other source other heating equipment
BOILP_PR	1 – 100 Missing=Not applicable
BOILP_FK	1 – 100 Missing=Not applicable
Boiler	1=Yes 2=No Missing=Not applicable
BOILER_EL	1=Yes 2=No Missing=Not applicable

Variable	Response Codes
BOILER_NG	1=Yes 2=No Missing=Not applicable
BOILER_PR	1=Yes 2=No Missing=Not applicable
BOILER_FK	1=Yes 2=No Missing=Not applicable
NGHT1	1=Yes 2=No
NGHT2	1=Yes 2=No
PRHT1	1=Yes 2=No
PRHT2	1=Yes 2=No
ELHT1	1=Yes 2=No
ELHT2	1=Yes 2=No
FKHT1	1=Yes 2=No
FKHT2	1=Yes 2=No
NWMNHT	1=Yes 2=No Missing=Not applicable
ELWATR	1=Yes 2=No
NGWATR	1=Yes 2=No
FKWATR	1=Yes 2=No
NGHTBTU	0 – 375,885,522 Missing=Not applicable
LPHTBTU*	-
FKHTBTU	0 – 76,090,274 Missing=Not applicable
ELHTBTU	0 – 8,865,298 Missing=Not applicable
NGWTBTU	0 – 139,741,802 Missing=Not applicable
LPWTBTU*	-
FKWTBTU	0 – 12,873,874 Missing=Not applicable
ELWTBTU	0 – 14,285,208 Missing=Not applicable

Variable	Response Codes
ELCNS	36 – 113,727,053 Missing=Not applicable
NGCNS	1 – 4,401,986 Missing=Not applicable
FKCNS	1 – 609,037 Missing=Not applicable
ELBTU	124 – 388,036,704 Missing=Not applicable
NGBTU	103 – 456,926,121 Missing=Not applicable
FKBTU	10 – 83,699,301 Missing=Not applicable
ELEXP	92 – 14,875,685 Missing=Not applicable
NGEXP	46 – 2,225,547 Missing=Not applicable
FKEXP	2 – 1,247,389 Missing=Not applicable

* Not part of CBECS 2018 variables.

REFERENCES

1. U.S. Department of Energy–Energy Information Administration. *2020 Residential Energy Consumption Survey (RECS)*. 2020. (Last accessed June 1, 2024.) https://www.eia.gov/consumption/residential/data/2020/.

2. U.S. Department of Energy–Energy Information Administration. *2018 Commercial Buildings Energy Consumption Survey (CBECS)*. 2018. (Last accessed July 1, 2024.) https://www.eia.gov/consumption/commercial/data/2018/.

APPENDIX 7B. DETAILS ABOUT THE ENERGY USE METHODOLOGY AND DATA

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APPENDIX 7B. DETAILS ABOUT THE ENERGY USE METHODOLOGY AND DATA

7B.1 INTRODUCTION

Energy use analysis is to determine the annual energy consumption of water heaters in use in the United States and to assess the energy savings potential of increases in Uniform Energy Factor (UEF). In contrast to the current federal test procedure, which uses typical operating conditions in a laboratory setting, the energy use analysis in this chapter seeks to estimate the distribution of annual energy consumption for gas-fired instantaneous water heaters in the field across a range of climate zones, building characteristics, and applications.

DOE calculated the energy use of Gas-fired Instantaneous Water Heaters (GIWHs). The calculation considers the primary factors that determine energy use:

- hot water use per household,
- the energy efficiency characteristics of the water heater, and
- water heater operating conditions.

To represent actual residential and commercial consumers[a] likely to purchase and use water heaters, U.S. Department of Energy (DOE) developed a water heater sample based primarily on data from the Energy Information Administration's (EIA) 2020 Residential Energy Consumption Survey (RECS 2020)[1] and EIA's 2018 Commercial Building Energy Consumption Survey (CBECS 2018).[2] These are the latest available surveys for residential households and commercial buildings. DOE used the samples not only to determine water heater annual energy consumption, but also as the basis for conducting the LCC analysis.

DOE used RECS 2020- or CBECS 2018-reported water heating energy consumption (based on the existing water heating system) to determine the daily hot water use of each household or building. The characteristics of each water heater's energy efficiency were taken from the engineering analysis. DOE developed water heater operating conditions from weather data and other relevant sources.

7B.2 CALCULATION OF ENERGY CONSUMPTION

To calculate the energy use of gas-fired instantaneous water heaters, DOE determined the energy consumption associated with water heating and any auxiliary electrical use. The calculation used for determining total gas-fired instantaneous water heater energy use is:

$$Energy\ Use_{Total} = FuelUse + ElecUse$$

Eq. 7B.1

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[a] To accurately estimate the costs and benefits of potential standards, DOE must consider all applications of the covered product, including commercial-sector usage of a consumer product.

Where:

$FuelUse$ = total fuel consumption as a result of hot water use (MMBtu/yr), and
$ElecUse$ = electrical consumption of all electrical components, including standby mode and off mode consumption (kWh/yr).

DOE calculated the energy use of water heaters using a simplified energy equation, a water heater analysis model (WHAM).[3] WHAM accounts for a range of operating conditions and energy efficiency characteristics of water heaters. The current version of WHAM is appropriate for calculating the energy use of electric resistance storage water heaters. To account for the characteristics of gas instantaneous water heaters, energy use must be calculated using modified versions of the WHAM equation. To describe energy efficiency characteristics of water heaters, the revised WHAM uses three parameters that are also used in the DOE test procedure:[4] recovery efficiency (*RE*) and rated input power (P_{ON}). Water heater operating conditions are indicated by the daily hot water draw volume, inlet water temperature, and thermostat setting. The WHAM equation yields average daily water heater energy consumption (Q_{in}). The equation is expressed as follows.

$$Q_{in} = \frac{vol \times den \times C_P \times (T_{tank} - T_{in})}{RE} \times \left(1 - \frac{UA \times (T_{tank} - T_{amb})}{Pon}\right) + 24 \times UA \times (T_{tank} - T_{amb})$$

Eq. 7B.2

Where:

Q_{in} = total water heater energy consumption in British thermal units per day, Btu/day,
RE = recovery efficiency, %,
P_{ON} = rated input power, Btu/h,
UA = standby heat-loss coefficient, set as 0 for GIWHs, Btu/h-°F,
T_{tank} = thermostat set point temperature, °F,
T_{in} = inlet water temperature, °F,
T_{amb} = temperature of the ambient air, °F,
vol = volume of hot water drawn in 24 hours, gal/day,
den = density of stored water, set constant at 8.29 pounds per gallon, lb/gal, and
C_P = specific heat of stored water, set constant at 1.000743, Btu/lb-°F.

WHAM provides total water heater energy consumption. For gas-fired instantaneous water heaters, Q_{in} is the sum of fuel and electricity consumption, and the values for electricity and fuel consumption must be disaggregated. DOE calculated electricity consumption as follows.

$$Q_{electricity} = \frac{Q_{in}}{P_{ON}} \times \left(P_{aux} - P_{standby}\right) - P_{standby} \times 24$$

Eq. 7B.3

Where:

$Q_{electricity}$ =	electricity consumption, kWh/day,
Q_{in} =	total water heater energy consumption, kWh/day,
P_{ON} =	rated input power, kW,
P_{aux} =	electricity demand when burner is on, kW, and
$P_{standby}$ =	electricity demand when burner is off, kW.

DOE calculated gas consumption by subtracting electricity consumption from the total energy consumption for the water heater (Q_{in}).

7B.3 DESCRIPTION OF KEY VARIABLES

The following is a description of the key variables for calculating energy use by water heaters.

- ***Recovery Efficiency (RE)***. The recovery efficiency (*RE*) is the ratio of energy added to the water compared to the energy input to the water heater. It represents how efficiently energy is transferred to the water when the heating element is on or the burner is firing. *RE* covers steady-state energy efficiency only.

- ***Rated Input Power (P_{ON}).*** Rated input power is the nominal power rating the manufacturer assigns to a particular design expressed in Btu/h.

- ***Set Point of Thermostat (T_{tank}).*** The thermostat set point is the desired delivery temperature of the hot water.

- ***Inlet Water Temperature (T_{in}).*** The inlet water temperature is the temperature of the water supplied to the water heater.

- ***Temperature of the Air Surrounding the Water Heater (T_{amb}).*** The temperature surrounding the water heater is the ambient air temperature of the space where the water heater is located.

- ***Volume of Hot Water Drawn in 24-Hour Period (vol).*** The estimated daily household use of hot water.

- ***Density of Water (den).*** The density of hot water at the average of the set point and inlet temperatures (8.24 lb/gal). The density is mass per unit volume, expressed as lb/gal (kg/l).

- ***Specific Heat of Water (C_p).*** The specific heat of water at the average of the set point and inlet temperatures (1.000743 Btu/lb-oF). The specific heat is the amount of heat needed to increase or decrease the temperature of 1 pound mass of water by 1 °F (1 kJ/kg - Kelvin).

7B.4 DERIVATION OF HOT WATER USE

Hot water use differs widely among households, because it depends on characteristics of the household and the water heater, such as the number and ages of the people who live in the household, the way they consume hot water, the presence of hot-water-using appliances, the tank size and thermostat set point of the water heater, and the climate in which the residence is situated. DOE used RECS 2020 and CBECS 2018 water heating energy use estimates per sampled home or building to estimate the annual hot water use volume. The annual hot water use equation, derived from WHAM equations, is expressed as follows.

$$vol_{annual} = \frac{Q_{in,existing} - 24 \times UA \times (T_{tank} - T_{amb})}{\left(1 - \dfrac{UA \times (T_{tank} - T_{amb})}{Pon, existing}\right)} \times \frac{RE_{existing}}{den \times C_P \times (T_{tank} - T_{in})}$$

Eq. 7B.4

Where:

vol_{annual} = annual hot water use volume, gal/year,
$Q_{in,existing}$ = total water heater energy consumption in RECS 2020 or CBECS 2018, Btu/year,
UA = set as 0 for GIWHs,
den = density of water, lb/gal,
C_p = specific heat of water, Btu/lb-°F,
T_{tank} = set point of tank thermostat, °F,
T_{in} = inlet water temperature, °F,
$RE_{existing}$ = recovery efficiency of the existing equipment, %, and
$P_{ON,existing}$ = rated input power of the existing equipment, Btu/h.

Figure 7B.4.1 shows the range in hot water use among sample households. DOE calculated average daily hot water use to be 71 gallons for households having gas-fired instantaneous water heaters. These results are similar to recent field data and hot water draw models. [5,6,7,8,9,10,11]

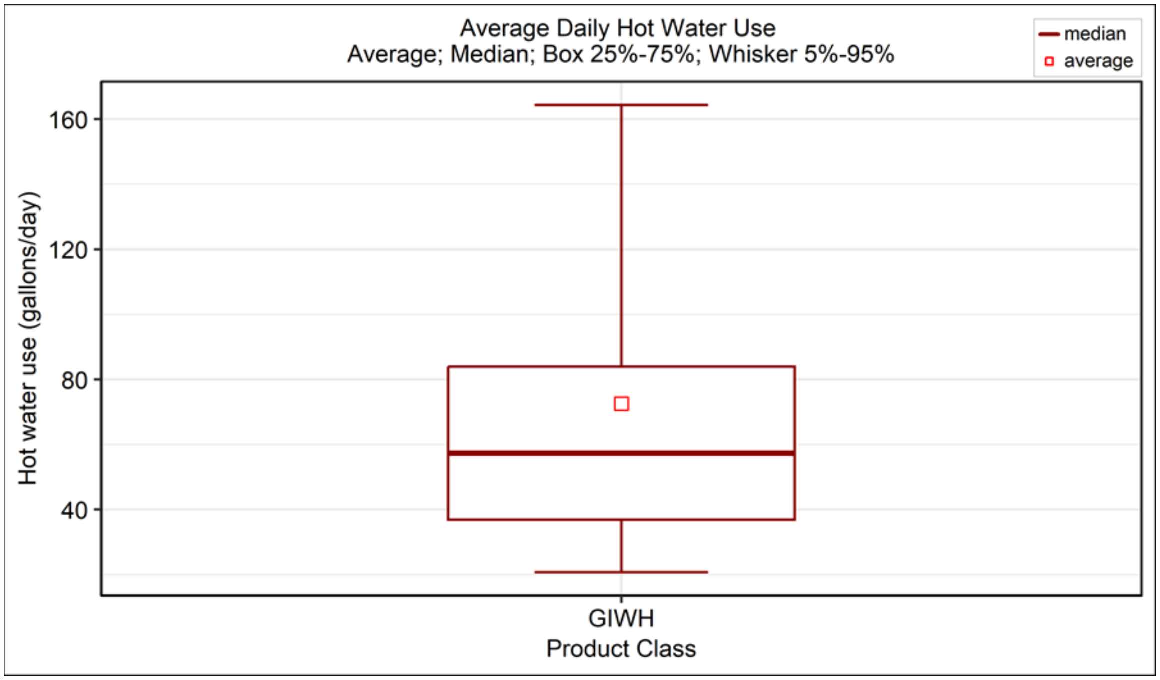

Figure 7B.4.1 Range of Daily Hot Water Use in Sample Households for Gas-fired Instantaneous Water Heaters

7B.5 ASSIGNMENT OF DRAW PATTERNS

In the LCC analysis, DOE accounted for different draw patterns. DOE gathered data from a variety of sources including:

1) AHRI certification directory[12] and DOE's public Certification Compliance Database (CCD)[13] with other publicly available data from manufacturers' catalogs of gas-fired instantaneous water heaters,
2) Combination of confidential data provided by AHRI from 2004-2007,[14] and
3) Disaggregated shipments data from BRG Building Solutions 2023 report with shipment data from 2007 to 2022.[15]

Table 7B.5.1 shows the percentages of GIWH samples that were assigned to each draw pattern for the LCC analysis.

Table 7B.5.1 Assignment of Water Heater Draw Patterns

Product Class	Draw Pattern		
	Low	Medium	High
GIWH	-	15%	85%

7B.6 DERIVATION OF OTHER ENERGY PARAMETERS

Key parameters in DOE's calculation of water heater energy consumption are the recovery efficiency (*RE*) and the rated input power (P_{on}). DOE's test procedure for water heaters provided the definitions for these parameters.[28] DOE developed the parameters for selected energy efficiency level as described below. (See chapter 5 for a discussion of DOE's selection of energy efficiency levels.)

Determining RE. Table 7B.6.1 shows the most common assignment of *RE* values for gas-fired instantaneous water heaters by efficiency level based on the distribution of models at each efficiency level.

Table 7B.6.1 Assignment of *RE* for Gas-Fired Instantaneous Water Heaters

Efficiency Level	UEF		RE
	Med Draw	Large Draw	
0	0.81	0.81	82%
1	0.87	0.89	88%/90%
2	0.91	0.93	92%/94%
3	0.92	0.95	93%/96%
4	0.93	0.96	94%/97%

Determining P_{ON}. DOE determined appropriate bins for rated input power (P_{ON}) based on the models listed in the AHRI Directory.[12] The assignment of the input capacity is shown in Table 7B.6.2.

Table 7B.6.2 Assignment of Input Capacity

Product Class	Input Capacity *(P_{ON})* *(kBtu/h)*
Gas-fired Instantaneous Water Heaters	120/199

7B.7 DERIVATION OF TEMPERATURES

The temperatures for thermostat set point and inlet water temperature are derived from the average annual outdoor air temperature for each sample household.

Outdoor Air Temperature. RECS 2020 provides data on heating and cooling degree-days, but not on air temperatures for each household in the sample. To each RECS 2020 household DOE assigned a physical location from which outdoor air temperatures could be derived as follows:

- DOE assembled weather data from 282 weather stations that provide 30-year averages for annual average outdoor air temperatures.[16,17] DOE also gathered the heating and cooling degree-days at a base temperature of 65 ºF for 2020 for those weather stations.[18] The 2020 heating and cooling degree-days match the period used to determine the degree-days in RECS 2020.

- RECS 2020 reports both heating and cooling degree-days to base temperature 65 ºF for each housing record. DOE assigned each RECS 2020 household to one of the 282 weather stations by calculating which station (within the appropriate census region or large state) gave the best fit of RECS 2020 data to weather data.

Details about the derivation of the annual average outdoor air temperatures for the RECS 2020 and CBECS 2018 water heater sample are provided in appendix 7C, Mapping of Weather Station Data to RECS and CBECS Buildings. Figure 7B.7.1 shows the range of average annual outdoor air temperatures among sample households.

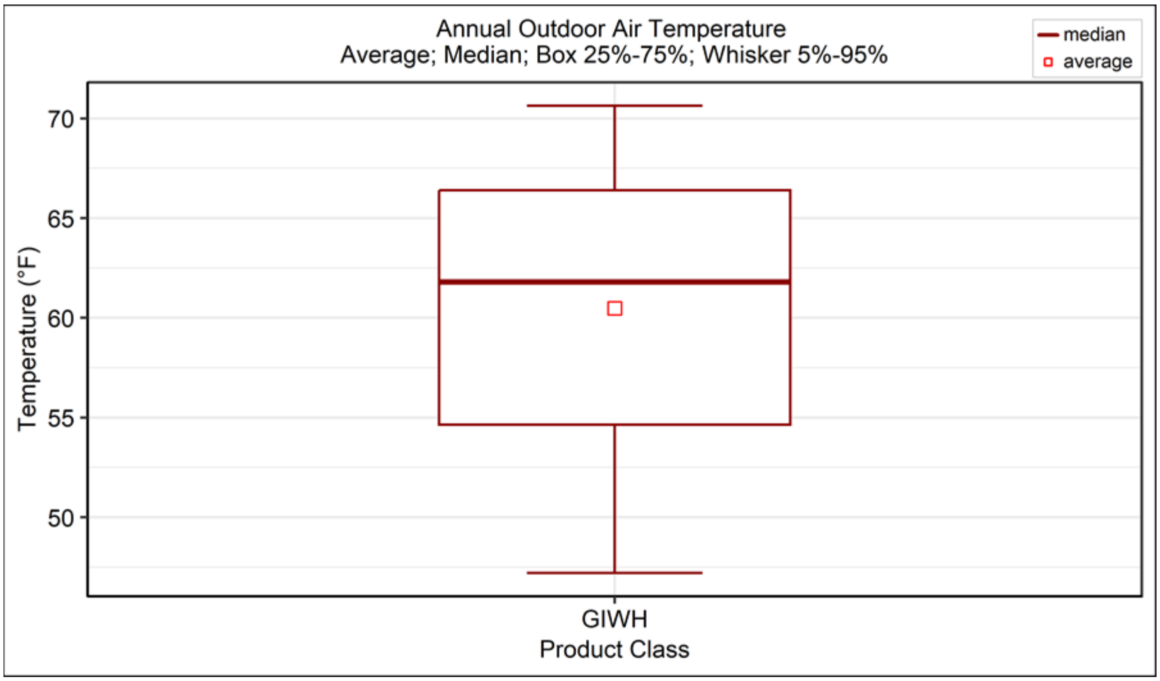

Figure 7B.7.1 Range of Annual Outdoor Air Temperature for Sample Households for Gas-fired Instantaneous Water Heaters

Inlet Water Temperature. The inlet water comes to the water heater either from a municipal treatment plant or from ground well sources. RECS 2020 provides ground water temperature data for each household. DOE was also able to gather annual average outdoor air temperature.

DOE then derived inlet water temperature using an approach developed by the National Renewable Energy Laboratory.[19,20] This approach accounts for seasonal variations in inlet water temperature as a function of annual average outdoor air temperature. The monthly average inlet water temperature varies directly with the average annual outdoor air temperature corrected by an offset term. The equation for inlet water temperature has the following form:

$$T_{IN} = T_{air,avg} + offset + lag$$

Eq. 7B.5

The calculation details and the parameter definitions are described in appendix 7B. DOE calculated the offset using data from cold water inlet temperatures for select U.S. locations available in the HOTCALC Commercial Water Heating Performance Simulation Tool.[21] shows the range of inlet water temperatures among sample households.

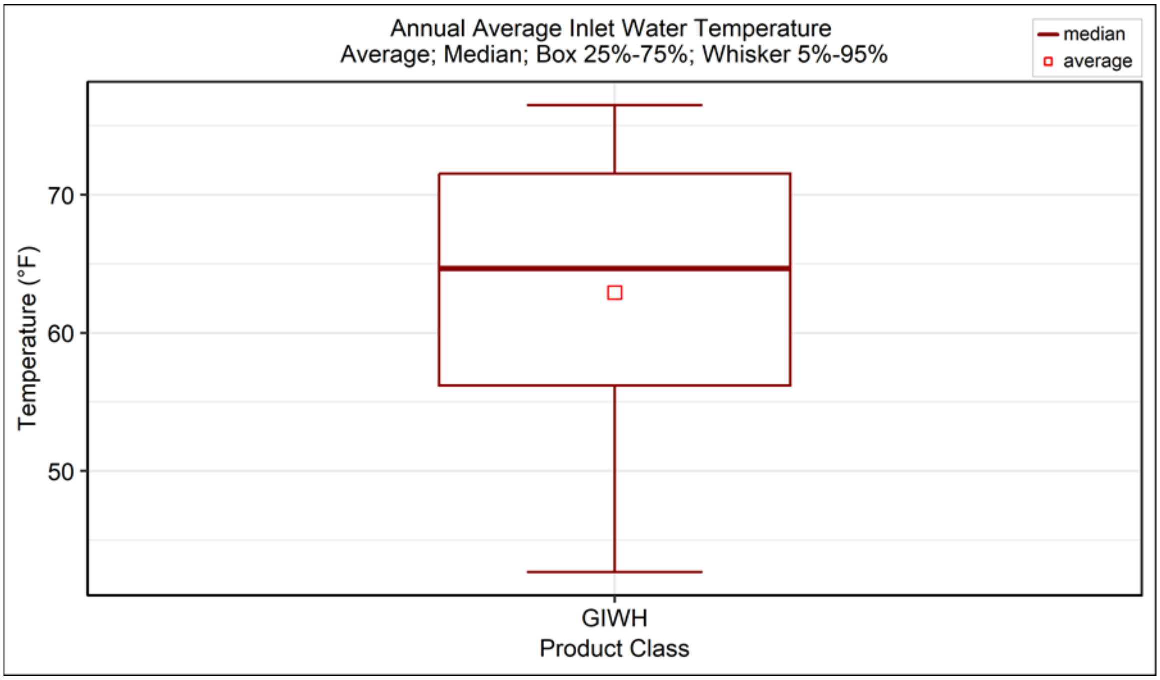

Figure 7B.7.2 Range of Daily Average Annual Inlet Water Temperature for Sample Households for Gas-fired Instantaneous Water Heaters

Water Heater Thermostat Settings. DOE assigned water heater thermostat settings to the RECS 2020 households based on a 2006-2017 contractor survey from ClearSeas.[22,23] The information about thermostat settings reflects the results from a survey of more than 300 plumbing/hydronic heating contractor firms per survey year that install water heaters throughout the United States in new and replacement markets.

The survey indicated that 31 percent of responding contractors always install a water heater with a set point temperature of 120 °F; 45 percent usually install the water heater with a thermostat at 120 °F. In total, over 75 percent usually or always set the setpoint temperature to 120 °F. Based on this information, DOE estimated that a total of 70 percent of water heaters set to 120 °F, with 30 percent uniformly distributed between 121 °F and 140 °F.[b] This approach resulted in a mean temperature set point of 123 °F for the RECS water heater household sample. This matches available field data.[9,24]

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[b] 140 °F is the maximum allowed to avoid scalding.

Although water heaters are shipped having the thermostat set to 120 °F, several factors may cause contractors and/or household occupants to increase the set-point temperature, such as:

- High hot water draws: Increasing the set point temperature decreases the likelihood of running out of hot water.
- Cold inlet water: Increasing the set point temperature can help compensate for the mixture produced by very cold water and hot water.

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APPENDIX 7C. MAPPING OF WEATHER STATION DATA TO RECS AND CBECS BUILDINGS

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7C.1 INTRODUCTION

The Energy Information Administration's (EIA) 2020 Residential Energy Consumption Survey (RECS 2020)[1] and EIA's 2018 Commercial Building Energy Consumption Survey (CBECS 2018)[2] provide annual data on heating and cooling degree-days but not on other weather parameters needed for the analysis such as monthly heating degree days (HDD) and monthly cooling degree days (CDD), and average outdoor temperature. This mapping allowed DOE to assign each individual sampled building to a state, thus allowing DOE to use state level inputs such as labor rates, markups, and energy prices.

7C.2 MAPPING METHODOLOGY

To derive the additional weather data that is needed for the analysis (e.g., ODT, average outdoor temperature, monthly HDD, monthly CDD), for each building in the sample, DOE developed an approach to assign a physical location to each RECS household and CBECS building. [a] The methodology consists of the following steps:

1. DOE assembled monthly weather data from 360 weather stations from the National Oceanic and Atmospheric Administration (NOAA) that provide the heating and cooling degree-days at base temperature 65ºF for year 2020 (for the RECS sample) and year 2018 (for the CBECS sample), for these weather stations.[3] The 2020 and 2018 heating and cooling degree days match the period used to determine the degree-days in RECS 2020 and in CBECS 2018, respectively.
2. RECS 2020 and CBECS 2018 report both HDD and CDD to base temperature 65ºF for each building record. DOE assigned each building to one of the 360 weather stations by calculating which weather station (within the appropriate state for RECS 2020 and census division for CBECS 2018) was the closest using the best linear least squares fit of the RECS 2020 and CBECS 2018 data to the weather data for each region in the RECS 2020 and CBECS 2018 data. Differential between the heating and cooling degree days is normalized using the maximum heating and cooling degree days by region from the weather station data.
3. To make sure that the final weighting of RECS households by state matches the U.S. Census city population data,[b] DOE added a city weighting adjustment factor. DOE does not have any comparable state level data for commercial buildings, so no correction factor was added to CBECS 2018 weather station matching.

Eq. 7C.1 calculates the U.S. weather station closest (or with minimum "distance") to the RECS/CBECS building:

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[a] For confidentiality, heating and cooling degree day values were altered slightly by EIA to mask the exact geographic location of the housing unit or building.
[b] Annual Estimates of Housing Units for the United States, Regions, States, and the District of Columbia: April 1, 2020 to July 1, 2022 (NST-EST2022-HU)

$$"\text{Distance}" = \left(\sqrt{\frac{(HDD_2 - HDD_1)^2}{HDD_{MAX}^2} + \frac{(CDD_2 - CDD_1)^2}{CDD_{MAX}^2}}\right) \times CityAdjustmentFactor$$

Eq. 7C.1

Where:

HDD_1 = heating degree days from U.S. weather data,
HDD_2 = heating degree days from RECS/CBECS data,
HDD_{MAX} = maximum heating degree days from U.S. weather data,
CDD_1 = cooling degree days from U.S. weather data,
CDD_2 = cooling degree days from RECS/CBECS data,
CDD_{MAX} = maximum cooling degree days from U.S. weather data,
CityAdjustmentFactor = adjustment factor used to be able to match the U.S. Census housing data for RECS households.

7C.3 MAPPING RESULTS

Table 7C.3.1 shows the imputation results for all RECS and CBECS locations. Note that some U.S. weather station data match with several of the RECS/CBECS weather data. The number of RECS/CBECS buildings that were matched to the specified weather station is indicated in the column "Count". Table 7C.3.1 shows the data matches (360 weather stations) including the heating and cooling degree days as well as outdoor design temperature (ODT) for each of the weather stations.[c]

Table 7C.3.1 Weather Station Mapping Statistics, Heating and Cooling ODT, and HDD/CDD in RECS/CBECS Years

Station Location			2018	2018	2020	2020	ODT	ODT	CBECS 2018	RECS 2020
Code	City	State	HDD	CDD	HDD	CDD	Heating	Cooling	Sample Mapping Count	Sample Mapping Count
BHM	BIRMINGHAM	Alabama	2526	2592	2076	2221	21	92.6	106	61
HSV	HUNTSVILLE	Alabama	2981	2510	2666	1865	16	92.2	8	56
MOB	MOBILE	Alabama	1473	3092	1324	2609	29	91.8	0	46
MGM	MONTGOMERY	Alabama	2004	2809	1558	2708	25	94	0	50
MSL	MUSCLE SHOALS	Alabama	2949	2588	2351	2230	21	93.1	0	5
TCL	TUSCALOOSA	Alabama	2287	2857	1908	2424	23	93.4	0	24
ANC	ANCHORAGE	Alaska	8758	14	10129	4	-18	68.3	3	213
BRW	BARROW	Alaska	17412	0	18288	0	-36	55.6	0	3
BET	BETHEL	Alaska	10784	1	12035	3	-24	68	1	3
BTT	BETTLES	Alaska	13881	30	15012	12	-35	73.7	0	1
BIG	BIG DELTA	Alaska	11834	79	13426	3	-25	74.6	0	1
CDB	COLD BAY	Alaska	8361	0	8958	0	10	57	0	1
CDV	CORDOVA	Alaska	8518	0	9041	1	1	67	4	3
FAI	FAIRBANKS	Alaska	12428	59	13718	14	-32	76.8	0	16

[c] The names of weather stations MQT, SSI, and SSM changed to SAW, BQK, and ANJ, respectively.

Station Location			2018	2018	2020	2020	ODT	ODT	CBECS 2018	RECS 2020
Code	**City**	**State**	**HDD**	**CDD**	**HDD**	**CDD**	**Heating**	**Cooling**	**Sample Mapping Count**	**Sample Mapping Count**
GKN	GULKANA	Alaska	12762	5	13638	1	-27	71.8	0	1
HOM	HOMER	Alaska	8404	0	9261	0	4	62	2	5
JNU	JUNEAU	Alaska	7895	17	8137	1	1	69.9	1	20
ENA	KENAI	Alaska	9708	1	10170	4	-14	65	1	6
KTN	KETCHIKAN	Alaska	6210	71	6926	4	20	68	0	2
AKN	KING SALMON	Alaska	9247	1	10755	1	-19	67	0	5
ADQ	KODIAK	Alaska	7603	8	8375	12	13	65	2	3
OTZ	KOTZEBUE	Alaska	12857	6	14691	0	-26	69.2	0	10
MCG	MCGRATH	Alaska	11992	36	13618	3	-30	74.7	0	1
OME	NOME	Alaska	12139	0	12773	0	-18	65.9	0	3
ORT	NORTHWAY	Alaska	14253	22	14966	2	-37	73.8	0	3
SNP	ST PAUL ISLAND	Alaska	9306	0	8944	0	3	52	1	1
SIT	SITKA	Alaska	6480	1	7095	10	21	64	0	1
TKA	TALKEETNA	Alaska	9880	5	10763	12	-21	73	2	1
UNK	UNALAKLEET	Alaska	11339	2	12675	17	-28	73.2	0	2
VWS	VALDEZ	Alaska	5498	84	6844	61	7	66	0	5
YAK	YAKUTAT	Alaska	7889	10	8783	1	2	63	0	1
DUG	DOUGLAS	Arizona	2421	1991	887	6073	31	98	13	11
FLG	FLAGSTAFF	Arizona	6343	214	3363	2471	4	83	0	21
PHX	PHOENIX	Arizona	657	4953	830	5427	34	108.1	0	330
TUS	TUCSON	Arizona	1009	3592	1289	4150	32	103.6	9	113
INW	WINSLOW	Arizona	4119	1689	4143	1616	10	93	46	1
NYL	YUMA	Arizona	553	4897	670	5044	39	108.6	0	19
ELD	EL DORADO	Arkansas	2662	2697	2214	2117	21	96.3	62	10
FYV	FAYETTEVILLE	Arkansas	4230	1704	3480	1450	12	92.7	40	63
FSM	FORT SMITH	Arkansas	3270	2544	2826	2066	17	96.4	0	48
HRO	HARRISON	Arkansas	4056	1870	2901	2926	13	92.4	30	9
LIT	LITTLE ROCK	Arkansas	3246	2381	2227	2322	20	95.3	27	121
TXK	TEXARKANA	Arkansas	2716	2617	2140	2117	23	96	2	17
BFL	BAKERSFIELD	California	1504	2802	1938	2981	32	100.7	0	63
BLH	BLYTHE	California	689	5068	916	5071	33	112	0	5
EKA	EUREKA	California	4532	0	4706	7	33	65	0	5
FAT	FRESNO	California	1686	2537	1949	2801	30	101.1	5	87
IPL	IMPERIAL	California	666	4665	898	4786	31	107.5	2	2
LAX	LOS ANGELES	California	868	1068	937	839	43	80.4	106	525
MHS	MT SHASTA	California	5099	454	3584	2950	21	88	45	1
PRB	PASO ROBLES	California	2251	1176	2460	1362	29	98	32	12
RBL	RED BLUFF	California	2142	2107	2135	2550	32	102	52	2
RDD	REDDING	California	2208	2205	2275	2512	31	102.4	3	1
SAC	SACRAMENTO	California	2262	1243	1604	3008	32	97.9	29	92
SAN	SAN DIEGO	California	684	1267	826	1244	44	81.1	121	157
SFO	SAN FRANCISCO	California	2191	190	2115	349	38	78.3	98	140
SCK	STOCKTON	California	1944	1550	2027	2100	30	97.9	125	60
AKO	AKRON	Colorado	5945	921	5954	1102	5	88.4	21	2
ALS	ALAMOSA	Colorado	7594	107	7469	151	-16	82	5	8
COS	COLORADO SPRINGS	Colorado	5603	743	5564	907	2	87.7	26	136
DEN	DENVER	Colorado	5602	1040	5679	1156	1	91.8	7	179
EGE	EAGLE	Colorado	6923	332	7302	315	-7	86	21	4
GJT	GRAND JUNCTION	Colorado	5157	1639	5423	1497	4	93.1	1	12

Station Location			2018	2018	2020	2020	ODT	ODT	CBECS 2018	RECS 2020
Code	City	State	HDD	CDD	HDD	CDD	Heating	Cooling	Sample Mapping Count	Sample Mapping Count
LHX	LA JUNTA	Colorado	4728	1809	4711	1689	8	93	5	1
PUB	PUEBLO	Colorado	5069	1436	5087	1407	0	95.8	32	17
TAD	TRINIDAD	Colorado	4984	1184	4955	1157	3	90	17	1
BDR	BRIDGEPORT	Connecticut	5194	1162	4648	1179	9	84.5	4	149
BDL	HARTFORD	Connecticut	5937	1079	5387	1054	7	87.8	65	145
ILG	WILMINGTON	Delaware	4724	1506	3504	2212	14	89.3	22	143
DCA	WASHINGTON	D.C.	3842	2048	3317	1735	17	93	5	221
DAB	DAYTONA BEACH	Florida	708	3410	380	5271	35	90.8	0	19
FLL	FT LAUDERDALE	Florida	134	4784	59	6436	46	90.6	0	54
FMY	FORT MYERS	Florida	236	4438	173	4639	44	92.6	0	24
GNV	GAINESVILLE	Florida	1086	3371	627	4638	31	92	90	17
JAX	JACKSONVILLE	Florida	1168	3128	956	3199	32	92.7	1	190
EYW	KEY WEST	Florida	33	5410	29	5596	57	89	0	2
MLB	MELBOURNE	Florida	412	4306	389	3971	43	90.8	0	22
MIA	MIAMI	Florida	79	4793	77	5361	47	90.7	0	107
MCO	ORLANDO	Florida	517	3850	385	4208	38	92.6	0	75
PNS	PENSACOLA	Florida	1240	3244	933	3270	29	91.6	90	3
TLH	TALLAHASSEE	Florida	1384	3085	1146	3181	30	93.5	257	23
TPA	TAMPA	Florida	413	4338	332	4514	40	91.3	3	96
VRB	VERO BEACH	Florida	399	3882	158	5626	43	90.5	0	4
PBI	WEST PALM BEACH	Florida	202	4350	125	5020	45	90.2	0	19
ABY	ALBANY	Georgia	545	5594	415	5828	29	94.5	0	15
AHN	ATHENS	Georgia	2698	2271	2159	2167	22	92.7	93	46
ATL	ATLANTA	Georgia	2566	2429	2121	2092	22	91.5	33	164
AGS	AUGUSTA	Georgia	2212	2574	1751	2577	23	94.7	6	46
BQK	BRUNSWICK	Georgia	1578	2658	1224	2790	32	91	12	5
CSG	COLUMBUS	Georgia	1910	2865	1612	2611	24	94.1	10	55
MCN	MACON	Georgia	2158	2627	1756	2465	25	94.3	8	40
SAV	SAVANNAH	Georgia	1617	2999	1171	3163	27	93.3	5	40
AYS	WAYCROSS	Georgia	1508	3009	1200	3037	29	94	5	6
ITO	HILO-HAWAII	Hawaii	0	4038	0	4342	62	84.6	9	39
HNL	HONOLULU-OAHU	Hawaii	0	5153	0	5214	63	89.1	9	206
OGG	KAHULUI-MAUI	Hawaii	11	4490	0	5147	61	88	4	24
LIH	LIHUE-KAUAI	Hawaii	0	4213	36	4555	62	85	0	13
BOI	BOISE	Idaho	4961	1125	4997	1089	10	95	0	137
BYI	BURLEY	Idaho	5769	596	5899	595	2	90	4	10
IDA	IDAHO FALLS	Idaho	7221	288	7949	282	-6	89.4	4	66
LWS	LEWISTON	Idaho	4518	949	4631	964	6	94.3	5	12
PIH	POCATELLO	Idaho	6408	466	6718	494	-1	91.3	24	45
ORD	CHICAGO	Illinois	6274	1293	5511	1287	0	89.6	38	439
MLI	MOLINE	Illinois	6319	1335	5656	1069	-4	90.6	28	16
PIA	PEORIA	Illinois	5933	1477	5473	1132	-4	90.1	53	15
UIN	QUINCY	Illinois	5717	1656	4413	2265	3	90.4	10	1
RFD	ROCKFORD	Illinois	6780	971	5934	1035	-4	88.5	97	39
SPI	SPRINGFIELD	Illinois	5547	1735	5125	1196	2	90.5	36	20
EVV	EVANSVILLE	Indiana	4639	1932	4106	1490	9	91.6	26	38
FWA	FORT WAYNE	Indiana	5850	1204	5662	918	1	88.4	64	75
IND	INDIANAPOLIS	Indiana	5451	1612	4901	1201	2	88.6	13	249
SBN	SOUTH BEND	Indiana	6536	935	5741	969	1	88.1	41	31

Station Location			2018	2018	2020	2020	ODT	ODT	CBECS 2018	RECS 2020
Code	City	State	HDD	CDD	HDD	CDD	Heating	Cooling	Sample Mapping Count	Sample Mapping Count
LAF	WEST LAFAYETTE	Indiana	6058	1261	4943	1317	3	90	10	7
BRL	BURLINGTON	Iowa	6107	1428	4656	2394	-3	91	2	10
CID	CEDAR RAPIDS	Iowa	6851	1035	6669	792	-5	88.6	9	62
DSM	DES MOINES	Iowa	6418	1442	5950	1203	-5	90.2	3	86
DBQ	DUBUQUE	Iowa	7220	849	6789	756	-7	86.3	13	28
MCW	MASON CITY	Iowa	8014	849	7422	740	-11	88	6	12
OTM	OTTUMWA	Iowa	6380	1320	5968	956	-4	92	1	21
SUX	SIOUX CITY	Iowa	7301	1047	6519	1050	-7	90.4	14	40
SPW	SPENCER	Iowa	7856	1048	5849	2510	-7	87.3	4	5
ALO	WATERLOO	Iowa	7444	892	6578	1044	-10	88.8	23	22
CNU	CHANUTE	Kansas	4530	1930	3887	1767	10	94.5	8	2
CNK	CONCORDIA	Kansas	5620	1527	4637	1712	3	96	8	2
DDC	DODGE CITY	Kansas	4949	1757	4526	1579	5	97	6	8
GCK	GARDEN CITY	Kansas	5327	1470	4964	1336	4	97	3	10
GLD	GOODLAND	Kansas	5756	1139	5482	1189	0	94	4	3
RSL	RUSSELL	Kansas	5210	1709	4864	1455	4	96	13	3
SLN	SALINA	Kansas	4979	1984	4627	1591	5	98.2	6	15
TOP	TOPEKA	Kansas	5148	1963	4601	1526	4	94.1	6	37
ICT	WICHITA	Kansas	4545	2128	4218	1762	7	97.2	2	128
BWG	BOWLING GREEN	Kentucky	3939	2171	3508	1642	10	91	22	32
JKL	JACKSON	Kentucky	4226	1630	3102	2248	14	87	8	3
LEX	LEXINGTON	Kentucky	4457	1726	4419	1137	8	89	23	137
SDF	LOUISVILLE	Kentucky	4118	2182	3591	1737	10	91	12	245
PAH	PADUCAH	Kentucky	4182	2138	3648	1640	12	93	9	11
BTR	BATON ROUGE	Louisiana	1518	3209	734	4581	29	93	27	69
LFT	LAFAYETTE	Louisiana	1364	3337	1062	3068	30	93	21	34
LCH	LAKE CHARLES	Louisiana	1290	3379	1020	3163	31	92.5	22	22
MLU	MONROE	Louisiana	2216	2912	1752	2565	25	95	13	20
MSY	NEW ORLEANS	Louisiana	1098	3650	717	3720	33	92	16	115
SHV	SHREVEPORT	Louisiana	2187	3073	1702	2624	25	95	5	51
AUG	AUGUSTA	Maine	7337	557	6861	563	-3	84	6	31
BGR	BANGOR	Maine	7703	501	5814	1633	-6	84	18	52
CAR	CARIBOU	Maine	9176	403	8633	458	-13	82	5	12
HUL	HOULTON	Maine	9156	299	8550	398	-13	85	0	8
PWM	PORTLAND	Maine	6906	574	6327	667	-1	83	8	120
BWI	BALTIMORE	Maryland	4557	1607	3797	1538	13	91	84	343
SBY	SALISBURY	Maryland	4160	1663	2926	2558	16	90	68	16
BOS	BOSTON	Massachusetts	5417	1128	5073	895	9	87	15	420
CHH	CHATHAM	Massachusetts	5372	659	3923	1381	8	85.3	32	4
ORH	WORCESTER	Massachusetts	6637	710	5146	1593	4	83	76	128
APN	ALPENA	Michigan	7984	573	7406	457	-6	84	23	9
DTW	DETROIT	Michigan	6103	1227	5721	963	6	87	2	40
FNT	FLINT	Michigan	6934	785	5964	774	1	86	43	68
GRR	GRAND RAPIDS	Michigan	6499	987	6213	807	5	86	9	34
CMX	HANCOCK	Michigan	9067	277	8401	371	-8	78.9	0	4
HTL	HOUGHTON LAKE	Michigan	7871	552	7504	546	1	85	45	22
JXN	JACKSON	Michigan	6567	923	6255	641	5	86	1	25
LAN	LANSING	Michigan	6708	906	6317	805	1	86	4	24
SAW	MARQUETTE	Michigan	9449	282	8718	328	-8	83	0	11

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Code	City	State	HDD	CDD	HDD	CDD	Heating	Cooling	Sample Mapping Count	Sample Mapping Count
MKG	MUSKEGON	Michigan	6464	901	6019	814	6	83	4	59
MBS	SAGINAW	Michigan	6852	866	6283	830	4	87	13	32
ANJ	SAULT ST MARIE	Michigan	8379	458	7817	365	-8	80	39	10
TVC	TRAVERSE CITY	Michigan	7109	829	6698	702	1	86	7	50
AXN	ALEXANDRIA	Minnesota	8506	927	8381	579	-16	86	39	10
DLH	DULUTH	Minnesota	9314	392	8982	350	-16	81	0	37
HIB	HIBBING	Minnesota	10598	163	10134	182	-20	81	0	7
INL	INT'L FALLS	Minnesota	10400	244	9835	245	-25	83	0	5
MSP	MINNEAPOLIS	Minnesota	7754	1138	7149	939	-12	88	22	177
RST	ROCHESTER	Minnesota	8249	711	7678	629	-12	85	35	51
STC	SAINT CLOUD	Minnesota	8864	651	8167	567	-11	88	44	38
GWO	GREENWOOD	Mississippi	2550	2597	1373	4101	20	94	0	10
JAN	JACKSON	Mississippi	2242	2646	1726	2497	23	96	0	102
MCB	MCCOMB	Mississippi	1750	2928	1420	2723	26	92	0	8
MEI	MERIDIAN	Mississippi	2067	2870	1703	2524	24	96.6	0	21
TUP	TUPELO	Mississippi	2913	2483	2278	2206	19	94	128	27
COU	COLUMBIA	Missouri	5029	1953	4494	1406	4	92	6	36
JLN	JOPLIN	Missouri	4394	2016	3806	1651	10	94	43	12
MCI	KANSAS CITY	Missouri	5379	1758	4690	1374	6	93	5	129
STL	SAINT LOUIS	Missouri	4827	2182	4171	1755	6	93	1	73
SGF	SPRINGFIELD	Missouri	4543	1977	4203	1450	9	92	8	46
BIL	BILLINGS	Montana	7203	560	6461	760	-10	90	5	51
BTM	BUTTE	Montana	8979	97	7001	1407	-17	84	0	9
CTB	CUT BANK	Montana	8982	195	6940	1336	-20	84	7	3
GGW	GLASGOW	Montana	8878	731	7747	633	-9	85.9	0	2
GTF	GREAT FALLS	Montana	7943	392	7364	307	-15	89	4	29
HVR	HAVRE	Montana	8989	429	7809	445	-11	90	0	3
HLN	HELENA	Montana	7640	412	6825	509	-16	87	0	17
FCA	KALISPELL	Montana	7816	147	6236	399	-7	86	4	16
LWT	LEWISTOWN	Montana	8582	210	7787	250	-16	86	2	5
MLS	MILES CITY	Montana	8353	677	7169	732	-15	93	0	2
MSO	MISSOULA	Montana	7224	281	7025	326	-6	88	1	35
GRI	GRAND ISLAND	Nebraska	6477	1283	5574	1285	-3	93	8	1
LNK	LINCOLN	Nebraska	6328	1484	5714	1263	-2	94	2	56
OFK	NORFOLK	Nebraska	7135	1083	6171	1118	-4	92	3	23
LBF	NORTH PLATTE	Nebraska	6801	1088	5967	1127	-4	92	9	16
OMA	OMAHA	Nebraska	6309	1562	5708	1401	-3	90	5	88
BFF	SCOTTSBLUFF	Nebraska	6316	875	6038	1104	-3	92	7	3
VTN	VALENTINE	Nebraska	7014	1062	6086	1144	-8	94	2	2
EKO	ELKO	Nevada	6325	713	6264	742	-2	92	9	10
ELY	ELY	Nevada	6904	401	6873	364	-4	87	0	2
LAS	LAS VEGAS	Nevada	1507	4274	1737	4251	28	106	56	142
LOL	LOVELOCK	Nevada	5648	865	3860	4090	12	97	0	1
RNO	RENO	Nevada	4402	1294	4441	1173	10	92	3	71
TPH	TONOPAH	Nevada	4782	1186	4853	1132	10	92	0	2
WMC	WINNEMUCCA	Nevada	5775	809	5651	995	3	94	1	3
CON	CONCORD	New Hampshire	6953	716	6561	724	-3	87	3	131
LEB	LEBANON	New Hampshire	7261	672	5338	2215	-3	86	17	43
MWN	MT WASHINGTON	New Hampshire	13158	0	12907	0	-18	63.8	0	1

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ACY	ATLANTIC CITY	New Jersey	4543	1560	4043	1337	13	89.4	52	49
EWR	NEWARK	New Jersey	4747	1495	4194	1402	14	91	144	407
ABQ	ALBUQUERQUE	New Mexico	3753	1738	3773	1740	16	93	1	150
CNM	CARLSBAD	New Mexico	2816	2482	2589	2596	19	98	1	10
CAO	CLAYTON	New Mexico	4764	1191	4648	1192	9	91	10	1
GUP	GALLUP	New Mexico	5842	600	5672	721	5	87	17	4
ROW	ROSWELL	New Mexico	2996	2470	2702	2663	18	96	0	9
CVN	TUCUMCARI	New Mexico	3896	1497	3797	1675	15	94.5	5	4
ALB	ALBANY	New York	6366	1040	6034	807	-1	86	39	45
BGM	BINGHAMTON	New York	7167	528	6653	555	1	82	10	10
BUF	BUFFALO	New York	6514	904	5844	924	6	84	44	46
GFL	GLENS FALLS	New York	7363	593	6100	1482	-5	85	6	9
MSS	MASSENA	New York	7874	672	7465	575	-8	84	40	12
LGA	NEW YORK	New York	4511	1688	3930	1635	15	89	51	684
ROC	ROCHESTER	New York	6317	978	6136	778	5	86	90	40
SYR	SYRACUSE	New York	6789	798	5964	974	2	86	87	34
UCA	UTICA	New York	4908	2189	3979	2268	-6	84.5	0	9
ART	WATERTOWN	New York	7492	615	6921	624	-6	83	23	15
AVL	ASHEVILLE	North Carolina	3834	1416	3504	1139	14	85.8	12	28
HAT	CAPE HATTERAS	North Carolina	1139	4536	585	4473	29	86	0	1
CLT	CHARLOTTE	North Carolina	3086	2270	2602	1853	22	91	11	221
GSO	GREENSBORO	North Carolina	3664	1945	3175	1485	18	90	33	73
HKY	HICKORY	North Carolina	3664	1757	2504	2673	18	90.1	55	8
EWN	NEW BERN	North Carolina	2791	2207	2192	1988	24	92	15	12
RDU	RALEIGH DURHAM	North Carolina	3399	2116	2694	1818	20	91.7	82	110
ILM	WILMINGTON	North Carolina	2491	2352	1869	2281	26	91	1	26
BIS	BISMARCK	North Dakota	8822	703	7798	779	-19	90	3	63
P11	DEVIL'S LAKE	North Dakota	7278	1888	6336	1910	-21	87	0	7
DIK	DICKINSON	North Dakota	8877	449	8159	320	-9	83	0	27
FAR	FARGO	North Dakota	9227	695	8709	649	-18	88	5	109
GFK	GRAND FORKS	North Dakota	9851	523	8312	1504	-22	88.6	6	39
JMS	JAMESTOWN	North Dakota	9350	543	8459	575	-15	82.5	3	19
MOT	MINOT	North Dakota	9056	666	8109	519	-20	89	3	50
ISN	WILLISTON	North Dakota	9218	534	5375	2410	-21	92	2	17
CAK	AKRON CANTON	Ohio	5786	1271	5205	1031	6	85.9	0	28
CLE	CLEVELAND	Ohio	5706	1267	5214	890	5	86.7	6	63
CMH	COLUMBUS	Ohio	5256	1523	4932	1199	5	89	31	130
CVG	CINCINNATI	Ohio	4989	1628	4475	1253	6	90	33	39
DAY	DAYTON	Ohio	5577	1337	4847	1186	4	87.9	36	19
FDY	FINDLAY	Ohio	5740	1338	5173	1166	3	87	14	4
MFD	MANSFIELD	Ohio	6050	1121	4657	1838	5	85	62	3
TOL	TOLEDO	Ohio	6040	1218	5341	1091	1	88.4	6	32
YNG	YOUNGSTOWN	Ohio	6038	978	5494	768	4	85.8	42	14
LHQ	ZANESVILLE	Ohio	5533	1230	5117	942	6	88.1	30	7
GAG	GAGE	Oklahoma	4192	2187	3022	3385	13	95.9	9	1
HBR	HOBART	Oklahoma	3499	2720	3100	2338	16	101	2	3
MLC	MCALESTER	Oklahoma	3140	2322	2809	2036	19	96	14	8
OKC	OKLAHOMA CITY	Oklahoma	3811	2087	3382	1765	13	96	22	135
PNC	PONCA CITY	Oklahoma	4178	2256	2783	3477	12	96.3	5	6

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TUL	TULSA	Oklahoma	3713	2453	3154	2036	13	97	14	79
AST	ASTORIA	Oregon	4532	16	4843	45	29	72	0	11
BKE	BAKER	Oregon	6261	366	6242	352	6	91	12	6
BNO	BURNS	Oregon	7341	235	6819	379	2	82.5	18	1
EUG	EUGENE	Oregon	4449	345	4152	432	22	87.6	15	48
MFR	MEDFORD	Oregon	3929	995	3862	1182	23	95	12	18
OTH	NORTH BEND	Oregon	4253	26	2631	1863	23	74.3	0	6
PDT	PENDLETON	Oregon	4783	757	4630	761	5	93	6	4
PDX	PORTLAND	Oregon	3661	700	3792	611	23	87.1	1	167
RDM	REDMOND	Oregon	5858	380	4822	1715	9	89.9	5	6
SLE	SALEM	Oregon	3903	522	4295	438	23	87.9	0	46
ABE	ALLENTOWN	Pennsylvania	5248	1278	4826	1018	9	88	154	38
AOO	ALTOONA	Pennsylvania	5783	1096	8262	555	5	86	8	9
BFD	BRADFORD	Pennsylvania	7225	438	6708	382	-1	80	0	7
DUJ	DU BOIS	Pennsylvania	6562	616	6027	634	5	84	5	3
ERI	ERIE	Pennsylvania	6002	1124	5275	962	9	84	6	19
CXY	HARRISBURG	Pennsylvania	4880	1598	4230	1570	11	89.6	2	17
PHL	PHILADELPHIA	Pennsylvania	4558	1574	3998	1493	14	90	2	421
PIT	PITTSBURGH	Pennsylvania	5689	1125	5215	963	5	86.6	38	77
AVP	SCRANTON	Pennsylvania	5940	917	5175	1024	4	87.6	15	20
IPT	WILLIAMSPORT	Pennsylvania	5690	1059	5331	1056	7	87	35	6
PVD	PROVIDENCE	Rhode Island	5422	1061	5001	1027	9	86	25	191
CHS	CHARLESTON	South Carolina	1774	2898	1464	2645	27	93	2	120
CAE	COLUMBIA	South Carolina	2335	2897	2013	2337	24	94	9	111
FLO	FLORENCE	South Carolina	2410	2730	1904	2386	25	94	6	37
GSP	GREENVILLE	South Carolina	3087	2096	2807	1696	22	91	73	66
ABR	ABERDEEN	South Dakota	8734	849	7802	856	-15	91	4	13
HON	HURON	South Dakota	8167	952	7417	861	-14	91	1	9
PIR	PIERRE	South Dakota	7866	1011	5733	2643	-10	95	5	3
RAP	RAPID CITY	South Dakota	7678	497	6939	679	-7	91	0	45
FSD	SIOUX FALLS	South Dakota	7781	922	6912	1097	-11	90	11	102
ATY	WATERTOWN	South Dakota	8905	662	8211	644	-12	84.9	1	11
TRI	BRISTOL	Tennessee	4076	1589	2964	2530	14	87	5	7
CHA	CHATTANOOGA	Tennessee	3153	2273	2549	2087	18	92	15	37
CSV	CROSSVILLE	Tennessee	4238	1272	2986	2521	15	87	0	6
MKL	JACKSON	Tennessee	3604	2181	3275	1620	16	93	38	14
TYS	KNOXVILLE	Tennessee	3625	1979	3128	1611	19	90	29	61
MEM	MEMPHIS	Tennessee	3118	2569	2605	2156	18	94	8	184
BNA	NASHVILLE	Tennessee	3401	2338	2998	1917	14	92	31	196
ABI	ABILENE	Texas	2647	2794	2145	2754	20	97	44	13
ALI	ALICE	Texas	967	3917	551	4295	34	99	64	2
AMA	AMARILLO	Texas	3902	1927	3786	1849	11	94.8	55	17
AUS	AUSTIN	Texas	1768	3343	1284	3499	28	96	7	83
BRO	BROWNSVILLE	Texas	523	4779	282	4835	39	94	0	16
CLL	COLLEGE STATION	Texas	1670	3317	724	5030	29	96	9	8
CRP	CORPUS CHRISTI	Texas	878	3683	600	3955	35	94	0	16
DHT	DALHART	Texas	4534	1605	3207	3153	12	92.6	42	1
DFW	DALLAS FT WORTH	Texas	2223	3153	1948	2775	22	98	18	279
DRT	DEL RIO	Texas	1394	3789	888	4404	31	98	27	4

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ELP	EL PASO	Texas	1902	3192	1989	3314	24	98	12	85
GLS	GALVESTON	Texas	903	3704	547	4061	36	90.6	5	5
IAH	HOUSTON	Texas	1304	3511	944	3620	32	96	10	216
LRD	LAREDO	Texas	859	4644	556	4655	36	101	3	8
LBB	LUBBOCK	Texas	3327	2422	3039	2300	15	96.3	73	20
LFK	LUFKIN	Texas	1942	2963	1491	2885	29	95	11	10
MFE	MCALLEN	Texas	535	5310	327	5057	39	98.8	0	3
MAF	MIDLAND ODESSA	Texas	2415	3035	2241	2900	21	98	17	16
PSX	PALACIOS	Texas	1032	3678	756	3603	32	99.5	10	1
CXO	PORT ARTHUR	Texas	1740	3036	1370	3116	30	97.7	33	21
SJT	SAN ANGELO	Texas	2295	3047	1935	2953	22	97	4	27
SAT	SAN ANTONIO	Texas	1459	3462	1062	3636	30	97	14	116
VCT	VICTORIA	Texas	1203	3521	839	3833	32	94.9	18	15
ACT	WACO	Texas	2230	3376	1790	2888	26	99	20	16
SPS	WICHITA FALLS	Texas	3080	2789	2597	2331	18	100	34	18
CDC	CEDAR CITY	Utah	5474	971	5538	1004	5	91	58	37
SLC	SALT LAKE CITY	Utah	4658	1587	4964	1658	8	94.8	19	151
BTV	BURLINGTON	Vermont	7021	907	6546	869	-7	85.3	2	202
MPV	MONTPELIER	Vermont	8239	378	7773	389	-6	83	9	43
LYH	LYNCHBURG	Virginia	4355	1509	3524	1481	16	90	40	53
ORF	NORFOLK	Virginia	3149	2326	2418	2080	22	91	30	170
RIC	RICHMOND	Virginia	3761	1994	3179	1672	17	92	44	159
ROA	ROANOKE	Virginia	4041	1674	3469	1499	16	89.8	47	69
BLI	BELLINGHAM	Washington	4786	151	4878	95	15	76	4	36
HQM	HOQUIAM	Washington	4501	27	4827	58	18	74.9	0	3
OLM	OLYMPIA	Washington	5004	199	4974	150	22	83	9	21
UIL	QUILLAYUTE	Washington	5396	9	5343	32	27	74	1	2
SEA	SEATTLE TACOMA	Washington	4028	411	4133	334	26	81.3	23	257
GEG	SPOKANE	Washington	6014	579	6034	560	2	89	22	74
ALW	WALLA WALLA	Washington	4247	1083	3557	3270	7	95	14	12
EAT	WENATCHEE	Washington	5382	932	5345	932	5	88.6	4	13
YKM	YAKIMA	Washington	5039	695	5182	740	5	92	25	21
BKW	BECKLEY	West Virginia	5090	917	4794	771	4	84	2	17
CRW	CHARLESTON	West Virginia	4484	1563	4082	1291	11	88	3	48
EKN	ELKINS	West Virginia	5479	829	4996	731	6	83	0	9
HTS	HUNTINGTON	West Virginia	4431	1627	4069	1314	10	89	9	45
MRB	MARTINSBURG	West Virginia	4986	1326	4536	1157	10	91	7	21
MGW	MORGANTOWN	West Virginia	5097	1283	4596	1105	8	87	15	31
PKB	PARKERSBURG	West Virginia	4980	1572	4107	1507	11	88	4	26
EAU	EAU CLAIRE	Wisconsin	8394	713	7578	660	-11	87	8	24
GRB	GREEN BAY	Wisconsin	7541	693	7164	662	-9	85	83	37
LSE	LACROSSE	Wisconsin	7116	1200	6585	1027	-9	89	13	18
MSN	MADISON	Wisconsin	7308	801	6829	726	-7	87	13	81
MKE	MILWAUKEE	Wisconsin	6679	929	6106	929	-4	87	2	181
AUW	WAUSAU	Wisconsin	8389	636	7944	516	-12	85	23	16
CPR	CASPER	Wyoming	7378	433	7492	545	-5	91.1	6	59
CYS	CHEYENNE	Wyoming	6716	435	6725	605	-1	86.3	5	69
COD	CODY	Wyoming	7544	357	7071	495	-13	87	1	5
LND	LANDER	Wyoming	7536	521	7595	686	-11	87	0	6

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RKS	ROCK SPRINGS	Wyoming	7581	405	7957	457	-3	84	0	25
SHR	SHERIDAN	Wyoming	7694	402	7085	612	-8	90	0	19
WRL	WORLAND	Wyoming	8234	538	7552	712	-13	93	0	7

7C.3.1 Developing Monthly Heating and Cooling Degree Day Fractions

Table 7C.3.2 and Table 7C.3.3 show the 10-year average monthly HDD and CDD data based on NOAA data for each weather station.[3] This data was then used to determine the monthly fractions of HDD and CDD as shown in Table 7C.3.4 and Table 7C.3.5.

Table 7C.3.2 Weather Station Monthly Heating Degree Day Data (10-Year Average, 2013-2022)

Station Location			10-year Average Monthly HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BHM	BIRMINGHAM	AL	628	432	278	103	23	0	0	0	4	78	341	467
HSV	HUNTSVILLE	AL	703	515	351	139	32	0	0	0	5	104	400	533
MOB	MOBILE	AL	452	276	161	47	6	0	0	0	0	30	205	319
MGM	MONTGOMERY	AL	519	318	198	59	9	0	0	0	0	46	274	377
MSL	MUSCLE SHOALS	AL	686	514	334	128	27	0	0	0	4	105	394	531
TCL	TUSCALOOSA	AL	591	409	252	89	16	0	0	0	1	69	331	439
ANC	ANCHORAGE	AK	1363	1201	1158	792	465	212	115	187	422	785	1188	1342
BRW	BARROW	AK	2238	2110	2177	1765	1226	834	684	771	902	1231	1617	2103
BET	BETHEL	AK	1656	1420	1460	988	610	285	237	307	536	897	1324	1551
BTT	BETTLES	AK	2228	1957	1808	1199	562	195	152	342	677	1207	1854	2110
BIG	BIG DELTA	AK	1902	1658	1508	965	480	188	130	272	588	1077	1648	1853
CDB	COLD BAY	AK	1060	888	998	821	680	475	355	333	460	670	831	972
CDV	CORDOVA	AK	1098	997	1011	793	570	364	278	306	458	711	978	1079
FAI	FAIRBANKS	AK	2160	1836	1609	967	415	122	74	209	543	1057	1727	2030
GKN	GULKANA	AK	1977	1695	1496	972	551	274	171	315	588	1092	1700	1969
HOM	HOMER	AK	1138	980	1013	759	539	331	234	259	431	694	975	1106
JNU	JUNEAU	AK	1024	975	957	710	436	269	199	226	405	668	915	1064
ENA	KENAI	AK	1425	1234	1209	840	566	347	243	276	482	809	1206	1396
KTN	KETCHIKAN	AK	841	815	798	621	400	262	159	152	294	539	728	907
AKN	KING SALMON	AK	1364	1110	1208	834	563	320	222	265	478	783	1134	1311
ADQ	KODIAK	AK	1006	880	927	759	561	357	217	225	392	642	849	966
OTZ	KOTZEBUE	AK	1920	1786	1854	1340	876	436	259	345	621	1057	1551	1839
MCG	MCGRATH	AK	2048	1698	1566	981	480	168	130	258	558	1013	1619	1936
OME	NOME	AK	1712	1556	1634	1172	778	436	373	411	627	957	1333	1617
ORT	NORTHWAY	AK	2328	1986	1706	1042	510	226	145	302	630	1210	1946	2283
SNP	ST PAUL ISLAND	AK	1130	1018	1127	950	802	590	471	422	508	710	867	1015
SIT	SITKA	AK	812	788	799	644	470	312	209	189	301	524	713	828
TKA	TALKEETNA	AK	1489	1278	1240	849	484	204	122	225	484	869	1285	1465
UNK	UNALAKLEET	AK	1732	1522	1553	1069	675	360	257	334	579	960	1479	1627
VWS	VALDEZ	AK	964	826	794	517	252	77	44	72	247	472	812	923
YAK	YAKUTAT	AK	1040	963	987	780	560	358	261	271	425	670	919	1042
DUG	DOUGLAS	AZ	496	326	183	85	23	0	0	0	1	50	233	444

Station Location			10-year Average Monthly HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
FLG	FLAGSTAFF	AZ	973	780	655	453	331	65	13	32	135	393	662	917
PHX	PHOENIX	AZ	237	138	39	1	0	0	0	0	0	3	66	251
TUS	TUCSON	AZ	327	222	91	17	1	0	0	0	0	14	111	320
INW	WINSLOW	AZ	898	653	489	262	101	2	0	0	19	240	583	876
NYL	YUMA	AZ	176	106	37	3	0	0	0	0	0	2	44	206
ELD	EL DORADO	AR	624	493	294	118	18	0	0	0	2	95	359	505
FYV	FAYETTEVILLE	AR	868	716	490	254	90	2	0	0	17	221	527	735
FSM	FORT SMITH	AR	742	590	348	143	30	0	0	0	1	112	400	618
HRO	HARRISON	AR	786	661	417	195	63	1	0	0	7	150	427	632
LIT	LITTLE ROCK	AR	707	550	323	130	25	0	0	0	2	108	406	579
TXK	TEXARKANA	AR	605	477	268	108	17	0	0	0	1	80	323	482
BFL	BAKERSFIELD	CA	423	286	166	56	13	0	0	0	1	31	227	456
BLH	BLYTHE	CA	264	141	45	3	1	0	0	0	0	5	92	283
EKA	EUREKA	CA	524	491	506	436	383	276	228	218	229	347	454	549
FAT	FRESNO	CA	446	303	182	65	18	0	0	0	1	28	251	498
IPL	IMPERIAL	CA	250	149	51	5	1	0	0	0	0	5	78	260
LAX	LOS ANGELES	CA	198	182	151	88	57	6	1	0	0	11	80	207
MHS	MT SHASTA	CA	761	633	575	368	173	51	3	4	93	296	548	785
PRB	PASO ROBLES	CA	449	379	297	157	71	10	1	0	9	86	302	503
RBL	RED BLUFF	CA	474	344	270	116	25	1	0	0	4	53	307	518
RDD	REDDING	CA	485	360	286	132	29	2	0	0	6	68	337	538
SAC	SACRAMENTO	CA	489	340	231	112	34	2	0	0	3	54	318	526
SAN	SAN DIEGO	CA	185	155	110	51	30	4	0	0	0	6	64	194
SFO	SAN FRANCISCO	CA	372	286	259	193	145	58	45	20	28	74	235	394
SCK	STOCKTON	CA	481	345	245	109	27	2	0	0	2	53	301	507
AKO	AKRON	CO	1075	1001	748	540	291	22	3	7	83	432	743	1082
ALS	ALAMOSA	CO	1531	1090	878	639	407	95	18	63	210	618	989	1389
COS	COLORADO SPRINGS	CO	996	923	721	511	273	30	4	6	68	417	726	994
DEN	DENVER	CO	1004	945	726	520	277	24	1	5	69	404	720	1023
EGE	EAGLE	CO	1331	1029	842	621	380	61	5	21	155	578	907	1283
GJT	GRAND JUNCTION	CO	1185	843	601	384	158	9	0	1	42	377	736	1121
LHX	LA JUNTA	CO	953	833	576	338	137	5	0	0	30	298	649	968
PUB	PUEBLO	CO	993	864	634	392	168	8	0	0	37	345	691	985
TAD	TRINIDAD	CO	957	828	638	437	211	16	1	3	48	349	667	934
BDR	BRIDGEPORT	CT	1031	901	786	460	172	17	0	0	33	230	569	829
BDL	HARTFORD	CT	1154	995	846	480	174	27	2	2	73	327	676	959
ILG	WILMINGTON	DE	938	771	630	294	92	6	0	0	17	167	488	717
DCA	WASHINGTON	DC	852	685	533	229	63	1	0	0	7	135	457	669
DAB	DAYTONA BEACH	FL	176	87	71	6	1	0	0	0	0	3	35	79
FLL	FT LAUDERDALE	FL	33	14	8	0	0	0	0	0	0	0	4	11
FMY	FORT MYERS	FL	82	33	17	0	0	0	0	0	0	1	9	32
GNV	GAINESVILLE	FL	265	148	104	14	2	0	0	0	0	11	83	140
JAX	JACKSONVILLE	FL	341	205	144	31	4	0	0	0	0	17	129	216
EYW	KEY WEST	FL	12	5	2	0	0	0	1	0	0	0	0	6
MLB	MELBOURNE	FL	140	69	48	3	0	0	0	0	0	2	23	67
MIA	MIAMI	FL	31	12	5	0	0	0	0	0	0	0	3	15
MCO	ORLANDO	FL	162	71	45	2	0	0	0	0	0	2	30	77
PNS	PENSACOLA	FL	375	205	116	22	2	0	0	0	0	13	149	241
TLH	TALLAHASSEE	FL	383	221	143	34	3	0	0	0	0	23	163	250
TPA	TAMPA	FL	146	64	39	1	0	0	0	0	0	2	26	63
VRB	VERO BEACH	FL	91	48	41	2	0	0	0	0	0	2	17	39

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
PBI	WEST PALM BEACH	FL	56	24	17	0	0	0	0	0	0	0	6	27
ABY	ALBANY	GA	333	198	114	21	5	0	0	0	0	12	108	178
AHN	ATHENS	GA	627	442	305	119	25	0	0	0	4	102	355	495
ATL	ATLANTA	GA	617	426	280	105	22	0	0	0	3	74	329	461
AGS	AUGUSTA	GA	551	375	261	95	14	0	0	0	1	67	303	423
BQK	BRUNSWICK	GA	386	242	169	51	4	0	0	0	0	27	180	273
CSG	COLUMBUS	GA	517	334	211	65	10	0	0	0	1	43	256	377
MCN	MACON	GA	545	367	246	91	16	0	0	0	1	64	302	407
SAV	SAVANNAH	GA	420	269	181	48	4	0	0	0	1	28	198	290
AYS	WAYCROSS	GA	364	209	136	36	3	0	0	0	0	24	165	254
ITO	HILO-HAWAII	HI	0	0	5	5	0	0	0	0	0	0	0	0
HNL	HONOLULU-OAHU	HI	0	0	0	0	0	0	0	0	0	0	0	0
OGG	KAHULUI-MAUI	HI	0	0	1	0	0	0	0	0	0	0	1	0
LIH	LIHUE-KAUAI	HI	1	0	0	0	0	0	0	0	0	0	2	0
BOI	BOISE	ID	1038	774	579	402	171	40	1	1	69	342	735	1045
BYI	BURLEY	ID	1109	877	700	533	287	78	6	14	145	480	798	1104
IDA	IDAHO FALLS	ID	1374	1126	852	604	346	106	12	28	189	587	940	1347
LWS	LEWISTON	ID	884	741	589	378	143	37	1	1	60	346	694	932
PIH	POCATELLO	ID	1215	965	762	564	319	86	6	16	156	536	874	1213
ORD	CHICAGO	IL	1254	1095	826	494	200	18	3	1	49	344	734	1037
MLI	MOLINE	IL	1296	1124	803	443	149	5	2	1	53	356	749	1057
PIA	PEORIA	IL	1218	1061	745	395	130	4	2	0	36	309	705	996
UIN	QUINCY	IL	1114	958	644	325	101	3	2	1	24	240	605	881
RFD	ROCKFORD	IL	1333	1182	867	495	185	13	2	2	68	389	790	1104
SPI	SPRINGFIELD	IL	1141	988	693	353	115	2	2	1	36	303	677	943
EVV	EVANSVILLE	IN	965	800	576	266	79	1	0	0	19	218	590	781
FWA	FORT WAYNE	IN	1205	1052	832	474	164	13	3	6	70	346	727	995
IND	INDIANAPOLIS	IN	1134	947	714	369	127	5	1	1	35	288	677	928
SBN	SOUTH BEND	IN	1241	1091	874	526	206	23	5	7	72	362	742	1027
LAF	WEST LAFAYETTE	IN	1199	1030	772	424	148	10	5	3	57	329	721	982
BRL	BURLINGTON	IA	1186	1028	704	354	107	2	3	1	30	259	641	948
CID	CEDAR RAPIDS	IA	1393	1233	894	516	195	11	6	10	81	430	835	1171
DSM	DES MOINES	IA	1278	1131	768	418	144	3	0	0	45	355	748	1093
DBQ	DUBUQUE	IA	1427	1272	939	554	218	18	7	8	95	439	861	1198
MCW	MASON CITY	IA	1504	1360	995	608	244	17	9	15	113	512	933	1299
OTM	OTTUMWA	IA	1282	1129	793	449	164	7	4	3	61	384	754	1078
SUX	SIOUX CITY	IA	1319	1193	832	501	195	10	3	5	69	442	836	1209
SPW	SPENCER	IA	1376	1257	882	512	174	14	7	10	63	399	814	1216
ALO	WATERLOO	IA	1437	1284	930	535	202	11	4	6	87	447	866	1203
CNU	CHANUTE	KS	929	817	511	260	87	1	0	0	14	212	546	807
CNK	CONCORDIA	KS	1073	951	637	360	128	2	1	0	34	284	639	974
DDC	DODGE CITY	KS	971	870	596	350	129	5	2	0	28	274	619	927
GCK	GARDEN CITY	KS	1016	904	631	384	146	6	1	0	35	311	659	982
GLD	GOODLAND	KS	1043	961	708	471	213	17	2	3	63	380	686	984
RSL	RUSSELL	KS	1031	915	626	366	135	4	1	0	34	293	648	971
SLN	SALINA	KS	998	875	576	318	103	2	0	0	21	256	600	927
TOP	TOPEKA	KS	1030	906	583	314	98	1	0	0	23	266	613	906
ICT	WICHITA	KS	938	826	521	277	84	1	0	0	12	209	563	857
BWG	BOWLING GREEN	KY	865	685	494	225	60	0	0	0	16	182	521	677
JKL	JACKSON	KY	874	673	493	208	71	2	0	0	15	165	471	640
LEX	LEXINGTON	KY	975	788	598	293	95	5	0	0	28	227	589	763

Station Location			10-year Average Monthly HDD Data											
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SDF	LOUISVILLE	KY	909	734	516	223	59	1	0	0	12	178	523	707
PAH	PADUCAH	KY	911	757	530	241	68	1	0	0	16	203	548	728
BTR	BATON ROUGE	LA	378	215	114	31	5	0	0	0	0	16	162	247
LFT	LAFAYETTE	LA	398	246	125	34	4	0	0	0	0	19	175	281
LCH	LAKE CHARLES	LA	402	251	127	32	4	0	0	0	0	20	174	288
MLU	MONROE	LA	557	416	225	83	9	0	0	0	0	58	299	432
MSY	NEW ORLEANS	LA	350	196	98	18	2	0	0	0	0	10	133	225
SHV	SHREVEPORT	LA	524	396	204	74	8	0	0	0	0	52	269	413
AUG	AUGUSTA	ME	1336	1169	1041	637	292	83	12	12	131	441	805	1152
BGR	BANGOR	ME	1332	1179	1034	606	245	75	7	10	118	391	767	1123
CAR	CARIBOU	ME	1600	1420	1274	803	389	148	37	47	235	579	972	1379
HUL	HOULTON	ME	1556	1398	1244	792	418	176	47	61	252	586	943	1331
PWM	PORTLAND	ME	1242	1091	977	624	314	85	8	9	127	420	762	1072
BWI	BALTIMORE	MD	953	780	640	308	102	5	0	0	23	209	544	758
SBY	SALISBURY	MD	815	652	543	252	82	5	0	0	7	132	411	608
BOS	BOSTON	MA	1054	917	827	490	215	38	3	0	49	267	595	865
CHH	CHATHAM	MA	963	845	783	505	243	53	2	2	47	217	513	757
ORH	WORCESTER	MA	1168	1006	897	522	222	53	5	7	85	318	666	960
APN	ALPENA	MI	1397	1296	1124	760	369	118	27	33	181	517	851	1155
DTW	DETROIT	MI	1212	1070	862	504	177	17	2	2	66	345	723	987
FNT	FLINT	MI	1263	1147	931	563	216	36	4	10	108	397	765	1039
GRR	GRAND RAPIDS	MI	1240	1128	932	564	216	29	4	8	88	403	760	1044
CMX	HANCOCK	MI	1484	1420	1246	864	455	173	60	78	226	601	956	1293
HTL	HOUGHTON LAKE	MI	1408	1306	1115	719	319	93	31	43	193	528	867	1188
JXN	JACKSON	MI	1259	1126	921	558	221	38	7	14	105	411	775	1038
LAN	LANSING	MI	1268	1142	937	565	223	32	6	11	103	410	774	1048
SAW	MARQUETTE	MI	1539	1445	1245	876	463	172	77	95	248	638	1000	1351
MKG	MUSKEGON	MI	1193	1105	936	586	245	37	9	9	81	385	720	1002
MBS	SAGINAW	MI	1271	1165	963	589	230	34	4	8	100	402	767	1063
ANJ	SAULT ST MARIE	MI	1475	1373	1198	807	390	140	37	37	182	541	897	1250
TVC	TRAVERSE CITY	MI	1281	1197	1038	682	318	75	17	15	112	435	779	1080
AXN	ALEXANDRIA	MN	1638	1501	1122	714	276	32	7	13	134	570	1017	1472
DLH	DULUTH	MN	1658	1508	1182	813	402	126	29	44	202	614	1052	1481
HIB	HIBBING	MN	1789	1643	1269	870	458	163	63	109	300	719	1156	1599
INL	INT'L FALLS	MN	1829	1683	1290	863	427	134	52	96	274	695	1141	1625
MSP	MINNEAPOLIS	MN	1493	1344	972	597	206	12	3	3	81	471	899	1317
RST	ROCHESTER	MN	1544	1405	1038	642	258	25	8	17	121	524	948	1345
STC	SAINT CLOUD	MN	1610	1464	1090	698	286	35	8	20	149	574	1001	1434
GWO	GREENWOOD	MS	563	405	242	84	17	0	0	0	0	62	272	407
JAN	JACKSON	MS	557	387	227	85	12	0	0	0	0	58	295	411
MCB	MCCOMB	MS	490	318	181	63	9	0	0	0	0	39	241	357
MEI	MERIDIAN	MS	563	385	236	86	13	0	0	0	1	66	308	416
TUP	TUPELO	MS	674	510	322	125	23	0	0	0	2	96	388	528
COU	COLUMBIA	MO	1033	896	588	298	98	2	0	0	19	261	598	865
JLN	JOPLIN	MO	902	773	494	254	91	2	0	0	13	218	519	767
MCI	KANSAS CITY	MO	1069	935	612	338	110	3	0	1	28	278	629	922
STL	SAINT LOUIS	MO	989	842	554	259	76	1	0	0	12	210	560	808
SGF	SPRINGFIELD	MO	943	801	536	279	98	3	0	0	15	236	560	799
BIL	BILLINGS	MT	1122	1105	821	583	296	52	2	21	144	504	849	1176
BTM	BUTTE	MT	1283	1186	937	703	439	195	41	77	258	599	990	1314
CTB	CUT BANK	MT	1191	1219	966	678	380	154	35	56	237	577	931	1256

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
GGW	GLASGOW	MT	1458	1360	1020	646	286	53	5	24	178	595	1051	1477
GTF	GREAT FALLS	MT	1160	1198	929	687	401	140	23	46	233	599	943	1252
HVR	HAVRE	MT	1361	1311	1014	663	341	97	12	34	214	635	1033	1405
HLN	HELENA	MT	1242	1130	870	608	331	92	7	22	181	559	960	1265
FCA	KALISPELL	MT	1218	1092	850	587	306	139	36	62	286	679	979	1265
LWT	LEWISTOWN	MT	1216	1241	978	734	453	179	31	57	259	635	972	1282
MLS	MILES CITY	MT	1338	1234	905	610	292	48	1	17	141	551	957	1341
MSO	MISSOULA	MT	1219	1044	833	610	327	126	18	28	211	606	969	1227
GRI	GRAND ISLAND	NE	1172	1065	740	449	176	6	2	2	52	373	735	1095
LNK	LINCOLN	NE	1201	1077	727	416	146	4	1	1	49	357	732	1087
OFK	NORFOLK	NE	1261	1151	810	486	201	14	4	6	66	432	799	1175
LBF	NORTH PLATTE	NE	1171	1083	775	516	246	19	4	6	73	454	805	1144
OMA	OMAHA	NE	1226	1090	730	404	141	3	1	0	40	345	737	1096
BFF	SCOTTSBLUFF	NE	1109	1025	764	544	276	20	2	8	85	475	802	1144
VTN	VALENTINE	NE	1200	1124	823	565	252	22	3	9	85	482	828	1230
EKO	ELKO	NV	1130	902	737	550	319	68	2	6	139	496	852	1177
ELY	ELY	NV	1176	985	825	630	430	104	6	16	175	568	874	1190
LAS	LAS VEGAS	NV	445	284	127	23	6	0	0	0	0	23	207	479
LOL	LOVELOCK	NV	940	726	578	347	151	24	0	1	81	341	654	964
RNO	RENO	NV	828	667	549	341	163	24	0	1	53	298	615	879
TPH	TONOPAH	NV	912	759	620	381	176	18	0	0	55	337	665	970
WMC	WINNEMUCCA	NV	1005	783	695	507	281	66	3	5	134	480	767	1065
CON	CONCORD	NH	1290	1128	990	604	259	67	6	17	138	442	803	1114
LEB	LEBANON	NH	1291	1121	970	546	189	52	5	13	103	358	741	1065
MWN	MT WASHINGTON	NH	1815	1648	1650	1257	858	592	423	479	620	950	1337	1603
ACY	ATLANTIC CITY	NJ	972	797	701	384	138	12	0	0	30	219	548	761
EWR	NEWARK	NJ	999	838	697	359	114	8	0	0	22	203	532	779
ABQ	ALBUQUERQUE	NM	845	633	430	219	67	1	0	0	14	198	541	820
CNM	CARLSBAD	NM	661	474	270	99	20	0	0	0	7	112	379	587
CAO	CLAYTON	NM	884	780	568	380	163	11	0	2	37	306	600	864
GUP	GALLUP	NM	1062	842	707	502	279	23	3	8	84	448	766	1029
ROW	ROSWELL	NM	722	511	303	119	24	0	0	0	8	126	426	665
CVN	TUCUMCARI	NM	819	653	464	266	83	3	0	0	21	230	533	766
ALB	ALBANY	NY	1252	1075	925	534	197	38	3	7	106	380	748	1027
BGM	BINGHAMTON	NY	1315	1131	1019	624	267	78	11	27	150	442	811	1087
BUF	BUFFALO	NY	1206	1087	942	589	228	46	3	5	84	361	715	986
GFL	GLENS FALLS	NY	1324	1149	971	543	200	61	4	15	114	372	743	1060
MSS	MASSENA	NY	1503	1330	1143	670	283	82	14	23	175	491	871	1214
LGA	NEW YORK	NY	953	807	694	363	114	7	0	0	13	164	480	739
ROC	ROCHESTER	NY	1215	1079	937	575	225	45	4	8	97	370	716	991
SYR	SYRACUSE	NY	1265	1109	971	571	219	48	2	6	98	366	730	1018
UCA	UTICA	NY	1035	887	707	294	42	0	0	0	11	159	533	825
ART	WATERTOWN	NY	1377	1231	1064	658	303	95	14	24	162	443	790	1106
AVL	ASHEVILLE	NC	831	630	503	258	79	2	0	1	26	213	529	668
HAT	CAPE HATTERAS	NC	317	235	163	24	1	0	0	0	0	1	77	179
CLT	CHARLOTTE	NC	711	512	385	150	39	1	0	0	8	117	416	557
GSO	GREENSBORO	NC	799	601	462	191	58	2	0	0	16	150	471	636
HKY	HICKORY	NC	723	529	397	170	44	2	0	0	7	112	393	550
EWN	NEW BERN	NC	628	459	366	139	29	0	0	0	2	71	321	461
RDU	RALEIGH DURHAM	NC	734	549	434	170	49	1	0	0	8	125	424	569
ILM	WILMINGTON	NC	579	423	331	117	21	0	0	0	1	58	295	415

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BIS	BISMARCK	ND	1526	1388	1047	706	300	42	7	17	149	603	1036	1476
P11	DEVIL'S LAKE	ND	1560	1456	1108	650	196	26	10	14	85	463	954	1437
DIK	DICKINSON	ND	1490	1318	1066	733	362	81	14	31	219	638	1050	1421
FAR	FARGO	ND	1664	1529	1152	728	278	32	8	19	144	589	1045	1522
GFK	GRAND FORKS	ND	1675	1551	1182	728	278	43	11	24	136	554	1037	1536
JMS	JAMESTOWN	ND	1621	1503	1159	772	327	47	8	29	181	637	1067	1528
MOT	MINOT	ND	1548	1464	1127	755	302	52	10	25	177	621	1063	1493
ISN	WILLISTON	ND	1439	1354	983	611	235	43	8	22	153	526	967	1384
CAK	AKRON CANTON	OH	1150	994	811	446	161	20	2	3	59	309	682	926
CLE	CLEVELAND	OH	1132	999	822	467	180	20	2	3	56	295	660	904
CMH	COLUMBUS	OH	1090	930	712	374	127	8	0	1	40	281	655	881
CVG	CINCINNATI	OH	1037	861	651	325	111	5	1	0	32	256	631	833
DAY	DAYTON	OH	1118	946	734	383	128	9	1	3	47	287	666	906
FDY	FINDLAY	OH	1165	1016	797	439	146	11	2	3	50	303	681	941
MFD	MANSFIELD	OH	1142	982	788	426	150	21	3	6	49	270	649	905
TOL	TOLEDO	OH	1207	1065	851	491	175	18	3	5	67	337	706	974
YNG	YOUNGSTOWN	OH	1186	1024	852	490	200	39	6	10	87	357	712	953
LHQ	ZANESVILLE	OH	1105	936	733	402	140	14	2	5	65	321	685	888
GAG	GAGE	OK	792	707	406	218	67	1	0	0	9	161	442	717
HBR	HOBART	OK	772	664	388	193	45	0	0	0	6	141	408	690
MLC	MCALESTER	OK	721	599	351	161	38	0	0	0	3	137	397	586
OKC	OKLAHOMA CITY	OK	786	671	394	198	49	0	0	0	7	155	453	707
PNC	PONCA CITY	OK	722	623	342	163	38	0	0	0	5	122	367	615
TUL	TULSA	OK	797	673	393	184	49	0	0	0	3	152	441	686
AST	ASTORIA	OR	628	589	574	455	316	187	101	77	142	331	515	669
BKE	BAKER	OR	1173	932	774	603	357	158	22	37	227	564	896	1192
BNO	BURNS	OR	1206	931	795	621	382	155	19	36	245	600	950	1258
EUG	EUGENE	OR	709	603	536	394	232	93	8	6	79	318	580	748
MFR	MEDFORD	OR	729	587	473	304	126	38	0	0	43	245	562	777
OTH	NORTH BEND	OR	470	444	430	335	209	140	88	76	100	195	363	488
PDT	PENDLETON	OR	916	765	610	417	190	55	1	3	90	368	721	959
PDX	PORTLAND	OR	704	598	497	336	150	51	2	2	52	261	523	727
RDM	REDMOND	OR	902	784	674	504	276	121	20	21	162	400	731	957
SLE	SALEM	OR	697	596	525	374	190	69	5	4	66	296	552	725
ABE	ALLENTOWN	PA	1094	928	781	410	149	15	0	2	59	293	660	898
AOO	ALTOONA	PA	1187	1072	955	541	310	123	67	66	195	475	855	1059
BFD	BRADFORD	PA	1303	1137	1005	621	291	104	36	52	175	462	838	1074
DUJ	DU BOIS	PA	1235	1065	909	528	225	56	8	18	116	394	769	1013
ERI	ERIE	PA	1140	1025	889	543	224	37	2	4	63	300	653	906
CXY	HARRISBURG	PA	1036	861	700	352	118	6	0	1	34	231	591	831
PHL	PHILADELPHIA	PA	953	787	652	315	92	3	0	0	16	181	515	750
PIT	PITTSBURGH	PA	1137	950	777	416	154	21	1	3	60	322	682	906
AVP	SCRANTON	PA	1163	977	847	465	169	28	1	4	80	317	682	929
IPT	WILLIAMSPORT	PA	1156	974	813	447	161	17	0	1	64	316	695	935
PVD	PROVIDENCE	RI	1064	923	814	479	195	29	1	0	51	285	618	879
CHS	CHARLESTON	SC	462	312	219	64	7	0	0	0	1	34	230	328
CAE	COLUMBIA	SC	574	399	276	88	15	0	0	0	2	68	327	448
FLO	FLORENCE	SC	577	411	307	97	16	0	0	0	3	66	317	443
GSP	GREENVILLE	SC	698	510	369	147	37	1	0	0	10	121	406	553
ABR	ABERDEEN	SD	1553	1425	1063	680	272	32	9	18	136	580	1006	1455
HON	HURON	SD	1475	1334	980	624	247	24	6	15	98	526	930	1370

Station Location			10-year Average Monthly HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
PIR	PIERRE	SD	1283	1187	851	546	223	23	4	8	68	403	806	1222
RAP	RAPID CITY	SD	1208	1173	891	668	354	58	4	19	137	546	887	1236
FSD	SIOUX FALLS	SD	1425	1295	929	581	234	19	5	8	81	482	895	1308
ATY	WATERTOWN	SD	1582	1455	1092	716	303	38	10	20	138	587	999	1447
TRI	BRISTOL	TN	820	614	462	216	64	2	0	0	9	160	473	622
CHA	CHATTANOOGA	TN	716	523	354	142	28	0	0	0	4	109	416	560
CSV	CROSSVILLE	TN	813	616	465	215	72	4	0	0	15	158	443	602
MKL	JACKSON	TN	792	632	437	200	52	0	0	0	10	161	470	640
TYS	KNOXVILLE	TN	803	599	431	194	52	0	0	0	11	156	485	632
MEM	MEMPHIS	TN	702	559	339	136	26	0	0	0	2	100	389	554
BNA	NASHVILLE	TN	779	601	411	176	45	0	0	0	7	137	453	606
ABI	ABILENE	TX	597	478	245	105	20	0	0	0	4	85	309	506
ALI	ALICE	TX	260	172	71	9	0	0	0	0	0	13	105	189
AMA	AMARILLO	TX	812	699	448	256	86	2	0	0	17	213	516	762
AUS	AUSTIN	TX	455	329	156	48	4	0	0	0	0	35	206	356
BRO	BROWNSVILLE	TX	168	109	35	4	0	0	0	0	0	4	58	109
CLL	COLLEGE STATION	TX	360	258	117	37	4	0	0	0	0	21	151	274
CRP	CORPUS CHRISTI	TX	260	174	68	8	0	0	0	0	0	11	100	189
DHT	DALHART	TX	787	675	442	268	89	1	0	0	13	188	465	717
DFW	DALLAS FT WORTH	TX	546	432	207	79	10	0	0	0	0	58	266	451
DRT	DEL RIO	TX	369	215	80	14	1	0	0	0	0	26	155	301
ELP	EL PASO	TX	574	354	167	42	6	0	0	0	2	50	272	515
GLS	GALVESTON	TX	289	183	74	12	1	0	3	0	0	6	92	195
IAH	HOUSTON	TX	367	248	115	29	2	0	0	0	0	19	158	275
LRD	LAREDO	TX	259	154	51	3	0	0	0	0	0	15	97	191
LBB	LUBBOCK	TX	735	585	348	162	42	0	0	0	12	155	434	667
LFK	LUFKIN	TX	476	336	173	60	5	0	0	0	0	44	232	381
MFE	MCALLEN	TX	175	112	34	3	0	0	0	0	0	8	67	123
MAF	MIDLAND ODESSA	TX	611	458	239	84	16	0	0	0	6	89	331	524
PSX	PALACIOS	TX	315	214	94	18	2	0	0	0	0	16	125	233
CXO	PORT ARTHUR	TX	462	320	172	57	6	0	0	0	0	41	220	354
SJT	SAN ANGELO	TX	551	413	207	72	14	0	0	0	3	74	287	457
SAT	SAN ANTONIO	TX	382	267	114	29	2	0	0	0	0	27	167	302
VCT	VICTORIA	TX	327	232	106	21	1	0	0	0	0	19	139	249
ACT	WACO	TX	536	413	223	82	9	0	0	0	0	55	266	448
SPS	WICHITA FALLS	TX	676	567	308	139	25	0	0	0	4	105	364	594
CDC	CEDAR CITY	UT	1056	861	688	482	275	26	0	2	86	437	752	1079
SLC	SALT LAKE CITY	UT	1037	780	557	377	153	17	0	1	49	315	666	1013
BTV	BURLINGTON	VT	1359	1180	1038	603	218	48	3	7	114	400	785	1102
MPV	MONTPELIER	VT	1469	1272	1156	714	331	132	28	48	203	523	907	1224
LYH	LYNCHBURG	VA	905	704	554	254	87	4	0	1	29	209	545	727
ORF	NORFOLK	VA	728	566	457	194	49	1	0	0	1	88	363	544
RIC	RICHMOND	VA	825	643	507	212	65	1	0	0	9	148	462	653
ROA	ROANOKE	VA	872	672	518	240	76	3	0	0	24	190	519	688
BLI	BELLINGHAM	WA	746	681	594	438	254	126	34	32	146	390	591	805
HQM	HOQUIAM	WA	645	600	568	449	319	189	103	77	133	331	530	682
OLM	OLYMPIA	WA	752	684	624	473	275	142	39	31	145	410	643	791
UIL	QUILLAYUTE	WA	683	641	628	508	365	239	136	110	192	390	578	734
SEA	SEATTLE TACOMA	WA	676	614	535	389	204	87	10	10	83	322	541	716
GEG	SPOKANE	WA	1082	935	742	513	238	95	8	10	139	483	849	1115
ALW	WALLA WALLA	WA	848	683	492	290	79	18	0	0	46	246	602	858

Station Location			10-year Average Monthly HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EAT	WENATCHEE	WA	1081	879	651	385	136	38	0	1	76	396	793	1119
YKM	YAKIMA	WA	984	800	622	393	153	47	1	4	104	398	769	1045
BKW	BECKLEY	WV	1033	820	694	366	146	22	4	6	65	309	646	825
CRW	CHARLESTON	WV	952	754	592	282	98	5	0	0	31	244	576	745
EKN	ELKINS	WV	1113	894	778	447	189	35	7	11	84	362	704	879
HTS	HUNTINGTON	WV	954	755	583	279	96	4	0	0	31	240	574	753
MRB	MARTINSBURG	WV	1017	827	683	348	132	9	0	1	49	273	611	835
MGW	MORGANTOWN	WV	1032	839	685	349	131	14	1	1	46	273	604	805
PKB	PARKERSBURG	WV	976	785	614	308	91	10	1	1	32	245	583	756
EAU	EAU CLAIRE	WI	1548	1406	1050	661	263	34	8	16	130	533	946	1355
GRB	GREEN BAY	WI	1428	1305	1025	652	268	40	7	17	122	474	856	1221
LSE	LACROSSE	WI	1424	1289	927	535	188	11	2	2	63	415	819	1210
MSN	MADISON	WI	1404	1260	960	578	233	26	5	9	103	448	846	1183
MKE	MILWAUKEE	WI	1276	1138	906	590	276	53	7	5	69	370	749	1064
AUW	WAUSAU	WI	1533	1397	1077	691	275	46	11	25	157	540	948	1343
CPR	CASPER	WY	1211	1152	908	704	419	85	5	23	173	596	916	1245
CYS	CHEYENNE	WY	1080	1046	856	676	416	68	10	20	135	540	834	1099
COD	CODY	WY	1152	1116	847	671	403	105	9	42	203	574	910	1195
LND	LANDER	WY	1341	1148	872	661	389	74	3	18	149	581	947	1335
RKS	ROCK SPRINGS	WY	1312	1123	921	704	435	102	7	26	199	629	979	1335
SHR	SHERIDAN	WY	1209	1184	884	669	380	87	6	25	171	586	919	1254
WRL	WORLAND	WY	1458	1267	866	617	314	53	2	17	166	600	1028	1453

Table 7C.3.3 Weather Station Monthly Cooling Degree Day Data (10-Year Average, 2013-2022)

Station Location			10-year Average Monthly CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BHM	BIRMINGHAM	AL	3	9	26	71	248	426	516	494	369	134	17	11
HSV	HUNTSVILLE	AL	1	5	11	56	228	422	505	467	332	105	13	4
MOB	MOBILE	AL	11	30	66	112	294	474	532	528	429	209	43	31
MGM	MONTGOMERY	AL	7	22	51	99	289	486	561	554	432	176	27	19
MSL	MUSCLE SHOALS	AL	2	7	17	62	230	444	528	479	334	109	14	6
TCL	TUSCALOOSA	AL	5	13	30	71	261	458	540	519	396	140	21	15
ANC	ANCHORAGE	AK	0	0	0	0	0	5	14	5	0	0	0	0
BRW	BARROW	AK	0	0	0	0	0	0	0	0	0	0	0	0
BET	BETHEL	AK	0	0	0	0	0	4	10	1	0	0	0	0
BTT	BETTLES	AK	0	0	0	0	1	15	21	3	0	0	0	0
BIG	BIG DELTA	AK	0	0	0	0	1	18	26	6	0	1	0	0
CDB	COLD BAY	AK	0	0	0	0	0	0	0	0	0	0	0	0
CDV	CORDOVA	AK	0	0	0	0	0	1	0	0	0	0	0	0
FAI	FAIRBANKS	AK	0	0	0	0	2	35	43	10	0	0	0	0
GKN	GULKANA	AK	0	0	0	0	0	7	10	1	0	0	0	0
HOM	HOMER	AK	0	0	0	0	0	0	0	0	0	0	0	0
JNU	JUNEAU	AK	0	0	0	0	0	3	5	2	0	0	0	0
ENA	KENAI	AK	0	0	0	0	0	1	1	1	0	0	0	0
KTN	KETCHIKAN	AK	0	0	0	0	0	5	14	7	0	0	0	0
AKN	KING SALMON	AK	0	0	0	0	0	2	4	0	0	0	0	0
ADQ	KODIAK	AK	0	0	0	0	0	1	6	7	0	0	0	0
OTZ	KOTZEBUE	AK	0	0	0	0	0	5	10	2	0	0	0	0
MCG	MCGRATH	AK	0	0	0	0	1	17	23	4	0	0	0	0
OME	NOME	AK	0	0	0	0	0	2	2	0	0	0	0	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
ORT	NORTHWAY	AK	0	0	0	0	0	9	9	2	0	0	0	0
SNP	ST PAUL ISLAND	AK	0	0	0	0	0	0	0	0	0	0	0	0
SIT	SITKA	AK	0	0	0	0	0	0	2	0	0	0	0	0
TKA	TALKEETNA	AK	0	0	0	0	0	10	17	2	0	0	0	0
UNK	UNALAKLEET	AK	0	0	0	0	1	2	4	2	0	0	0	0
VWS	VALDEZ	AK	0	0	0	0	4	29	54	27	1	0	0	0
YAK	YAKUTAT	AK	0	0	0	0	0	0	0	1	0	0	0	0
DUG	DOUGLAS	AZ	4	15	59	168	317	618	613	545	426	189	68	12
FLG	FLAGSTAFF	AZ	0	0	0	14	69	180	235	192	110	22	1	0
PHX	PHOENIX	AZ	3	28	138	319	538	867	972	921	743	408	109	5
TUS	TUCSON	AZ	1	8	62	184	379	704	744	699	556	284	61	3
INW	WINSLOW	AZ	0	0	0	14	56	345	481	404	196	10	1	0
NYL	YUMA	AZ	8	48	153	304	473	777	952	950	749	434	124	10
ELD	EL DORADO	AR	4	7	25	62	232	438	539	519	365	112	21	12
FYV	FAYETTEVILLE	AR	0	1	5	22	115	308	412	360	217	49	9	2
FSM	FORT SMITH	AR	0	2	12	49	204	455	572	528	373	106	10	1
HRO	HARRISON	AR	0	3	21	59	182	393	536	491	335	121	30	7
LIT	LITTLE ROCK	AR	0	5	34	65	217	437	544	514	373	107	10	4
TXK	TEXARKANA	AR	2	6	26	72	242	462	569	540	393	144	23	14
BFL	BAKERSFIELD	CA	1	1	21	99	243	511	697	647	456	159	6	0
BLH	BLYTHE	CA	3	26	153	294	475	805	979	983	738	389	68	16
EKA	EUREKA	CA	0	0	0	0	0	0	2	1	3	1	0	0
FAT	FRESNO	CA	0	0	18	82	225	486	658	609	422	141	3	0
IPL	IMPERIAL	CA	2	30	117	270	435	738	924	930	701	368	76	4
LAX	LOS ANGELES	CA	9	13	13	26	31	72	174	203	215	147	42	6
MHS	MT SHASTA	CA	0	2	2	16	80	209	364	332	183	62	0	0
PRB	PASO ROBLES	CA	0	0	3	15	72	234	339	323	232	67	4	0
RBL	RED BLUFF	CA	0	3	4	51	193	460	601	524	344	114	6	1
RDD	REDDING	CA	0	4	6	51	193	463	625	548	342	103	3	0
SAC	SACRAMENTO	CA	0	5	10	58	155	323	376	356	263	76	0	0
SAN	SAN DIEGO	CA	3	9	15	33	44	92	220	275	262	161	38	2
SFO	SAN FRANCISCO	CA	0	0	2	8	14	37	36	56	86	48	1	0
SCK	STOCKTON	CA	0	0	3	29	124	330	441	400	283	83	3	0
AKO	AKRON	CO	0	0	0	2	23	190	331	267	136	7	2	0
ALS	ALAMOSA	CO	0	0	0	0	0	18	61	20	8	0	0	0
COS	COLORADO SPRINGS	CO	0	0	0	1	16	155	247	200	104	3	0	0
DEN	DENVER	CO	0	0	0	1	20	181	336	287	143	5	0	0
EGE	EAGLE	CO	0	0	0	0	2	56	150	74	17	2	0	0
GJT	GRAND JUNCTION	CO	0	0	0	1	51	301	465	370	161	3	0	0
LHX	LA JUNTA	CO	0	0	1	10	85	334	473	388	228	18	1	0
PUB	PUEBLO	CO	0	0	0	2	51	276	423	340	177	9	2	0
TAD	TRINIDAD	CO	0	0	0	2	36	229	364	286	150	7	0	0
BDR	BRIDGEPORT	CT	0	0	0	1	38	172	374	333	145	23	0	0
BDL	HARTFORD	CT	0	0	0	3	59	160	338	275	102	12	1	0
ILG	WILMINGTON	DE	0	0	5	21	130	307	499	433	255	68	9	0
DCA	WASHINGTON	DC	0	1	2	34	157	359	517	459	271	63	4	0
DAB	DAYTONA BEACH	FL	68	119	188	275	414	546	638	654	571	440	236	158
FLL	FT LAUDERDALE	FL	208	270	323	437	513	587	666	673	613	562	394	330
FMY	FORT MYERS	FL	103	169	225	355	460	535	581	588	535	441	257	194
GNV	GAINESVILLE	FL	46	85	148	231	393	540	608	611	516	344	165	106
JAX	JACKSONVILLE	FL	22	41	82	145	305	470	540	538	429	241	76	46

Station Location			10-year Average Monthly CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
EYW	KEY WEST	FL	203	254	312	422	501	566	634	643	589	525	375	307
MLB	MELBOURNE	FL	72	118	170	276	396	506	577	581	514	409	224	150
MIA	MIAMI	FL	179	234	290	406	488	553	609	617	566	507	341	277
MCO	ORLANDO	FL	58	113	176	281	410	522	576	586	516	391	186	123
PNS	PENSACOLA	FL	17	33	82	145	350	514	574	557	470	259	67	42
TLH	TALLAHASSEE	FL	16	26	74	141	345	510	562	569	465	248	67	38
TPA	TAMPA	FL	67	119	186	314	464	556	600	609	550	429	208	143
VRB	VERO BEACH	FL	122	175	229	329	436	546	624	631	563	467	305	223
PBI	WEST PALM BEACH	FL	137	205	250	358	445	518	595	607	536	464	307	233
ABY	ALBANY	GA	40	91	168	272	495	654	710	704	582	389	152	91
AHN	ATHENS	GA	1	5	18	53	221	413	504	463	314	99	11	3
ATL	ATLANTA	GA	2	5	19	64	238	413	495	476	344	116	14	4
AGS	AUGUSTA	GA	7	12	31	71	246	440	542	511	355	133	33	10
BQK	BRUNSWICK	GA	18	26	60	118	299	468	539	515	394	197	53	24
CSG	COLUMBUS	GA	6	13	36	88	287	469	555	530	407	165	29	12
MCN	MACON	GA	6	10	30	67	249	443	537	506	355	132	22	11
SAV	SAVANNAH	GA	16	25	62	122	313	486	571	551	413	201	48	27
AYS	WAYCROSS	GA	20	45	100	177	352	538	618	582	444	232	66	46
ITO	HILO-HAWAII	HI	258	232	258	285	332	342	400	413	411	395	318	267
HNL	HONOLULU-OAHU	HI	300	277	310	371	421	469	534	546	518	490	415	344
OGG	KAHULUI-MAUI	HI	256	239	283	344	385	438	504	517	498	469	378	310
LIH	LIHUE-KAUAI	HI	246	211	240	311	360	401	472	495	479	427	354	295
BOI	BOISE	ID	0	0	0	2	38	197	457	386	132	7	0	0
BYI	BURLEY	ID	0	0	0	1	7	94	259	175	44	3	0	0
IDA	IDAHO FALLS	ID	0	0	0	0	2	52	182	116	29	2	0	0
LWS	LEWISTON	ID	0	0	0	2	41	166	405	379	108	5	0	0
PIH	POCATELLO	ID	0	0	0	0	4	77	243	172	43	1	0	0
ORD	CHICAGO	IL	0	0	0	5	75	206	312	297	150	20	1	0
MLI	MOLINE	IL	0	0	0	8	93	261	319	267	155	25	1	0
PIA	PEORIA	IL	0	0	0	10	113	281	348	311	188	33	2	0
UIN	QUINCY	IL	0	0	4	29	152	363	451	397	269	74	12	1
RFD	ROCKFORD	IL	0	0	0	4	74	209	285	240	122	16	1	0
SPI	SPRINGFIELD	IL	0	0	0	16	140	308	351	304	193	43	3	0
EVV	EVANSVILLE	IN	0	1	2	27	157	337	418	379	232	62	3	0
FWA	FORT WAYNE	IN	0	0	0	3	83	213	272	223	112	22	0	0
IND	INDIANAPOLIS	IN	0	1	0	10	114	257	337	316	181	35	1	0
SBN	SOUTH BEND	IN	0	0	0	4	71	183	251	227	118	18	1	0
LAF	WEST LAFAYETTE	IN	0	0	0	8	93	245	279	251	143	28	1	0
BRL	BURLINGTON	IA	0	0	3	28	153	370	437	385	268	72	14	1
CID	CEDAR RAPIDS	IA	0	0	0	5	65	205	255	202	114	13	1	0
DSM	DES MOINES	IA	0	0	0	10	93	295	372	318	180	18	0	0
DBQ	DUBUQUE	IA	0	0	0	3	52	170	230	175	88	9	0	0
MCW	MASON CITY	IA	0	0	0	1	47	181	218	152	82	4	0	0
OTM	OTTUMWA	IA	0	0	0	9	80	256	311	255	150	21	1	0
SUX	SIOUX CITY	IA	0	0	0	4	62	252	312	242	127	5	0	0
SPW	SPENCER	IA	0	0	0	13	99	320	373	298	196	31	3	0
ALO	WATERLOO	IA	0	0	0	4	63	214	273	208	111	9	0	0
CNU	CHANUTE	KS	0	0	3	25	133	379	487	436	274	56	7	0
CNK	CONCORDIA	KS	0	0	1	15	100	360	427	362	239	34	2	0
DDC	DODGE CITY	KS	0	0	2	19	104	363	461	407	257	36	0	0
GCK	GARDEN CITY	KS	0	0	1	11	85	338	428	359	221	25	3	0

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Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
GLD	GOODLAND	KS	0	0	0	3	47	245	362	302	169	10	1	0
RSL	RUSSELL	KS	0	0	1	20	96	365	456	397	250	31	1	0
SLN	SALINA	KS	0	0	2	23	131	420	515	436	275	43	5	0
TOP	TOPEKA	KS	0	0	1	18	130	379	452	391	238	40	2	0
ICT	WICHITA	KS	0	0	3	24	141	413	514	455	297	58	3	0
BWG	BOWLING GREEN	KY	0	2	4	36	175	360	461	411	244	66	7	2
JKL	JACKSON	KY	0	2	15	58	184	320	424	392	268	93	16	3
LEX	LEXINGTON	KY	0	1	1	23	137	276	364	332	200	49	3	0
SDF	LOUISVILLE	KY	0	2	4	42	193	373	464	432	272	72	5	0
PAH	PADUCAH	KY	0	1	2	29	168	357	435	384	241	70	5	1
BTR	BATON ROUGE	LA	23	57	128	203	399	562	650	643	534	312	103	79
LFT	LAFAYETTE	LA	19	38	90	163	358	517	587	571	466	244	68	53
LCH	LAKE CHARLES	LA	14	31	83	150	345	513	586	587	481	232	60	37
MLU	MONROE	LA	5	13	43	91	283	479	572	559	426	155	24	23
MSY	NEW ORLEANS	LA	19	51	112	187	391	550	609	604	509	302	78	55
SHV	SHREVEPORT	LA	5	14	48	107	298	505	602	602	454	176	32	25
AUG	AUGUSTA	ME	0	0	0	0	16	72	194	163	55	1	0	0
BGR	BANGOR	ME	0	0	0	0	45	132	258	237	103	12	3	0
CAR	CARIBOU	ME	0	0	0	0	13	38	114	93	22	0	0	0
HUL	HOULTON	ME	0	0	0	0	11	38	110	80	21	1	0	0
PWM	PORTLAND	ME	0	0	0	0	15	69	190	167	54	2	0	0
BWI	BALTIMORE	MD	0	0	1	19	112	280	443	372	199	42	2	0
SBY	SALISBURY	MD	0	1	9	42	156	344	543	459	288	100	20	2
BOS	BOSTON	MA	0	0	0	3	44	156	328	300	118	12	1	0
CHH	CHATHAM	MA	0	0	0	1	29	115	285	283	129	26	7	0
ORH	WORCESTER	MA	0	0	0	5	56	153	321	265	117	20	4	0
APN	ALPENA	MI	0	0	0	0	22	65	143	119	44	3	0	0
DTW	DETROIT	MI	0	0	0	2	74	185	304	272	118	17	0	0
FNT	FLINT	MI	0	0	0	1	58	152	237	201	81	11	1	0
GRR	GRAND RAPIDS	MI	0	0	0	1	57	156	251	213	89	9	0	0
CMX	HANCOCK	MI	0	0	0	0	10	39	104	71	26	1	0	0
HTL	HOUGHTON LAKE	MI	0	0	0	0	39	79	144	102	38	3	0	0
JXN	JACKSON	MI	0	0	0	2	53	141	217	182	82	11	1	0
LAN	LANSING	MI	0	0	0	2	58	152	240	207	84	11	0	0
SAW	MARQUETTE	MI	0	0	0	0	14	42	99	61	25	0	0	0
MKG	MUSKEGON	MI	0	0	0	1	44	123	226	207	85	10	1	0
MBS	SAGINAW	MI	0	0	0	1	58	146	244	193	78	10	0	0
ANJ	SAULT ST MARIE	MI	0	0	0	0	13	40	121	99	32	1	0	0
TVC	TRAVERSE CITY	MI	0	0	0	1	42	98	202	180	78	8	1	0
AXN	ALEXANDRIA	MN	0	0	0	1	33	148	229	159	60	1	0	0
DLH	DULUTH	MN	0	0	0	0	9	46	132	94	24	0	0	0
HIB	HIBBING	MN	0	0	0	0	6	31	70	42	11	0	0	0
INL	INT'L FALLS	MN	0	0	0	0	10	39	85	57	15	0	0	0
MSP	MINNEAPOLIS	MN	0	0	0	2	56	214	315	244	108	5	0	0
RST	ROCHESTER	MN	0	0	0	1	40	149	194	133	70	3	0	0
STC	SAINT CLOUD	MN	0	0	0	1	28	130	200	136	57	1	0	0
GWO	GREENWOOD	MS	8	23	62	133	329	518	622	611	486	246	65	54
JAN	JACKSON	MS	6	18	47	87	264	458	542	528	405	160	26	24
MCB	MCCOMB	MS	9	27	64	100	277	458	538	512	411	186	37	32
MEI	MERIDIAN	MS	7	19	44	81	252	454	537	518	394	150	19	19
TUP	TUPELO	MS	2	5	20	55	234	435	540	506	356	119	17	10

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COU	COLUMBIA	MO	0	0	1	22	130	327	409	370	224	46	3	0
JLN	JOPLIN	MO	0	1	4	27	139	366	480	425	266	66	8	1
MCI	KANSAS CITY	MO	0	0	1	15	110	333	406	361	212	37	2	0
STL	SAINT LOUIS	MO	0	0	2	35	188	408	491	440	282	71	5	0
SGF	SPRINGFIELD	MO	0	1	2	20	128	331	440	390	244	55	3	0
BIL	BILLINGS	MT	0	0	0	1	13	117	316	256	86	4	0	0
BTM	BUTTE	MT	0	0	0	1	8	77	218	187	81	13	0	0
CTB	CUT BANK	MT	0	0	0	3	9	73	235	213	81	16	2	0
GGW	GLASGOW	MT	0	0	0	0	18	99	269	235	52	2	0	0
GTF	GREAT FALLS	MT	0	0	0	0	3	40	174	147	37	1	0	0
HVR	HAVRE	MT	0	0	0	0	7	59	210	169	33	0	0	0
HLN	HELENA	MT	0	0	0	0	4	73	248	196	46	1	0	0
FCA	KALISPELL	MT	0	0	0	1	22	73	148	82	8	1	0	0
LWT	LEWISTOWN	MT	0	0	0	0	1	35	152	118	26	2	0	0
MLS	MILES CITY	MT	0	0	1	0	16	121	342	270	79	3	0	0
MSO	MISSOULA	MT	0	0	0	0	2	52	194	153	27	0	0	0
GRI	GRAND ISLAND	NE	0	0	0	8	70	301	361	289	163	11	1	0
LNK	LINCOLN	NE	0	0	0	10	91	323	392	330	193	17	2	0
OFK	NORFOLK	NE	0	0	0	11	59	248	322	252	139	10	0	0
LBF	NORTH PLATTE	NE	0	0	0	5	31	221	337	271	134	3	0	0
OMA	OMAHA	NE	0	0	0	12	97	326	397	341	195	17	0	0
BFF	SCOTTSBLUFF	NE	0	0	0	1	20	194	343	271	112	1	0	0
VTN	VALENTINE	NE	0	0	0	2	35	202	352	281	125	4	0	0
EKO	ELKO	NV	0	0	0	0	5	109	323	203	59	0	0	0
ELY	ELY	NV	0	0	0	0	2	71	184	108	28	0	0	0
LAS	LAS VEGAS	NV	0	3	51	189	392	771	915	851	606	228	23	0
LOL	LOVELOCK	NV	0	0	3	30	117	340	587	486	255	75	3	0
RNO	RENO	NV	0	0	0	3	34	238	443	368	150	7	0	0
TPH	TONOPAH	NV	0	0	0	2	46	251	432	334	118	8	0	0
WMC	WINNEMUCCA	NV	0	0	3	2	16	148	345	246	68	1	0	0
CON	CONCORD	NH	0	0	0	1	32	96	244	182	64	3	0	0
LEB	LEBANON	NH	0	0	1	1	86	182	322	276	131	26	4	0
MWN	MT WASHINGTON	NH	0	0	0	0	0	0	1	0	0	0	0	0
ACY	ATLANTIC CITY	NJ	0	0	1	10	77	226	402	342	171	32	3	0
EWR	NEWARK	NJ	0	0	1	10	91	261	453	394	194	35	3	0
ABQ	ALBUQUERQUE	NM	0	0	0	8	103	386	461	390	228	18	0	0
CNM	CARLSBAD	NM	0	1	13	76	267	521	595	529	314	82	10	3
CAO	CLAYTON	NM	0	0	1	5	61	258	351	280	168	17	3	0
GUP	GALLUP	NM	0	0	0	0	4	128	244	170	46	0	0	0
ROW	ROSWELL	NM	0	0	10	59	244	498	578	521	309	69	3	0
CVN	TUCUMCARI	NM	0	2	4	16	120	355	417	360	189	28	3	1
ALB	ALBANY	NY	0	0	0	3	56	139	281	218	84	7	1	0
BGM	BINGHAMTON	NY	0	0	0	1	34	72	169	128	57	5	0	0
BUF	BUFFALO	NY	0	0	0	1	53	115	241	215	89	11	1	0
GFL	GLENS FALLS	NY	0	0	0	4	72	153	309	237	109	20	4	0
MSS	MASSENA	NY	0	0	0	0	27	75	174	137	42	1	0	0
LGA	NEW YORK	NY	0	0	1	5	84	265	467	427	220	43	2	0
ROC	ROCHESTER	NY	0	0	0	2	55	124	240	204	84	11	1	0
SYR	SYRACUSE	NY	0	0	0	1	54	120	262	218	88	10	1	0
UCA	UTICA	NY	0	0	2	24	236	403	577	517	283	71	5	0
ART	WATERTOWN	NY	0	0	0	1	27	74	180	149	50	7	1	0

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AVL	ASHEVILLE	NC	0	1	1	10	84	227	320	275	160	32	2	0
HAT	CAPE HATTERAS	NC	27	48	102	240	445	634	760	720	602	407	142	73
CLT	CHARLOTTE	NC	1	4	14	49	196	383	495	441	284	76	7	2
GSO	GREENSBORO	NC	1	2	8	34	162	331	449	384	232	52	4	2
HKY	HICKORY	NC	2	3	24	64	199	381	511	453	304	111	26	9
EWN	NEW BERN	NC	4	7	20	63	218	389	507	463	326	114	18	14
RDU	RALEIGH DURHAM	NC	1	3	15	50	191	363	490	435	270	73	8	4
ILM	WILMINGTON	NC	6	7	26	68	232	399	507	473	338	130	25	14
BIS	BISMARCK	ND	0	0	0	0	22	134	259	190	53	2	0	0
P11	DEVIL'S LAKE	ND	0	0	0	2	99	284	400	330	151	16	0	0
DIK	DICKINSON	ND	0	0	0	0	13	44	163	125	30	2	0	0
FAR	FARGO	ND	0	0	0	0	37	152	233	155	58	4	0	0
GFK	GRAND FORKS	ND	0	0	0	1	52	182	288	234	100	19	0	0
JMS	JAMESTOWN	ND	0	0	0	0	20	121	215	125	35	2	0	0
MOT	MINOT	ND	0	0	0	0	24	104	214	176	43	2	0	0
ISN	WILLISTON	ND	0	0	0	4	58	207	362	324	125	19	0	0
CAK	AKRON CANTON	OH	0	1	0	9	86	188	297	262	133	27	1	0
CLE	CLEVELAND	OH	0	0	0	7	84	189	291	256	138	30	2	0
CMH	COLUMBUS	OH	0	1	0	12	116	250	336	303	163	36	1	0
CVG	CINCINNATI	OH	0	1	1	15	122	258	349	319	183	40	2	0
DAY	DAYTON	OH	0	0	0	10	112	241	313	283	161	32	1	0
FDY	FINDLAY	OH	0	0	0	7	98	238	313	263	146	30	2	0
MFD	MANSFIELD	OH	0	0	1	13	104	233	343	301	178	48	4	0
TOL	TOLEDO	OH	0	0	0	4	79	199	287	253	126	22	1	0
YNG	YOUNGSTOWN	OH	0	0	0	7	66	140	229	192	91	19	1	0
LHQ	ZANESVILLE	OH	0	1	0	7	91	215	272	230	120	25	1	0
GAG	GAGE	OK	0	3	22	73	209	490	638	594	423	133	29	2
HBR	HOBART	OK	0	1	10	50	213	474	613	573	375	105	10	1
MLC	MCALESTER	OK	1	4	21	60	188	427	552	517	353	108	16	4
OKC	OKLAHOMA CITY	OK	0	2	11	38	163	396	532	492	317	84	5	1
PNC	PONCA CITY	OK	0	11	50	130	296	597	734	719	547	235	49	4
TUL	TULSA	OK	0	3	12	44	189	453	564	520	351	93	7	1
AST	ASTORIA	OR	0	0	0	1	2	7	6	15	10	0	0	0
BKE	BAKER	OR	0	0	0	0	5	40	147	120	24	1	0	0
BNO	BURNS	OR	0	0	0	0	3	50	175	127	26	0	0	0
EUG	EUGENE	OR	0	0	0	0	4	56	158	178	49	3	0	0
MFR	MEDFORD	OR	0	0	0	5	46	189	404	368	149	18	0	0
OTH	NORTH BEND	OR	0	1	3	12	37	91	141	158	116	55	7	1
PDT	PENDLETON	OR	0	0	0	0	22	127	327	286	70	5	0	0
PDX	PORTLAND	OR	0	0	0	3	26	99	218	245	89	8	0	0
RDM	REDMOND	OR	0	0	0	2	16	117	290	267	112	32	0	0
SLE	SALEM	OR	0	0	0	1	14	81	202	212	67	4	0	0
ABE	ALLENTOWN	PA	0	0	0	6	68	188	348	282	126	19	1	0
AOO	ALTOONA	PA	0	0	0	6	53	115	216	179	74	23	1	0
BFD	BRADFORD	PA	0	0	0	1	27	56	113	88	36	6	0	0
DUJ	DU BOIS	PA	0	0	0	3	46	101	194	151	63	12	1	0
ERI	ERIE	PA	0	0	0	3	66	145	252	238	115	23	2	0
CXY	HARRISBURG	PA	0	0	1	10	100	250	416	347	173	36	2	0
PHL	PHILADELPHIA	PA	0	0	1	13	107	288	472	409	216	43	2	0
PIT	PITTSBURGH	PA	0	1	1	10	80	176	279	234	117	23	1	0
AVP	SCRANTON	PA	0	0	0	5	66	146	300	241	109	15	1	0

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
IPT	WILLIAMSPORT	PA	0	0	0	3	67	164	318	262	114	18	1	0
PVD	PROVIDENCE	RI	0	0	0	2	42	145	331	292	108	13	1	0
CHS	CHARLESTON	SC	10	16	44	104	297	467	557	529	398	178	40	20
CAE	COLUMBIA	SC	6	12	31	91	276	473	573	528	374	138	19	9
FLO	FLORENCE	SC	7	12	29	83	269	465	564	498	357	128	24	12
GSP	GREENVILLE	SC	0	3	10	43	184	369	470	419	279	69	6	2
ABR	ABERDEEN	SD	0	0	0	0	34	166	250	173	69	4	0	0
HON	HURON	SD	0	0	0	1	39	191	285	216	106	4	0	0
PIR	PIERRE	SD	0	0	1	6	71	264	487	418	236	43	3	0
RAP	RAPID CITY	SD	0	0	0	0	9	102	255	194	75	3	0	0
FSD	SIOUX FALLS	SD	0	0	0	3	41	212	290	222	106	6	1	0
ATY	WATERTOWN	SD	0	0	0	0	25	147	220	149	64	1	0	0
TRI	BRISTOL	TN	2	4	12	42	164	323	448	405	267	89	12	1
CHA	CHATTANOOGA	TN	1	3	8	48	215	406	501	469	323	94	8	2
CSV	CROSSVILLE	TN	1	3	14	50	161	291	414	378	251	95	18	5
MKL	JACKSON	TN	0	2	7	42	182	372	471	410	267	114	19	5
TYS	KNOXVILLE	TN	1	2	6	35	175	335	432	399	257	66	5	1
MEM	MEMPHIS	TN	1	4	14	61	248	461	558	529	391	123	14	6
BNA	NASHVILLE	TN	1	3	9	47	207	399	501	456	297	88	9	2
ABI	ABILENE	TX	1	8	43	119	295	496	620	610	403	170	21	6
ALI	ALICE	TX	44	84	175	291	471	592	672	670	532	354	137	79
AMA	AMARILLO	TX	0	1	3	28	137	358	468	423	246	48	2	0
AUS	AUSTIN	TX	7	26	78	156	353	547	648	659	492	238	62	27
BRO	BROWNSVILLE	TX	67	126	221	364	519	610	656	688	559	423	211	130
CLL	COLLEGE STATION	TX	24	46	129	220	418	617	749	767	600	351	123	81
CRP	CORPUS CHRISTI	TX	35	76	161	278	447	571	628	653	541	355	135	68
DHT	DALHART	TX	0	1	12	45	158	419	570	501	322	97	25	4
DFW	DALLAS FT WORTH	TX	2	12	48	113	300	544	671	662	478	197	29	11
DRT	DEL RIO	TX	7	36	132	277	473	628	733	734	526	291	65	20
ELP	EL PASO	TX	0	2	28	140	348	622	644	582	397	144	8	0
GLS	GALVESTON	TX	19	31	105	216	418	578	650	659	550	362	125	58
IAH	HOUSTON	TX	17	40	100	180	384	557	644	638	490	259	74	47
LRD	LAREDO	TX	36	95	220	369	553	688	774	768	582	399	152	68
LBB	LUBBOCK	TX	0	1	14	59	220	443	538	491	290	77	4	0
LFK	LUFKIN	TX	7	19	64	130	319	510	590	584	439	191	45	29
MFE	MCALLEN	TX	76	149	271	413	563	667	739	764	613	451	216	124
MAF	MIDLAND ODESSA	TX	0	5	41	125	332	529	613	583	372	152	14	1
PSX	PALACIOS	TX	23	38	111	215	420	569	643	641	497	296	105	55
CXO	PORT ARTHUR	TX	10	28	73	131	323	498	583	582	428	192	53	33
SJT	SAN ANGELO	TX	2	8	59	141	335	536	636	620	399	171	24	6
SAT	SAN ANTONIO	TX	8	31	94	193	392	561	665	683	513	280	72	28
VCT	VICTORIA	TX	22	47	114	209	409	562	633	651	503	288	92	48
ACT	WACO	TX	3	11	45	111	310	541	661	660	473	204	35	15
SPS	WICHITA FALLS	TX	1	4	22	68	246	479	607	593	397	131	11	4
CDC	CEDAR CITY	UT	0	0	0	4	13	167	320	237	80	1	0	0
SLC	SALT LAKE CITY	UT	0	0	1	4	63	314	567	464	206	10	0	0
BTV	BURLINGTON	VT	0	0	0	1	52	120	255	218	79	7	1	0
MPV	MONTPELIER	VT	0	0	0	0	20	51	128	94	30	2	0	0
LYH	LYNCHBURG	VA	0	0	3	23	116	261	390	329	183	39	4	0
ORF	NORFOLK	VA	1	2	13	51	180	371	519	455	297	91	12	3
RIC	RICHMOND	VA	0	1	7	40	167	336	480	417	256	60	7	1

Station Location			10-year Average Monthly CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
ROA	ROANOKE	VA	0	0	4	28	140	284	417	350	199	44	4	0
BLI	BELLINGHAM	WA	0	0	0	0	1	23	54	56	7	0	0	0
HQM	HOQUIAM	WA	0	0	0	1	2	12	6	21	14	0	0	0
OLM	OLYMPIA	WA	0	0	0	0	3	34	70	78	13	0	0	0
UIL	QUILLAYUTE	WA	0	0	0	0	1	12	5	21	7	0	0	0
SEA	SEATTLE TACOMA	WA	0	0	1	2	13	55	128	142	38	1	0	0
GEG	SPOKANE	WA	0	0	0	1	18	97	274	247	53	1	0	0
ALW	WALLA WALLA	WA	0	0	2	16	106	291	568	525	237	66	1	0
EAT	WENATCHEE	WA	0	0	0	2	52	177	405	348	88	9	0	0
YKM	YAKIMA	WA	0	0	0	1	46	153	342	280	58	2	0	0
BKW	BECKLEY	WV	0	0	2	11	66	140	225	190	95	17	1	0
CRW	CHARLESTON	WV	1	1	3	24	123	237	351	315	175	39	2	0
EKN	ELKINS	WV	0	0	1	2	42	114	206	165	79	12	1	0
HTS	HUNTINGTON	WV	1	1	3	27	129	252	349	311	181	43	3	0
MRB	MARTINSBURG	WV	0	1	1	14	87	221	362	290	143	26	0	0
MGW	MORGANTOWN	WV	0	1	1	18	106	205	316	271	151	33	3	0
PKB	PARKERSBURG	WV	1	1	2	20	148	259	379	313	186	38	3	0
EAU	EAU CLAIRE	WI	0	0	0	1	35	132	212	155	64	2	0	0
GRB	GREEN BAY	WI	0	0	0	1	39	119	200	150	58	4	0	0
LSE	LACROSSE	WI	0	0	0	5	72	226	323	257	123	10	0	0
MSN	MADISON	WI	0	0	0	2	54	154	236	183	77	7	0	0
MKE	MILWAUKEE	WI	0	0	0	1	42	138	262	240	112	13	1	0
AUW	WAUSAU	WI	0	0	0	1	37	109	189	133	50	2	0	0
CPR	CASPER	WY	0	0	0	0	3	67	217	153	48	1	0	0
CYS	CHEYENNE	WY	0	0	0	0	3	79	199	156	59	0	0	0
COD	CODY	WY	0	0	0	0	5	67	221	149	55	7	0	0
LND	LANDER	WY	0	0	0	0	6	85	249	242	90	0	0	0
RKS	ROCK SPRINGS	WY	0	0	0	0	2	63	198	122	30	0	0	0
SHR	SHERIDAN	WY	0	0	0	0	4	63	231	184	53	1	0	0
WRL	WORLAND	WY	0	0	0	0	11	126	293	234	65	2	0	0

Table 7C.3.4 Weather Station Monthly Heating Degree Day Data Fractions (10-Year Average, 2013-2022)

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	27%	18%	12%	4%	1%	0%	0%	0%	0%	3%	14%	20%
HSV	HUNTSVILLE	AL	25%	19%	13%	5%	1%	0%	0%	0%	0%	4%	14%	19%
MOB	MOBILE	AL	30%	18%	11%	3%	0%	0%	0%	0%	0%	2%	14%	21%
MGM	MONTGOMERY	AL	29%	18%	11%	3%	0%	0%	0%	0%	0%	3%	15%	21%
MSL	MUSCLE SHOALS	AL	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	14%	20%
TCL	TUSCALOOSA	AL	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	15%	20%
ANC	ANCHORAGE	AK	15%	13%	13%	9%	5%	2%	1%	2%	5%	9%	13%	15%
BRW	BARROW	AK	13%	12%	12%	10%	7%	5%	4%	4%	5%	7%	9%	12%
BET	BETHEL	AK	15%	13%	13%	9%	5%	3%	2%	3%	5%	8%	12%	14%
BTT	BETTLES	AK	16%	14%	13%	8%	4%	1%	1%	2%	5%	8%	13%	15%
BIG	BIG DELTA	AK	16%	14%	12%	8%	4%	2%	1%	2%	5%	9%	13%	15%
CDB	COLD BAY	AK	12%	10%	12%	10%	8%	6%	4%	4%	5%	8%	10%	11%
CDV	CORDOVA	AK	13%	12%	12%	9%	7%	4%	3%	4%	5%	8%	11%	12%
FAI	FAIRBANKS	AK	17%	14%	13%	8%	3%	1%	1%	2%	4%	8%	14%	16%
GKN	GULKANA	AK	15%	13%	12%	8%	4%	2%	1%	2%	5%	9%	13%	15%
HOM	HOMER	AK	13%	12%	12%	9%	6%	4%	3%	3%	5%	8%	12%	13%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
JNU	JUNEAU	AK	13%	12%	12%	9%	6%	3%	3%	3%	5%	9%	12%	14%
ENA	KENAI	AK	14%	12%	12%	8%	6%	3%	2%	3%	5%	8%	12%	14%
KTN	KETCHIKAN	AK	13%	13%	12%	10%	6%	4%	2%	2%	5%	8%	11%	14%
AKN	KING SALMON	AK	14%	12%	13%	9%	6%	3%	2%	3%	5%	8%	12%	14%
ADQ	KODIAK	AK	13%	11%	12%	10%	7%	5%	3%	3%	5%	8%	11%	12%
OTZ	KOTZEBUE	AK	14%	13%	13%	10%	6%	3%	2%	2%	4%	8%	11%	13%
MCG	MCGRATH	AK	16%	14%	13%	8%	4%	1%	1%	2%	4%	8%	13%	16%
OME	NOME	AK	14%	12%	13%	9%	6%	3%	3%	3%	5%	8%	11%	13%
ORT	NORTHWAY	AK	16%	14%	12%	7%	4%	2%	1%	2%	4%	8%	14%	16%
SNP	ST PAUL ISLAND	AK	12%	11%	12%	10%	8%	6%	5%	4%	5%	7%	9%	11%
SIT	SITKA	AK	12%	12%	12%	10%	7%	5%	3%	3%	5%	8%	11%	13%
TKA	TALKEETNA	AK	15%	13%	12%	8%	5%	2%	1%	2%	5%	9%	13%	15%
UNK	UNALAKLEET	AK	14%	13%	13%	9%	6%	3%	2%	3%	5%	8%	12%	13%
VWS	VALDEZ	AK	16%	14%	13%	9%	4%	1%	1%	1%	4%	8%	14%	15%
YAK	YAKUTAT	AK	13%	12%	12%	9%	7%	4%	3%	3%	5%	8%	11%	13%
DUG	DOUGLAS	AZ	27%	18%	10%	5%	1%	0%	0%	0%	0%	3%	13%	24%
FLG	FLAGSTAFF	AZ	18%	14%	12%	8%	6%	1%	0%	1%	2%	7%	12%	17%
PHX	PHOENIX	AZ	32%	19%	5%	0%	0%	0%	0%	0%	0%	0%	9%	34%
TUS	TUCSON	AZ	30%	20%	8%	1%	0%	0%	0%	0%	0%	1%	10%	29%
INW	WINSLOW	AZ	22%	16%	12%	6%	2%	0%	0%	0%	0%	6%	14%	21%
NYL	YUMA	AZ	31%	19%	7%	0%	0%	0%	0%	0%	0%	0%	8%	36%
ELD	EL DORADO	AR	25%	20%	12%	5%	1%	0%	0%	0%	0%	4%	14%	20%
FYV	FAYETTEVILLE	AR	22%	18%	13%	6%	2%	0%	0%	0%	0%	6%	13%	19%
FSM	FORT SMITH	AR	25%	20%	12%	5%	1%	0%	0%	0%	0%	4%	13%	21%
HRO	HARRISON	AR	24%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
LIT	LITTLE ROCK	AR	25%	19%	11%	5%	1%	0%	0%	0%	0%	4%	14%	20%
TXK	TEXARKANA	AR	26%	20%	11%	5%	1%	0%	0%	0%	0%	3%	14%	20%
BFL	BAKERSFIELD	CA	25%	17%	10%	3%	1%	0%	0%	0%	0%	2%	14%	27%
BLH	BLYTHE	CA	32%	17%	5%	0%	0%	0%	0%	0%	0%	1%	11%	34%
EKA	EUREKA	CA	11%	11%	11%	9%	8%	6%	5%	5%	5%	7%	10%	12%
FAT	FRESNO	CA	25%	17%	10%	4%	1%	0%	0%	0%	0%	2%	14%	28%
IPL	IMPERIAL	CA	31%	19%	6%	1%	0%	0%	0%	0%	0%	1%	10%	33%
LAX	LOS ANGELES	CA	20%	18%	15%	9%	6%	1%	0%	0%	0%	1%	8%	21%
MHS	MT SHASTA	CA	18%	15%	13%	9%	4%	1%	0%	0%	2%	7%	13%	18%
PRB	PASO ROBLES	CA	20%	17%	13%	7%	3%	0%	0%	0%	0%	4%	13%	22%
RBL	RED BLUFF	CA	22%	16%	13%	5%	1%	0%	0%	0%	0%	2%	15%	25%
RDD	REDDING	CA	22%	16%	13%	6%	1%	0%	0%	0%	0%	3%	15%	24%
SAC	SACRAMENTO	CA	23%	16%	11%	5%	2%	0%	0%	0%	0%	3%	15%	25%
SAN	SAN DIEGO	CA	23%	19%	14%	6%	4%	0%	0%	0%	0%	1%	8%	24%
SFO	SAN FRANCISCO	CA	18%	14%	12%	9%	7%	3%	2%	1%	1%	3%	11%	19%
SCK	STOCKTON	CA	23%	17%	12%	5%	1%	0%	0%	0%	0%	3%	15%	24%
AKO	AKRON	CO	18%	17%	12%	9%	5%	0%	0%	0%	1%	7%	12%	18%
ALS	ALAMOSA	CO	19%	14%	11%	8%	5%	1%	0%	1%	3%	8%	12%	18%
COS	COLORADO SPRINGS	CO	18%	16%	13%	9%	5%	1%	0%	0%	1%	7%	13%	18%
DEN	DENVER	CO	18%	17%	13%	9%	5%	0%	0%	0%	1%	7%	13%	18%
EGE	EAGLE	CO	18%	14%	12%	9%	5%	1%	0%	0%	2%	8%	13%	18%
GJT	GRAND JUNCTION	CO	22%	15%	11%	7%	3%	0%	0%	0%	1%	7%	13%	21%
LHX	LA JUNTA	CO	20%	17%	12%	7%	3%	0%	0%	0%	1%	6%	14%	20%
PUB	PUEBLO	CO	19%	17%	12%	8%	3%	0%	0%	0%	1%	7%	14%	19%
TAD	TRINIDAD	CO	19%	16%	13%	9%	4%	0%	0%	0%	1%	7%	13%	18%
BDR	BRIDGEPORT	CT	20%	18%	16%	9%	3%	0%	0%	0%	1%	5%	11%	16%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BDL	HARTFORD	CT	20%	17%	15%	8%	3%	0%	0%	0%	1%	6%	12%	17%
ILG	WILMINGTON	DE	23%	19%	15%	7%	2%	0%	0%	0%	0%	4%	12%	17%
DCA	WASHINGTON	DC	23%	19%	15%	6%	2%	0%	0%	0%	0%	4%	13%	18%
DAB	DAYTONA BEACH	FL	38%	19%	15%	1%	0%	0%	0%	0%	0%	1%	8%	17%
FLL	FT LAUDERDALE	FL	48%	20%	11%	0%	0%	0%	0%	0%	0%	0%	5%	16%
FMY	FORT MYERS	FL	47%	19%	10%	0%	0%	0%	0%	0%	0%	1%	5%	18%
GNV	GAINESVILLE	FL	35%	19%	14%	2%	0%	0%	0%	0%	0%	1%	11%	18%
JAX	JACKSONVILLE	FL	31%	19%	13%	3%	0%	0%	0%	0%	0%	2%	12%	20%
EYW	KEY WEST	FL	49%	18%	7%	0%	0%	0%	3%	0%	0%	0%	0%	22%
MLB	MELBOURNE	FL	40%	20%	14%	1%	0%	0%	0%	0%	0%	0%	7%	19%
MIA	MIAMI	FL	47%	19%	8%	0%	0%	0%	0%	0%	0%	0%	4%	22%
MCO	ORLANDO	FL	42%	18%	12%	1%	0%	0%	0%	0%	0%	1%	8%	20%
PNS	PENSACOLA	FL	33%	18%	10%	2%	0%	0%	0%	0%	0%	1%	13%	21%
TLH	TALLAHASSEE	FL	31%	18%	12%	3%	0%	0%	0%	0%	0%	2%	13%	21%
TPA	TAMPA	FL	43%	19%	12%	0%	0%	0%	0%	0%	0%	0%	8%	18%
VRB	VERO BEACH	FL	38%	20%	17%	1%	0%	0%	0%	0%	0%	1%	7%	16%
PBI	WEST PALM BEACH	FL	43%	19%	13%	0%	0%	0%	0%	0%	0%	0%	4%	21%
ABY	ALBANY	GA	34%	20%	12%	2%	0%	0%	0%	0%	0%	1%	11%	18%
AHN	ATHENS	GA	25%	18%	12%	5%	1%	0%	0%	0%	0%	4%	14%	20%
ATL	ATLANTA	GA	27%	18%	12%	5%	1%	0%	0%	0%	0%	3%	14%	20%
AGS	AUGUSTA	GA	26%	18%	12%	5%	1%	0%	0%	0%	0%	3%	15%	20%
BQK	BRUNSWICK	GA	29%	18%	13%	4%	0%	0%	0%	0%	0%	2%	13%	21%
CSG	COLUMBUS	GA	28%	18%	12%	4%	1%	0%	0%	0%	0%	2%	14%	21%
MCN	MACON	GA	27%	18%	12%	4%	1%	0%	0%	0%	0%	3%	15%	20%
SAV	SAVANNAH	GA	29%	19%	13%	3%	0%	0%	0%	0%	0%	2%	14%	20%
AYS	WAYCROSS	GA	31%	18%	11%	3%	0%	0%	0%	0%	0%	2%	14%	21%
ITO	HILO-HAWAII	HI	0%	1%	49%	49%	0%	0%	0%	0%	0%	0%	0%	0%
HNL	HONOLULU-OAHU	HI	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%
OGG	KAHULUI-MAUI	HI	0%	0%	69%	0%	0%	0%	0%	0%	0%	0%	31%	0%
LIH	LIHUE-KAUAI	HI	38%	3%	0%	0%	0%	0%	0%	0%	0%	0%	59%	0%
BOI	BOISE	ID	20%	15%	11%	8%	3%	1%	0%	0%	1%	7%	14%	20%
BYI	BURLEY	ID	18%	14%	11%	9%	5%	1%	0%	0%	2%	8%	13%	18%
IDA	IDAHO FALLS	ID	18%	15%	11%	8%	5%	1%	0%	0%	3%	8%	13%	18%
LWS	LEWISTON	ID	18%	15%	12%	8%	3%	1%	0%	0%	1%	7%	14%	19%
PIH	POCATELLO	ID	18%	14%	11%	8%	5%	1%	0%	0%	2%	8%	13%	18%
ORD	CHICAGO	IL	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
MLI	MOLINE	IL	21%	19%	13%	7%	2%	0%	0%	0%	1%	6%	12%	18%
PIA	PEORIA	IL	22%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
UIN	QUINCY	IL	23%	20%	13%	7%	2%	0%	0%	0%	0%	5%	12%	18%
RFD	ROCKFORD	IL	21%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	17%
SPI	SPRINGFIELD	IL	22%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	18%
EVV	EVANSVILLE	IN	22%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
FWA	FORT WAYNE	IN	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
IND	INDIANAPOLIS	IN	22%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	18%
SBN	SOUTH BEND	IN	20%	18%	14%	9%	3%	0%	0%	0%	1%	6%	12%	17%
LAF	WEST LAFAYETTE	IN	21%	18%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
BRL	BURLINGTON	IA	23%	20%	13%	7%	2%	0%	0%	0%	1%	5%	12%	18%
CID	CEDAR RAPIDS	IA	21%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	17%
DSM	DES MOINES	IA	21%	19%	13%	7%	2%	0%	0%	0%	1%	6%	12%	18%
DBQ	DUBUQUE	IA	20%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	17%
MCW	MASON CITY	IA	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	12%	17%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
OTM	OTTUMWA	IA	21%	18%	13%	7%	3%	0%	0%	0%	1%	6%	12%	18%
SUX	SIOUX CITY	IA	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	13%	18%
SPW	SPENCER	IA	20%	19%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
ALO	WATERLOO	IA	20%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	17%
CNU	CHANUTE	KS	22%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
CNK	CONCORDIA	KS	21%	19%	13%	7%	3%	0%	0%	0%	1%	6%	13%	19%
DDC	DODGE CITY	KS	20%	18%	12%	7%	3%	0%	0%	0%	1%	6%	13%	19%
GCK	GARDEN CITY	KS	20%	18%	12%	8%	3%	0%	0%	0%	1%	6%	13%	19%
GLD	GOODLAND	KS	19%	17%	13%	9%	4%	0%	0%	0%	1%	7%	12%	18%
RSL	RUSSELL	KS	21%	18%	12%	7%	3%	0%	0%	0%	1%	6%	13%	19%
SLN	SALINA	KS	21%	19%	12%	7%	2%	0%	0%	0%	0%	5%	13%	20%
TOP	TOPEKA	KS	22%	19%	12%	7%	2%	0%	0%	0%	0%	6%	13%	19%
ICT	WICHITA	KS	22%	19%	12%	6%	2%	0%	0%	0%	0%	5%	13%	20%
BWG	BOWLING GREEN	KY	23%	18%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
JKL	JACKSON	KY	24%	19%	14%	6%	2%	0%	0%	0%	0%	5%	13%	18%
LEX	LEXINGTON	KY	22%	18%	14%	7%	2%	0%	0%	0%	1%	5%	13%	17%
SDF	LOUISVILLE	KY	24%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
PAH	PADUCAH	KY	23%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
BTR	BATON ROUGE	LA	32%	18%	10%	3%	0%	0%	0%	0%	0%	1%	14%	21%
LFT	LAFAYETTE	LA	31%	19%	10%	3%	0%	0%	0%	0%	0%	1%	14%	22%
LCH	LAKE CHARLES	LA	31%	19%	10%	2%	0%	0%	0%	0%	0%	2%	13%	22%
MLU	MONROE	LA	27%	20%	11%	4%	0%	0%	0%	0%	0%	3%	14%	21%
MSY	NEW ORLEANS	LA	34%	19%	10%	2%	0%	0%	0%	0%	0%	1%	13%	22%
SHV	SHREVEPORT	LA	27%	20%	11%	4%	0%	0%	0%	0%	0%	3%	14%	21%
AUG	AUGUSTA	ME	19%	16%	15%	9%	4%	1%	0%	0%	2%	6%	11%	16%
BGR	BANGOR	ME	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	11%	16%
CAR	CARIBOU	ME	18%	16%	14%	9%	4%	2%	0%	1%	3%	7%	11%	16%
HUL	HOULTON	ME	18%	16%	14%	9%	5%	2%	1%	1%	3%	7%	11%	15%
PWM	PORTLAND	ME	18%	16%	15%	9%	5%	1%	0%	0%	2%	6%	11%	16%
BWI	BALTIMORE	MD	22%	18%	15%	7%	2%	0%	0%	0%	1%	5%	13%	18%
SBY	SALISBURY	MD	23%	19%	15%	7%	2%	0%	0%	0%	0%	4%	12%	17%
BOS	BOSTON	MA	20%	17%	16%	9%	4%	1%	0%	0%	1%	5%	11%	16%
CHH	CHATHAM	MA	20%	17%	16%	10%	5%	1%	0%	0%	1%	4%	10%	15%
ORH	WORCESTER	MA	20%	17%	15%	9%	4%	1%	0%	0%	1%	5%	11%	16%
APN	ALPENA	MI	18%	17%	14%	10%	5%	2%	0%	0%	2%	7%	11%	15%
DTW	DETROIT	MI	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
FNT	FLINT	MI	19%	18%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
GRR	GRAND RAPIDS	MI	19%	18%	15%	9%	3%	0%	0%	0%	1%	6%	12%	16%
CMX	HANCOCK	MI	17%	16%	14%	10%	5%	2%	1%	1%	3%	7%	11%	15%
HTL	HOUGHTON LAKE	MI	18%	17%	14%	9%	4%	1%	0%	1%	2%	7%	11%	15%
JXN	JACKSON	MI	19%	17%	14%	9%	3%	1%	0%	0%	2%	6%	12%	16%
LAN	LANSING	MI	19%	18%	14%	9%	3%	0%	0%	0%	2%	6%	12%	16%
SAW	MARQUETTE	MI	17%	16%	14%	10%	5%	2%	1%	1%	3%	7%	11%	15%
MKG	MUSKEGON	MI	19%	18%	15%	9%	4%	1%	0%	0%	1%	6%	11%	16%
MBS	SAGINAW	MI	19%	18%	15%	9%	3%	1%	0%	0%	2%	6%	12%	16%
ANJ	SAULT ST MARIE	MI	18%	16%	14%	10%	5%	2%	0%	0%	2%	6%	11%	15%
TVC	TRAVERSE CITY	MI	18%	17%	15%	10%	5%	1%	0%	0%	2%	6%	11%	15%
AXN	ALEXANDRIA	MN	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
DLH	DULUTH	MN	18%	17%	13%	9%	4%	1%	0%	0%	2%	7%	12%	16%
HIB	HIBBING	MN	18%	16%	13%	9%	5%	2%	1%	1%	3%	7%	11%	16%
INL	INT'L FALLS	MN	18%	17%	13%	9%	4%	1%	1%	1%	3%	7%	11%	16%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
MSP	MINNEAPOLIS	MN	20%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
RST	ROCHESTER	MN	20%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
STC	SAINT CLOUD	MN	19%	17%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
GWO	GREENWOOD	MS	27%	20%	12%	4%	1%	0%	0%	0%	0%	3%	13%	20%
JAN	JACKSON	MS	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	15%	20%
MCB	MCCOMB	MS	29%	19%	11%	4%	1%	0%	0%	0%	0%	2%	14%	21%
MEI	MERIDIAN	MS	27%	19%	11%	4%	1%	0%	0%	0%	0%	3%	15%	20%
TUP	TUPELO	MS	25%	19%	12%	5%	1%	0%	0%	0%	0%	4%	15%	20%
COU	COLUMBIA	MO	22%	19%	13%	6%	2%	0%	0%	0%	0%	6%	13%	19%
JLN	JOPLIN	MO	22%	19%	12%	6%	2%	0%	0%	0%	0%	5%	13%	19%
MCI	KANSAS CITY	MO	22%	19%	12%	7%	2%	0%	0%	0%	1%	6%	13%	19%
STL	SAINT LOUIS	MO	23%	20%	13%	6%	2%	0%	0%	0%	0%	5%	13%	19%
SGF	SPRINGFIELD	MO	22%	19%	13%	7%	2%	0%	0%	0%	0%	6%	13%	19%
BIL	BILLINGS	MT	17%	17%	12%	9%	4%	1%	0%	0%	2%	8%	13%	18%
BTM	BUTTE	MT	16%	15%	12%	9%	5%	2%	1%	1%	3%	7%	12%	16%
CTB	CUT BANK	MT	16%	16%	13%	9%	5%	2%	0%	1%	3%	8%	12%	16%
GGW	GLASGOW	MT	18%	17%	13%	8%	4%	1%	0%	0%	2%	7%	13%	18%
GTF	GREAT FALLS	MT	15%	16%	12%	9%	5%	2%	0%	1%	3%	8%	12%	16%
HVR	HAVRE	MT	17%	16%	12%	8%	4%	1%	0%	0%	3%	8%	13%	17%
HLN	HELENA	MT	17%	16%	12%	8%	5%	1%	0%	0%	2%	8%	13%	17%
FCA	KALISPELL	MT	16%	15%	11%	8%	4%	2%	0%	1%	4%	9%	13%	17%
LWT	LEWISTOWN	MT	15%	15%	12%	9%	6%	2%	0%	1%	3%	8%	12%	16%
MLS	MILES CITY	MT	18%	17%	12%	8%	4%	1%	0%	0%	2%	7%	13%	18%
MSO	MISSOULA	MT	17%	14%	12%	8%	5%	2%	0%	0%	3%	8%	13%	17%
GRI	GRAND ISLAND	NE	20%	18%	13%	8%	3%	0%	0%	0%	1%	6%	13%	19%
LNK	LINCOLN	NE	21%	19%	13%	7%	3%	0%	0%	0%	1%	6%	13%	19%
OFK	NORFOLK	NE	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	12%	18%
LBF	NORTH PLATTE	NE	19%	17%	12%	8%	4%	0%	0%	0%	1%	7%	13%	18%
OMA	OMAHA	NE	21%	19%	13%	7%	2%	0%	0%	0%	1%	6%	13%	19%
BFF	SCOTTSBLUFF	NE	18%	16%	12%	9%	4%	0%	0%	0%	1%	8%	13%	18%
VTN	VALENTINE	NE	18%	17%	12%	9%	4%	0%	0%	0%	1%	7%	13%	19%
EKO	ELKO	NV	18%	14%	12%	9%	5%	1%	0%	0%	2%	8%	13%	18%
ELY	ELY	NV	17%	14%	12%	9%	6%	1%	0%	0%	3%	8%	13%	17%
LAS	LAS VEGAS	NV	28%	18%	8%	1%	0%	0%	0%	0%	0%	1%	13%	30%
LOL	LOVELOCK	NV	20%	15%	12%	7%	3%	0%	0%	0%	2%	7%	14%	20%
RNO	RENO	NV	19%	15%	12%	8%	4%	1%	0%	0%	1%	7%	14%	20%
TPH	TONOPAH	NV	19%	16%	13%	8%	4%	0%	0%	0%	1%	7%	14%	20%
WMC	WINNEMUCCA	NV	17%	14%	12%	9%	5%	1%	0%	0%	2%	8%	13%	18%
CON	CONCORD	NH	19%	16%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%
LEB	LEBANON	NH	20%	17%	15%	8%	3%	1%	0%	0%	2%	6%	11%	16%
MWN	MT WASHINGTON	NH	14%	12%	12%	10%	6%	4%	3%	4%	5%	7%	10%	12%
ACY	ATLANTIC CITY	NJ	21%	17%	15%	8%	3%	0%	0%	0%	1%	5%	12%	17%
EWR	NEWARK	NJ	22%	18%	15%	8%	3%	0%	0%	0%	0%	4%	12%	17%
ABQ	ALBUQUERQUE	NM	22%	17%	11%	6%	2%	0%	0%	0%	0%	5%	14%	22%
CNM	CARLSBAD	NM	25%	18%	10%	4%	1%	0%	0%	0%	0%	4%	15%	23%
CAO	CLAYTON	NM	19%	17%	12%	8%	4%	0%	0%	0%	1%	7%	13%	19%
GUP	GALLUP	NM	18%	15%	12%	9%	5%	0%	0%	0%	1%	8%	13%	18%
ROW	ROSWELL	NM	25%	18%	10%	4%	1%	0%	0%	0%	0%	4%	15%	23%
CVN	TUCUMCARI	NM	21%	17%	12%	7%	2%	0%	0%	0%	1%	6%	14%	20%
ALB	ALBANY	NY	20%	17%	15%	8%	3%	1%	0%	0%	2%	6%	12%	16%
BGM	BINGHAMTON	NY	19%	16%	15%	9%	4%	1%	0%	0%	2%	6%	12%	16%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BUF	BUFFALO	NY	19%	17%	15%	9%	4%	1%	0%	0%	1%	6%	11%	16%
GFL	GLENS FALLS	NY	20%	18%	15%	8%	3%	1%	0%	0%	2%	6%	11%	16%
MSS	MASSENA	NY	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	11%	16%
LGA	NEW YORK	NY	22%	19%	16%	8%	3%	0%	0%	0%	0%	4%	11%	17%
ROC	ROCHESTER	NY	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	11%	16%
SYR	SYRACUSE	NY	20%	17%	15%	9%	3%	1%	0%	0%	2%	6%	11%	16%
UCA	UTICA	NY	23%	20%	16%	7%	1%	0%	0%	0%	0%	4%	12%	18%
ART	WATERTOWN	NY	19%	17%	15%	9%	4%	1%	0%	0%	2%	6%	11%	15%
AVL	ASHEVILLE	NC	22%	17%	13%	7%	2%	0%	0%	0%	1%	6%	14%	18%
HAT	CAPE HATTERAS	NC	32%	24%	16%	2%	0%	0%	0%	0%	0%	0%	8%	18%
CLT	CHARLOTTE	NC	25%	18%	13%	5%	1%	0%	0%	0%	0%	4%	14%	19%
GSO	GREENSBORO	NC	24%	18%	14%	6%	2%	0%	0%	0%	0%	4%	14%	19%
HKY	HICKORY	NC	25%	18%	14%	6%	2%	0%	0%	0%	0%	4%	13%	19%
EWN	NEW BERN	NC	25%	19%	15%	6%	1%	0%	0%	0%	0%	3%	13%	19%
RDU	RALEIGH DURHAM	NC	24%	18%	14%	6%	2%	0%	0%	0%	0%	4%	14%	19%
ILM	WILMINGTON	NC	26%	19%	15%	5%	1%	0%	0%	0%	0%	3%	13%	19%
BIS	BISMARCK	ND	18%	17%	13%	9%	4%	1%	0%	0%	2%	7%	12%	18%
P11	DEVIL'S LAKE	ND	20%	18%	14%	8%	2%	0%	0%	0%	1%	6%	12%	18%
DIK	DICKINSON	ND	18%	16%	13%	9%	4%	1%	0%	0%	3%	8%	12%	17%
FAR	FARGO	ND	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
GFK	GRAND FORKS	ND	19%	18%	13%	8%	3%	0%	0%	0%	2%	6%	12%	18%
JMS	JAMESTOWN	ND	18%	17%	13%	9%	4%	1%	0%	0%	2%	7%	12%	17%
MOT	MINOT	ND	18%	17%	13%	9%	4%	1%	0%	0%	2%	7%	12%	17%
ISN	WILLISTON	ND	19%	18%	13%	8%	3%	1%	0%	0%	2%	7%	13%	18%
CAK	AKRON CANTON	OH	21%	18%	15%	8%	3%	0%	0%	0%	1%	6%	12%	17%
CLE	CLEVELAND	OH	20%	18%	15%	8%	3%	0%	0%	0%	1%	5%	12%	16%
CMH	COLUMBUS	OH	21%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	17%
CVG	CINCINNATI	OH	22%	18%	14%	7%	2%	0%	0%	0%	1%	5%	13%	18%
DAY	DAYTON	OH	21%	18%	14%	7%	2%	0%	0%	0%	1%	5%	13%	17%
FDY	FINDLAY	OH	21%	18%	14%	8%	3%	0%	0%	0%	1%	5%	12%	17%
MFD	MANSFIELD	OH	21%	18%	15%	8%	3%	0%	0%	0%	1%	5%	12%	17%
TOL	TOLEDO	OH	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
YNG	YOUNGSTOWN	OH	20%	17%	14%	8%	3%	1%	0%	0%	1%	6%	12%	16%
LHQ	ZANESVILLE	OH	21%	18%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
GAG	GAGE	OK	22%	20%	12%	6%	2%	0%	0%	0%	0%	5%	13%	20%
HBR	HOBART	OK	23%	20%	12%	6%	1%	0%	0%	0%	0%	4%	12%	21%
MLC	MCALESTER	OK	24%	20%	12%	5%	1%	0%	0%	0%	0%	5%	13%	20%
OKC	OKLAHOMA CITY	OK	23%	20%	12%	6%	1%	0%	0%	0%	0%	5%	13%	21%
PNC	PONCA CITY	OK	24%	21%	11%	5%	1%	0%	0%	0%	0%	4%	12%	21%
TUL	TULSA	OK	24%	20%	12%	5%	1%	0%	0%	0%	0%	5%	13%	20%
AST	ASTORIA	OR	14%	13%	13%	10%	7%	4%	2%	2%	3%	7%	11%	15%
BKE	BAKER	OR	17%	13%	11%	9%	5%	2%	0%	1%	3%	8%	13%	17%
BNO	BURNS	OR	17%	13%	11%	9%	5%	2%	0%	0%	3%	8%	13%	17%
EUG	EUGENE	OR	16%	14%	12%	9%	5%	2%	0%	0%	2%	7%	13%	17%
MFR	MEDFORD	OR	19%	15%	12%	8%	3%	1%	0%	0%	1%	6%	14%	20%
OTH	NORTH BEND	OR	14%	13%	13%	10%	6%	4%	3%	2%	3%	6%	11%	15%
PDT	PENDLETON	OR	18%	15%	12%	8%	4%	1%	0%	0%	2%	7%	14%	19%
PDX	PORTLAND	OR	18%	15%	13%	9%	4%	1%	0%	0%	1%	7%	13%	19%
RDM	REDMOND	OR	16%	14%	12%	9%	5%	2%	0%	0%	3%	7%	13%	17%
SLE	SALEM	OR	17%	15%	13%	9%	5%	2%	0%	0%	2%	7%	13%	18%
ABE	ALLENTOWN	PA	21%	18%	15%	8%	3%	0%	0%	0%	1%	6%	12%	17%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
AOO	ALTOONA	PA	17%	16%	14%	8%	4%	2%	1%	1%	3%	7%	12%	15%
BFD	BRADFORD	PA	18%	16%	14%	9%	4%	1%	1%	1%	2%	7%	12%	15%
DUJ	DU BOIS	PA	19%	17%	14%	8%	4%	1%	0%	0%	2%	6%	12%	16%
ERI	ERIE	PA	20%	18%	15%	9%	4%	1%	0%	0%	1%	5%	11%	16%
CXY	HARRISBURG	PA	22%	18%	15%	7%	2%	0%	0%	0%	1%	5%	12%	17%
PHL	PHILADELPHIA	PA	22%	18%	15%	7%	2%	0%	0%	0%	0%	4%	12%	18%
PIT	PITTSBURGH	PA	21%	17%	14%	8%	3%	0%	0%	0%	1%	6%	13%	17%
AVP	SCRANTON	PA	21%	17%	15%	8%	3%	0%	0%	0%	1%	6%	12%	16%
IPT	WILLIAMSPORT	PA	21%	17%	15%	8%	3%	0%	0%	0%	1%	6%	12%	17%
PVD	PROVIDENCE	RI	20%	17%	15%	9%	4%	1%	0%	0%	1%	5%	12%	16%
CHS	CHARLESTON	SC	28%	19%	13%	4%	0%	0%	0%	0%	0%	2%	14%	20%
CAE	COLUMBIA	SC	26%	18%	13%	4%	1%	0%	0%	0%	0%	3%	15%	20%
FLO	FLORENCE	SC	26%	18%	14%	4%	1%	0%	0%	0%	0%	3%	14%	20%
GSP	GREENVILLE	SC	24%	18%	13%	5%	1%	0%	0%	0%	0%	4%	14%	19%
ABR	ABERDEEN	SD	19%	17%	13%	8%	3%	0%	0%	0%	2%	7%	12%	18%
HON	HURON	SD	19%	17%	13%	8%	3%	0%	0%	0%	1%	7%	12%	18%
PIR	PIERRE	SD	19%	18%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
RAP	RAPID CITY	SD	17%	16%	12%	9%	5%	1%	0%	0%	2%	8%	12%	17%
FSD	SIOUX FALLS	SD	20%	18%	13%	8%	3%	0%	0%	0%	1%	7%	12%	18%
ATY	WATERTOWN	SD	19%	17%	13%	9%	4%	0%	0%	0%	2%	7%	12%	17%
TRI	BRISTOL	TN	24%	18%	13%	6%	2%	0%	0%	0%	0%	5%	14%	18%
CHA	CHATTANOOGA	TN	25%	18%	12%	5%	1%	0%	0%	0%	0%	4%	15%	20%
CSV	CROSSVILLE	TN	24%	18%	14%	6%	2%	0%	0%	0%	0%	5%	13%	18%
MKL	JACKSON	TN	23%	19%	13%	6%	2%	0%	0%	0%	0%	5%	14%	19%
TYS	KNOXVILLE	TN	24%	18%	13%	6%	2%	0%	0%	0%	0%	5%	14%	19%
MEM	MEMPHIS	TN	25%	20%	12%	5%	1%	0%	0%	0%	0%	4%	14%	20%
BNA	NASHVILLE	TN	24%	19%	13%	5%	1%	0%	0%	0%	0%	4%	14%	19%
ABI	ABILENE	TX	25%	20%	10%	4%	1%	0%	0%	0%	0%	4%	13%	22%
ALI	ALICE	TX	32%	21%	9%	1%	0%	0%	0%	0%	0%	2%	13%	23%
AMA	AMARILLO	TX	21%	18%	12%	7%	2%	0%	0%	0%	0%	6%	14%	20%
AUS	AUSTIN	TX	29%	21%	10%	3%	0%	0%	0%	0%	0%	2%	13%	22%
BRO	BROWNSVILLE	TX	34%	22%	7%	1%	0%	0%	0%	0%	0%	1%	12%	22%
CLL	COLLEGE STATION	TX	29%	21%	10%	3%	0%	0%	0%	0%	0%	2%	12%	22%
CRP	CORPUS CHRISTI	TX	32%	21%	8%	1%	0%	0%	0%	0%	0%	1%	12%	23%
DHT	DALHART	TX	22%	19%	12%	7%	2%	0%	0%	0%	0%	5%	13%	20%
DFW	DALLAS FT WORTH	TX	27%	21%	10%	4%	1%	0%	0%	0%	0%	3%	13%	22%
DRT	DEL RIO	TX	32%	19%	7%	1%	0%	0%	0%	0%	0%	2%	13%	26%
ELP	EL PASO	TX	29%	18%	8%	2%	0%	0%	0%	0%	0%	3%	14%	26%
GLS	GALVESTON	TX	34%	21%	9%	1%	0%	0%	0%	0%	0%	1%	11%	23%
IAH	HOUSTON	TX	30%	20%	9%	2%	0%	0%	0%	0%	0%	2%	13%	23%
LRD	LAREDO	TX	34%	20%	7%	0%	0%	0%	0%	0%	0%	2%	13%	25%
LBB	LUBBOCK	TX	23%	19%	11%	5%	1%	0%	0%	0%	0%	5%	14%	21%
LFK	LUFKIN	TX	28%	20%	10%	4%	0%	0%	0%	0%	0%	3%	14%	22%
MFE	MCALLEN	TX	34%	22%	6%	1%	0%	0%	0%	0%	0%	2%	13%	24%
MAF	MIDLAND ODESSA	TX	26%	19%	10%	4%	1%	0%	0%	0%	0%	4%	14%	22%
PSX	PALACIOS	TX	31%	21%	9%	2%	0%	0%	0%	0%	0%	2%	12%	23%
CXO	PORT ARTHUR	TX	28%	20%	11%	3%	0%	0%	0%	0%	0%	3%	13%	22%
SJT	SAN ANGELO	TX	27%	20%	10%	3%	1%	0%	0%	0%	0%	4%	14%	22%
SAT	SAN ANTONIO	TX	30%	21%	9%	2%	0%	0%	0%	0%	0%	2%	13%	23%
VCT	VICTORIA	TX	30%	21%	10%	2%	0%	0%	0%	0%	0%	2%	13%	23%
ACT	WACO	TX	26%	20%	11%	4%	0%	0%	0%	0%	0%	3%	13%	22%

Station Location			10-year Average Monthly Fraction of Annual HDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
SPS	WICHITA FALLS	TX	24%	20%	11%	5%	1%	0%	0%	0%	0%	4%	13%	21%
CDC	CEDAR CITY	UT	18%	15%	12%	8%	5%	0%	0%	0%	2%	8%	13%	19%
SLC	SALT LAKE CITY	UT	21%	16%	11%	8%	3%	0%	0%	0%	1%	6%	13%	20%
BTV	BURLINGTON	VT	20%	17%	15%	9%	3%	1%	0%	0%	2%	6%	11%	16%
MPV	MONTPELIER	VT	18%	16%	14%	9%	4%	2%	0%	1%	3%	7%	11%	15%
LYH	LYNCHBURG	VA	23%	18%	14%	6%	2%	0%	0%	0%	1%	5%	14%	18%
ORF	NORFOLK	VA	24%	19%	15%	6%	2%	0%	0%	0%	0%	3%	12%	18%
RIC	RICHMOND	VA	23%	18%	14%	6%	2%	0%	0%	0%	0%	4%	13%	19%
ROA	ROANOKE	VA	23%	18%	14%	6%	2%	0%	0%	0%	1%	5%	14%	18%
BLI	BELLINGHAM	WA	15%	14%	12%	9%	5%	3%	1%	1%	3%	8%	12%	17%
HQM	HOQUIAM	WA	14%	13%	12%	10%	7%	4%	2%	2%	3%	7%	11%	15%
OLM	OLYMPIA	WA	15%	14%	12%	9%	5%	3%	1%	1%	3%	8%	13%	16%
UIL	QUILLAYUTE	WA	13%	12%	12%	10%	7%	5%	3%	2%	4%	7%	11%	14%
SEA	SEATTLE TACOMA	WA	16%	15%	13%	9%	5%	2%	0%	0%	2%	8%	13%	17%
GEG	SPOKANE	WA	17%	15%	12%	8%	4%	2%	0%	0%	2%	8%	14%	18%
ALW	WALLA WALLA	WA	20%	16%	12%	7%	2%	0%	0%	0%	1%	6%	14%	21%
EAT	WENATCHEE	WA	19%	16%	12%	7%	2%	1%	0%	0%	1%	7%	14%	20%
YKM	YAKIMA	WA	18%	15%	12%	7%	3%	1%	0%	0%	2%	7%	14%	20%
BKW	BECKLEY	WV	21%	17%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
CRW	CHARLESTON	WV	22%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	17%
EKN	ELKINS	WV	20%	16%	14%	8%	3%	1%	0%	0%	2%	7%	13%	16%
HTS	HUNTINGTON	WV	22%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	18%
MRB	MARTINSBURG	WV	21%	17%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
MGW	MORGANTOWN	WV	22%	18%	14%	7%	3%	0%	0%	0%	1%	6%	13%	17%
PKB	PARKERSBURG	WV	22%	18%	14%	7%	2%	0%	0%	0%	1%	6%	13%	17%
EAU	EAU CLAIRE	WI	19%	18%	13%	8%	3%	0%	0%	0%	2%	7%	12%	17%
GRB	GREEN BAY	WI	19%	18%	14%	9%	4%	1%	0%	0%	2%	6%	12%	16%
LSE	LACROSSE	WI	21%	19%	13%	8%	3%	0%	0%	0%	1%	6%	12%	18%
MSN	MADISON	WI	20%	18%	14%	8%	3%	0%	0%	0%	1%	6%	12%	17%
MKE	MILWAUKEE	WI	20%	17%	14%	9%	4%	1%	0%	0%	1%	6%	12%	16%
AUW	WAUSAU	WI	19%	17%	13%	9%	3%	1%	0%	0%	2%	7%	12%	17%
CPR	CASPER	WY	16%	15%	12%	9%	6%	1%	0%	0%	2%	8%	12%	17%
CYS	CHEYENNE	WY	16%	15%	13%	10%	6%	1%	0%	0%	2%	8%	12%	16%
COD	CODY	WY	16%	15%	12%	9%	6%	1%	0%	1%	3%	8%	13%	17%
LND	LANDER	WY	18%	15%	12%	9%	5%	1%	0%	0%	2%	8%	13%	18%
RKS	ROCK SPRINGS	WY	17%	14%	12%	9%	6%	1%	0%	0%	3%	8%	13%	17%
SHR	SHERIDAN	WY	16%	16%	12%	9%	5%	1%	0%	0%	2%	8%	12%	17%
WRL	WORLAND	WY	19%	16%	11%	8%	4%	1%	0%	0%	2%	8%	13%	19%

Table 7C.3.5 Weather Station Monthly Cooling Degree Day Data Fractions (10-Year Average, 2013-2022)

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
BHM	BIRMINGHAM	AL	0%	0%	1%	3%	11%	18%	22%	21%	16%	6%	1%	0%
HSV	HUNTSVILLE	AL	0%	0%	1%	3%	11%	20%	23%	22%	15%	5%	1%	0%
MOB	MOBILE	AL	0%	1%	2%	4%	11%	17%	19%	19%	16%	8%	2%	0%
MGM	MONTGOMERY	AL	0%	1%	2%	4%	11%	18%	21%	20%	16%	6%	1%	0%
MSL	MUSCLE SHOALS	AL	0%	0%	1%	3%	10%	20%	24%	21%	15%	5%	1%	0%
TCL	TUSCALOOSA	AL	0%	1%	1%	3%	11%	19%	22%	21%	16%	6%	1%	0%
ANC	ANCHORAGE	AK	0%	0%	0%	0%	0%	21%	59%	20%	0%	0%	0%	0%
BRW	BARROW	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BET	BETHEL	AK	0%	0%	0%	0%	0%	28%	66%	6%	0%	0%	0%	0%
BTT	BETTLES	AK	0%	0%	0%	0%	2%	38%	54%	7%	0%	0%	0%	0%
BIG	BIG DELTA	AK	0%	0%	0%	0%	2%	35%	50%	12%	0%	1%	0%	0%
CDB	COLD BAY	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
CDV	CORDOVA	AK	0%	0%	0%	0%	0%	75%	13%	13%	0%	0%	0%	0%
FAI	FAIRBANKS	AK	0%	0%	0%	0%	3%	38%	48%	11%	0%	0%	0%	0%
GKN	GULKANA	AK	0%	0%	0%	0%	0%	41%	56%	3%	0%	0%	0%	0%
HOM	HOMER	AK	0%	0%	0%	0%	0%	60%	40%	0%	0%	0%	0%	0%
JNU	JUNEAU	AK	0%	0%	0%	0%	0%	34%	50%	16%	0%	0%	0%	0%
ENA	KENAI	AK	0%	0%	0%	0%	0%	21%	29%	50%	0%	0%	0%	0%
KTN	KETCHIKAN	AK	0%	0%	0%	0%	0%	19%	54%	25%	1%	0%	0%	0%
AKN	KING SALMON	AK	0%	0%	0%	0%	0%	28%	67%	5%	0%	0%	0%	0%
ADQ	KODIAK	AK	0%	0%	0%	0%	2%	6%	42%	50%	0%	0%	0%	0%
OTZ	KOTZEBUE	AK	0%	0%	0%	0%	0%	27%	58%	15%	0%	0%	0%	0%
MCG	MCGRATH	AK	0%	0%	0%	0%	2%	37%	51%	9%	0%	0%	0%	0%
OME	NOME	AK	0%	0%	0%	0%	0%	48%	45%	8%	0%	0%	0%	0%
ORT	NORTHWAY	AK	0%	0%	0%	0%	0%	44%	47%	9%	0%	0%	0%	0%
SNP	ST PAUL ISLAND	AK	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%	8%
SIT	SITKA	AK	0%	0%	0%	0%	0%	14%	77%	9%	0%	0%	0%	0%
TKA	TALKEETNA	AK	0%	0%	0%	0%	0%	35%	58%	7%	0%	0%	0%	0%
UNK	UNALAKLEET	AK	0%	0%	0%	0%	13%	22%	41%	24%	0%	0%	0%	0%
VWS	VALDEZ	AK	0%	0%	0%	0%	4%	25%	47%	24%	0%	0%	0%	0%
YAK	YAKUTAT	AK	0%	0%	0%	0%	0%	20%	13%	67%	0%	0%	0%	0%
DUG	DOUGLAS	AZ	0%	1%	2%	6%	10%	20%	20%	18%	14%	6%	2%	0%
FLG	FLAGSTAFF	AZ	0%	0%	0%	2%	8%	22%	29%	23%	13%	3%	0%	0%
PHX	PHOENIX	AZ	0%	1%	3%	6%	11%	17%	19%	18%	15%	8%	2%	0%
TUS	TUCSON	AZ	0%	0%	2%	5%	10%	19%	20%	19%	15%	8%	2%	0%
INW	WINSLOW	AZ	0%	0%	0%	1%	4%	23%	32%	27%	13%	1%	0%	0%
NYL	YUMA	AZ	0%	1%	3%	6%	9%	16%	19%	19%	15%	9%	2%	0%
ELD	EL DORADO	AR	0%	0%	1%	3%	10%	19%	23%	22%	16%	5%	1%	0%
FYV	FAYETTEVILLE	AR	0%	0%	0%	1%	8%	21%	27%	24%	14%	3%	1%	0%
FSM	FORT SMITH	AR	0%	0%	1%	2%	9%	20%	25%	23%	16%	5%	0%	0%
HRO	HARRISON	AR	0%	0%	1%	3%	8%	18%	25%	23%	15%	6%	1%	0%
LIT	LITTLE ROCK	AR	0%	0%	1%	3%	9%	19%	24%	22%	16%	5%	0%	0%
TXK	TEXARKANA	AR	0%	0%	1%	3%	10%	19%	23%	22%	16%	6%	1%	0%
BFL	BAKERSFIELD	CA	0%	0%	1%	3%	9%	18%	25%	23%	16%	6%	0%	0%
BLH	BLYTHE	CA	0%	1%	3%	6%	10%	16%	20%	20%	15%	8%	1%	0%
EKA	EUREKA	CA	0%	0%	0%	0%	1%	6%	26%	13%	36%	16%	1%	0%
FAT	FRESNO	CA	0%	0%	1%	3%	9%	18%	25%	23%	16%	5%	0%	0%
IPL	IMPERIAL	CA	0%	1%	3%	6%	9%	16%	20%	20%	15%	8%	2%	0%
LAX	LOS ANGELES	CA	1%	1%	1%	3%	3%	8%	18%	21%	23%	16%	4%	1%
MHS	MT SHASTA	CA	0%	0%	0%	1%	6%	17%	29%	27%	15%	5%	0%	0%
PRB	PASO ROBLES	CA	0%	0%	0%	1%	6%	18%	26%	25%	18%	5%	0%	0%
RBL	RED BLUFF	CA	0%	0%	0%	2%	8%	20%	26%	23%	15%	5%	0%	0%
RDD	REDDING	CA	0%	0%	0%	2%	8%	20%	27%	23%	15%	4%	0%	0%
SAC	SACRAMENTO	CA	0%	0%	1%	4%	10%	20%	23%	22%	16%	5%	0%	0%
SAN	SAN DIEGO	CA	0%	1%	1%	3%	4%	8%	19%	24%	23%	14%	3%	0%
SFO	SAN FRANCISCO	CA	0%	0%	1%	3%	5%	13%	12%	20%	30%	17%	0%	0%
SCK	STOCKTON	CA	0%	0%	0%	2%	7%	19%	26%	24%	17%	5%	0%	0%
AKO	AKRON	CO	0%	0%	0%	0%	2%	20%	35%	28%	14%	1%	0%	0%
ALS	ALAMOSA	CO	0%	0%	0%	0%	0%	16%	57%	19%	8%	0%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
COS	COLORADO SPRINGS	CO	0%	0%	0%	0%	2%	21%	34%	28%	14%	0%	0%	0%
DEN	DENVER	CO	0%	0%	0%	0%	2%	19%	35%	29%	15%	1%	0%	0%
EGE	EAGLE	CO	0%	0%	0%	0%	0%	19%	50%	25%	6%	1%	0%	0%
GJT	GRAND JUNCTION	CO	0%	0%	0%	0%	4%	22%	34%	27%	12%	0%	0%	0%
LHX	LA JUNTA	CO	0%	0%	0%	1%	5%	22%	31%	25%	15%	1%	0%	0%
PUB	PUEBLO	CO	0%	0%	0%	0%	4%	22%	33%	27%	14%	1%	0%	0%
TAD	TRINIDAD	CO	0%	0%	0%	0%	3%	21%	34%	27%	14%	1%	0%	0%
BDR	BRIDGEPORT	CT	0%	0%	0%	0%	3%	16%	34%	31%	13%	2%	0%	0%
BDL	HARTFORD	CT	0%	0%	0%	0%	6%	17%	36%	29%	11%	1%	0%	0%
ILG	WILMINGTON	DE	0%	0%	0%	1%	8%	18%	29%	25%	15%	4%	0%	0%
DCA	WASHINGTON	DC	0%	0%	0%	2%	8%	19%	28%	25%	15%	3%	0%	0%
DAB	DAYTONA BEACH	FL	2%	3%	4%	6%	10%	13%	15%	15%	13%	10%	5%	2%
FLL	FT LAUDERDALE	FL	4%	5%	6%	8%	9%	11%	12%	12%	11%	10%	7%	4%
FMY	FORT MYERS	FL	2%	4%	5%	8%	10%	12%	13%	13%	12%	10%	6%	2%
GNV	GAINESVILLE	FL	1%	2%	4%	6%	10%	14%	16%	16%	14%	9%	4%	1%
JAX	JACKSONVILLE	FL	1%	1%	3%	5%	10%	16%	18%	18%	15%	8%	3%	1%
EYW	KEY WEST	FL	4%	5%	6%	8%	9%	11%	12%	12%	11%	10%	7%	4%
MLB	MELBOURNE	FL	2%	3%	4%	7%	10%	13%	14%	15%	13%	10%	6%	2%
MIA	MIAMI	FL	4%	5%	6%	8%	10%	11%	12%	12%	11%	10%	7%	4%
MCO	ORLANDO	FL	1%	3%	4%	7%	10%	13%	15%	15%	13%	10%	5%	1%
PNS	PENSACOLA	FL	1%	1%	3%	5%	11%	17%	18%	18%	15%	8%	2%	1%
TLH	TALLAHASSEE	FL	1%	1%	2%	5%	11%	17%	18%	19%	15%	8%	2%	1%
TPA	TAMPA	FL	2%	3%	4%	7%	11%	13%	14%	14%	13%	10%	5%	2%
VRB	VERO BEACH	FL	3%	4%	5%	7%	9%	12%	13%	14%	12%	10%	7%	3%
PBI	WEST PALM BEACH	FL	3%	4%	5%	8%	10%	11%	13%	13%	12%	10%	7%	3%
ABY	ALBANY	GA	1%	2%	4%	6%	11%	15%	16%	16%	13%	9%	4%	1%
AHN	ATHENS	GA	0%	0%	1%	3%	10%	20%	24%	22%	15%	5%	1%	0%
ATL	ATLANTA	GA	0%	0%	1%	3%	11%	19%	23%	22%	16%	5%	1%	0%
AGS	AUGUSTA	GA	0%	0%	1%	3%	10%	18%	23%	21%	15%	6%	1%	0%
BQK	BRUNSWICK	GA	1%	1%	2%	4%	11%	17%	20%	19%	15%	7%	2%	1%
CSG	COLUMBUS	GA	0%	1%	1%	3%	11%	18%	21%	20%	16%	6%	1%	0%
MCN	MACON	GA	0%	0%	1%	3%	11%	19%	23%	21%	15%	6%	1%	0%
SAV	SAVANNAH	GA	1%	1%	2%	4%	11%	17%	20%	19%	15%	7%	2%	1%
AYS	WAYCROSS	GA	1%	1%	3%	5%	11%	17%	19%	18%	14%	7%	2%	1%
ITO	HILO-HAWAII	HI	7%	6%	7%	7%	8%	9%	10%	11%	11%	10%	8%	7%
HNL	HONOLULU-OAHU	HI	6%	6%	6%	7%	8%	9%	11%	11%	10%	10%	8%	6%
OGG	KAHULUI-MAUI	HI	6%	5%	6%	7%	8%	9%	11%	11%	11%	10%	8%	6%
LIH	LIHUE-KAUAI	HI	6%	5%	6%	7%	8%	9%	11%	12%	11%	10%	8%	6%
BOI	BOISE	ID	0%	0%	0%	0%	3%	16%	38%	32%	11%	1%	0%	0%
BYI	BURLEY	ID	0%	0%	0%	0%	1%	16%	44%	30%	7%	1%	0%	0%
IDA	IDAHO FALLS	ID	0%	0%	0%	0%	0%	14%	47%	30%	8%	1%	0%	0%
LWS	LEWISTON	ID	0%	0%	0%	0%	4%	15%	37%	34%	10%	0%	0%	0%
PIH	POCATELLO	ID	0%	0%	0%	0%	1%	14%	45%	32%	8%	0%	0%	0%
ORD	CHICAGO	IL	0%	0%	0%	1%	7%	19%	29%	28%	14%	2%	0%	0%
MLI	MOLINE	IL	0%	0%	0%	1%	8%	23%	28%	24%	14%	2%	0%	0%
PIA	PEORIA	IL	0%	0%	0%	1%	9%	22%	27%	24%	15%	3%	0%	0%
UIN	QUINCY	IL	0%	0%	0%	2%	9%	21%	26%	23%	15%	4%	1%	0%
RFD	ROCKFORD	IL	0%	0%	0%	0%	8%	22%	30%	25%	13%	2%	0%	0%
SPI	SPRINGFIELD	IL	0%	0%	0%	1%	10%	23%	26%	22%	14%	3%	0%	0%
EVV	EVANSVILLE	IN	0%	0%	0%	2%	10%	21%	26%	23%	14%	4%	0%	0%
FWA	FORT WAYNE	IN	0%	0%	0%	0%	9%	23%	29%	24%	12%	2%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
IND	INDIANAPOLIS	IN	0%	0%	0%	1%	9%	21%	27%	25%	14%	3%	0%	0%
SBN	SOUTH BEND	IN	0%	0%	0%	0%	8%	21%	29%	26%	13%	2%	0%	0%
LAF	WEST LAFAYETTE	IN	0%	0%	0%	1%	9%	23%	27%	24%	14%	3%	0%	0%
BRL	BURLINGTON	IA	0%	0%	0%	2%	9%	21%	25%	22%	15%	4%	1%	0%
CID	CEDAR RAPIDS	IA	0%	0%	0%	1%	8%	24%	30%	23%	13%	1%	0%	0%
DSM	DES MOINES	IA	0%	0%	0%	1%	7%	23%	29%	25%	14%	1%	0%	0%
DBQ	DUBUQUE	IA	0%	0%	0%	0%	7%	23%	32%	24%	12%	1%	0%	0%
MCW	MASON CITY	IA	0%	0%	0%	0%	7%	26%	32%	22%	12%	1%	0%	0%
OTM	OTTUMWA	IA	0%	0%	0%	1%	7%	24%	29%	24%	14%	2%	0%	0%
SUX	SIOUX CITY	IA	0%	0%	0%	0%	6%	25%	31%	24%	13%	0%	0%	0%
SPW	SPENCER	IA	0%	0%	0%	1%	7%	24%	28%	22%	15%	2%	0%	0%
ALO	WATERLOO	IA	0%	0%	0%	0%	7%	24%	31%	24%	13%	1%	0%	0%
CNU	CHANUTE	KS	0%	0%	0%	1%	7%	21%	27%	24%	15%	3%	0%	0%
CNK	CONCORDIA	KS	0%	0%	0%	1%	6%	23%	28%	23%	16%	2%	0%	0%
DDC	DODGE CITY	KS	0%	0%	0%	1%	6%	22%	28%	25%	16%	2%	0%	0%
GCK	GARDEN CITY	KS	0%	0%	0%	1%	6%	23%	29%	24%	15%	2%	0%	0%
GLD	GOODLAND	KS	0%	0%	0%	0%	4%	22%	32%	27%	15%	1%	0%	0%
RSL	RUSSELL	KS	0%	0%	0%	1%	6%	23%	28%	25%	15%	2%	0%	0%
SLN	SALINA	KS	0%	0%	0%	1%	7%	23%	28%	24%	15%	2%	0%	0%
TOP	TOPEKA	KS	0%	0%	0%	1%	8%	23%	27%	24%	14%	2%	0%	0%
ICT	WICHITA	KS	0%	0%	0%	1%	7%	22%	27%	24%	16%	3%	0%	0%
BWG	BOWLING GREEN	KY	0%	0%	0%	2%	10%	20%	26%	23%	14%	4%	0%	0%
JKL	JACKSON	KY	0%	0%	1%	3%	10%	18%	24%	22%	15%	5%	1%	0%
LEX	LEXINGTON	KY	0%	0%	0%	2%	10%	20%	26%	24%	14%	4%	0%	0%
SDF	LOUISVILLE	KY	0%	0%	0%	2%	10%	20%	25%	23%	15%	4%	0%	0%
PAH	PADUCAH	KY	0%	0%	0%	2%	10%	21%	26%	23%	14%	4%	0%	0%
BTR	BATON ROUGE	LA	1%	2%	3%	6%	11%	15%	18%	17%	14%	8%	3%	1%
LFT	LAFAYETTE	LA	1%	1%	3%	5%	11%	16%	18%	18%	15%	8%	2%	1%
LCH	LAKE CHARLES	LA	0%	1%	3%	5%	11%	16%	19%	19%	15%	7%	2%	0%
MLU	MONROE	LA	0%	0%	2%	3%	11%	18%	21%	21%	16%	6%	1%	0%
MSY	NEW ORLEANS	LA	1%	1%	3%	5%	11%	16%	18%	17%	15%	9%	2%	1%
SHV	SHREVEPORT	LA	0%	0%	2%	4%	10%	18%	21%	21%	16%	6%	1%	0%
AUG	AUGUSTA	ME	0%	0%	0%	0%	3%	14%	39%	32%	11%	0%	0%	0%
BGR	BANGOR	ME	0%	0%	0%	0%	6%	17%	33%	30%	13%	1%	0%	0%
CAR	CARIBOU	ME	0%	0%	0%	0%	5%	13%	41%	33%	8%	0%	0%	0%
HUL	HOULTON	ME	0%	0%	0%	0%	4%	15%	42%	31%	8%	0%	0%	0%
PWM	PORTLAND	ME	0%	0%	0%	0%	3%	14%	38%	34%	11%	0%	0%	0%
BWI	BALTIMORE	MD	0%	0%	0%	1%	8%	19%	30%	25%	14%	3%	0%	0%
SBY	SALISBURY	MD	0%	0%	0%	2%	8%	18%	28%	23%	15%	5%	1%	0%
BOS	BOSTON	MA	0%	0%	0%	0%	5%	16%	34%	31%	12%	1%	0%	0%
CHH	CHATHAM	MA	0%	0%	0%	0%	3%	13%	33%	32%	15%	3%	1%	0%
ORH	WORCESTER	MA	0%	0%	0%	0%	6%	16%	34%	28%	12%	2%	0%	0%
APN	ALPENA	MI	0%	0%	0%	0%	6%	16%	36%	30%	11%	1%	0%	0%
DTW	DETROIT	MI	0%	0%	0%	0%	8%	19%	31%	28%	12%	2%	0%	0%
FNT	FLINT	MI	0%	0%	0%	0%	8%	20%	32%	27%	11%	2%	0%	0%
GRR	GRAND RAPIDS	MI	0%	0%	0%	0%	7%	20%	32%	27%	12%	1%	0%	0%
CMX	HANCOCK	MI	0%	0%	0%	0%	4%	15%	41%	28%	10%	1%	0%	0%
HTL	HOUGHTON LAKE	MI	0%	0%	0%	0%	10%	19%	36%	25%	9%	1%	0%	0%
JXN	JACKSON	MI	0%	0%	0%	0%	8%	20%	32%	26%	12%	2%	0%	0%
LAN	LANSING	MI	0%	0%	0%	0%	8%	20%	32%	27%	11%	1%	0%	0%
SAW	MARQUETTE	MI	0%	0%	0%	0%	6%	18%	41%	25%	10%	0%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MKG	MUSKEGON	MI	0%	0%	0%	0%	6%	18%	32%	30%	12%	1%	0%	0%
MBS	SAGINAW	MI	0%	0%	0%	0%	8%	20%	33%	26%	11%	1%	0%	0%
ANJ	SAULT ST MARIE	MI	0%	0%	0%	0%	4%	13%	40%	32%	10%	0%	0%	0%
TVC	TRAVERSE CITY	MI	0%	0%	0%	0%	7%	16%	33%	30%	13%	1%	0%	0%
AXN	ALEXANDRIA	MN	0%	0%	0%	0%	5%	23%	36%	25%	10%	0%	0%	0%
DLH	DULUTH	MN	0%	0%	0%	0%	3%	15%	43%	31%	8%	0%	0%	0%
HIB	HIBBING	MN	0%	0%	0%	0%	4%	19%	44%	26%	7%	0%	0%	0%
INL	INT'L FALLS	MN	0%	0%	0%	0%	5%	19%	41%	28%	7%	0%	0%	0%
MSP	MINNEAPOLIS	MN	0%	0%	0%	0%	6%	23%	33%	26%	11%	1%	0%	0%
RST	ROCHESTER	MN	0%	0%	0%	0%	7%	25%	33%	23%	12%	0%	0%	0%
STC	SAINT CLOUD	MN	0%	0%	0%	0%	5%	23%	36%	25%	10%	0%	0%	0%
GWO	GREENWOOD	MS	0%	1%	2%	4%	10%	16%	20%	19%	15%	8%	2%	0%
JAN	JACKSON	MS	0%	1%	2%	3%	10%	18%	21%	21%	16%	6%	1%	0%
MCB	MCCOMB	MS	0%	1%	2%	4%	10%	17%	20%	19%	16%	7%	1%	0%
MEI	MERIDIAN	MS	0%	1%	2%	3%	10%	18%	22%	21%	16%	6%	1%	0%
TUP	TUPELO	MS	0%	0%	1%	2%	10%	19%	23%	22%	15%	5%	1%	0%
COU	COLUMBIA	MO	0%	0%	0%	1%	8%	21%	27%	24%	15%	3%	0%	0%
JLN	JOPLIN	MO	0%	0%	0%	2%	8%	21%	27%	24%	15%	4%	0%	0%
MCI	KANSAS CITY	MO	0%	0%	0%	1%	7%	23%	28%	24%	14%	2%	0%	0%
STL	SAINT LOUIS	MO	0%	0%	0%	2%	10%	21%	26%	23%	15%	4%	0%	0%
SGF	SPRINGFIELD	MO	0%	0%	0%	1%	8%	21%	27%	24%	15%	3%	0%	0%
BIL	BILLINGS	MT	0%	0%	0%	0%	2%	15%	40%	32%	11%	0%	0%	0%
BTM	BUTTE	MT	0%	0%	0%	0%	1%	13%	37%	32%	14%	2%	0%	0%
CTB	CUT BANK	MT	0%	0%	0%	0%	1%	12%	37%	34%	13%	3%	0%	0%
GGW	GLASGOW	MT	0%	0%	0%	0%	3%	15%	40%	35%	8%	0%	0%	0%
GTF	GREAT FALLS	MT	0%	0%	0%	0%	1%	10%	43%	36%	9%	0%	0%	0%
HVR	HAVRE	MT	0%	0%	0%	0%	1%	12%	44%	35%	7%	0%	0%	0%
HLN	HELENA	MT	0%	0%	0%	0%	1%	13%	44%	35%	8%	0%	0%	0%
FCA	KALISPELL	MT	0%	0%	0%	0%	7%	22%	44%	25%	2%	0%	0%	0%
LWT	LEWISTOWN	MT	0%	0%	0%	0%	0%	10%	46%	35%	8%	1%	0%	0%
MLS	MILES CITY	MT	0%	0%	0%	0%	2%	15%	41%	32%	10%	0%	0%	0%
MSO	MISSOULA	MT	0%	0%	0%	0%	1%	12%	45%	36%	6%	0%	0%	0%
GRI	GRAND ISLAND	NE	0%	0%	0%	1%	6%	25%	30%	24%	14%	1%	0%	0%
LNK	LINCOLN	NE	0%	0%	0%	1%	7%	24%	29%	24%	14%	1%	0%	0%
OFK	NORFOLK	NE	0%	0%	0%	1%	6%	24%	31%	24%	13%	1%	0%	0%
LBF	NORTH PLATTE	NE	0%	0%	0%	0%	3%	22%	34%	27%	13%	0%	0%	0%
OMA	OMAHA	NE	0%	0%	0%	1%	7%	24%	29%	25%	14%	1%	0%	0%
BFF	SCOTTSBLUFF	NE	0%	0%	0%	0%	2%	21%	36%	29%	12%	0%	0%	0%
VTN	VALENTINE	NE	0%	0%	0%	0%	3%	20%	35%	28%	13%	0%	0%	0%
EKO	ELKO	NV	0%	0%	0%	0%	1%	16%	46%	29%	8%	0%	0%	0%
ELY	ELY	NV	0%	0%	0%	0%	0%	18%	47%	28%	7%	0%	0%	0%
LAS	LAS VEGAS	NV	0%	0%	1%	5%	10%	19%	23%	21%	15%	6%	1%	0%
LOL	LOVELOCK	NV	0%	0%	0%	2%	6%	18%	31%	26%	13%	4%	0%	0%
RNO	RENO	NV	0%	0%	0%	0%	3%	19%	36%	30%	12%	1%	0%	0%
TPH	TONOPAH	NV	0%	0%	0%	0%	4%	21%	36%	28%	10%	1%	0%	0%
WMC	WINNEMUCCA	NV	0%	0%	0%	0%	2%	18%	42%	30%	8%	0%	0%	0%
CON	CONCORD	NH	0%	0%	0%	0%	5%	15%	39%	29%	10%	0%	0%	0%
LEB	LEBANON	NH	0%	0%	0%	0%	8%	18%	31%	27%	13%	3%	0%	0%
MWN	MT WASHINGTON	NH	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%
ACY	ATLANTIC CITY	NJ	0%	0%	0%	1%	6%	18%	32%	27%	14%	3%	0%	0%
EWR	NEWARK	NJ	0%	0%	0%	1%	6%	18%	31%	27%	13%	2%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
ABQ	ALBUQUERQUE	NM	0%	0%	0%	1%	6%	24%	29%	24%	14%	1%	0%	0%
CNM	CARLSBAD	NM	0%	0%	1%	3%	11%	22%	25%	22%	13%	3%	0%	0%
CAO	CLAYTON	NM	0%	0%	0%	0%	5%	23%	31%	24%	15%	1%	0%	0%
GUP	GALLUP	NM	0%	0%	0%	0%	1%	22%	41%	29%	8%	0%	0%	0%
ROW	ROSWELL	NM	0%	0%	0%	3%	11%	22%	25%	23%	13%	3%	0%	0%
CVN	TUCUMCARI	NM	0%	0%	0%	1%	8%	24%	28%	24%	13%	2%	0%	0%
ALB	ALBANY	NY	0%	0%	0%	0%	7%	18%	36%	28%	11%	1%	0%	0%
BGM	BINGHAMTON	NY	0%	0%	0%	0%	7%	15%	36%	27%	12%	1%	0%	0%
BUF	BUFFALO	NY	0%	0%	0%	0%	7%	16%	33%	30%	12%	2%	0%	0%
GFL	GLENS FALLS	NY	0%	0%	0%	0%	8%	17%	34%	26%	12%	2%	0%	0%
MSS	MASSENA	NY	0%	0%	0%	0%	6%	16%	38%	30%	9%	0%	0%	0%
LGA	NEW YORK	NY	0%	0%	0%	0%	6%	18%	31%	28%	15%	3%	0%	0%
ROC	ROCHESTER	NY	0%	0%	0%	0%	8%	17%	33%	28%	12%	2%	0%	0%
SYR	SYRACUSE	NY	0%	0%	0%	0%	7%	16%	35%	29%	12%	1%	0%	0%
UCA	UTICA	NY	0%	0%	0%	1%	11%	19%	27%	24%	13%	3%	0%	0%
ART	WATERTOWN	NY	0%	0%	0%	0%	6%	15%	37%	30%	10%	1%	0%	0%
AVL	ASHEVILLE	NC	0%	0%	0%	1%	8%	20%	29%	25%	14%	3%	0%	0%
HAT	CAPE HATTERAS	NC	1%	1%	2%	6%	11%	15%	18%	17%	14%	10%	3%	1%
CLT	CHARLOTTE	NC	0%	0%	1%	3%	10%	20%	25%	23%	15%	4%	0%	0%
GSO	GREENSBORO	NC	0%	0%	0%	2%	10%	20%	27%	23%	14%	3%	0%	0%
HKY	HICKORY	NC	0%	0%	1%	3%	10%	18%	24%	22%	15%	5%	1%	0%
EWN	NEW BERN	NC	0%	0%	1%	3%	10%	18%	24%	22%	15%	5%	1%	0%
RDU	RALEIGH DURHAM	NC	0%	0%	1%	3%	10%	19%	26%	23%	14%	4%	0%	0%
ILM	WILMINGTON	NC	0%	0%	1%	3%	10%	18%	23%	21%	15%	6%	1%	0%
BIS	BISMARCK	ND	0%	0%	0%	0%	3%	20%	39%	29%	8%	0%	0%	0%
P11	DEVIL'S LAKE	ND	0%	0%	0%	0%	8%	22%	31%	26%	12%	1%	0%	0%
DIK	DICKINSON	ND	0%	0%	0%	0%	3%	12%	43%	33%	8%	0%	0%	0%
FAR	FARGO	ND	0%	0%	0%	0%	6%	24%	37%	24%	9%	1%	0%	0%
GFK	GRAND FORKS	ND	0%	0%	0%	0%	6%	21%	33%	27%	11%	2%	0%	0%
JMS	JAMESTOWN	ND	0%	0%	0%	0%	4%	23%	42%	24%	7%	0%	0%	0%
MOT	MINOT	ND	0%	0%	0%	0%	4%	18%	38%	31%	8%	0%	0%	0%
ISN	WILLISTON	ND	0%	0%	0%	0%	5%	19%	33%	30%	11%	2%	0%	0%
CAK	AKRON CANTON	OH	0%	0%	0%	1%	9%	19%	30%	26%	13%	3%	0%	0%
CLE	CLEVELAND	OH	0%	0%	0%	1%	8%	19%	29%	26%	14%	3%	0%	0%
CMH	COLUMBUS	OH	0%	0%	0%	1%	10%	21%	28%	25%	13%	3%	0%	0%
CVG	CINCINNATI	OH	0%	0%	0%	1%	9%	20%	27%	25%	14%	3%	0%	0%
DAY	DAYTON	OH	0%	0%	0%	1%	10%	21%	27%	25%	14%	3%	0%	0%
FDY	FINDLAY	OH	0%	0%	0%	1%	9%	22%	29%	24%	13%	3%	0%	0%
MFD	MANSFIELD	OH	0%	0%	0%	1%	9%	19%	28%	25%	15%	4%	0%	0%
TOL	TOLEDO	OH	0%	0%	0%	0%	8%	20%	30%	26%	13%	2%	0%	0%
YNG	YOUNGSTOWN	OH	0%	0%	0%	1%	9%	19%	31%	26%	12%	3%	0%	0%
LHQ	ZANESVILLE	OH	0%	0%	0%	1%	9%	22%	28%	24%	13%	3%	0%	0%
GAG	GAGE	OK	0%	0%	1%	3%	8%	19%	24%	23%	16%	5%	1%	0%
HBR	HOBART	OK	0%	0%	0%	2%	9%	20%	25%	24%	15%	4%	0%	0%
MLC	MCALESTER	OK	0%	0%	1%	3%	8%	19%	25%	23%	16%	5%	1%	0%
OKC	OKLAHOMA CITY	OK	0%	0%	1%	2%	8%	19%	26%	24%	16%	4%	0%	0%
PNC	PONCA CITY	OK	0%	0%	1%	4%	9%	18%	22%	21%	16%	7%	1%	0%
TUL	TULSA	OK	0%	0%	1%	2%	8%	20%	25%	23%	16%	4%	0%	0%
AST	ASTORIA	OR	0%	0%	0%	2%	4%	18%	13%	37%	25%	1%	0%	0%
BKE	BAKER	OR	0%	0%	0%	0%	1%	12%	44%	36%	7%	0%	0%	0%
BNO	BURNS	OR	0%	0%	0%	0%	1%	13%	46%	33%	7%	0%	0%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
EUG	EUGENE	OR	0%	0%	0%	0%	1%	12%	35%	40%	11%	1%	0%	0%
MFR	MEDFORD	OR	0%	0%	0%	0%	4%	16%	34%	31%	13%	2%	0%	0%
OTH	NORTH BEND	OR	0%	0%	0%	2%	6%	15%	23%	25%	19%	9%	1%	0%
PDT	PENDLETON	OR	0%	0%	0%	0%	3%	15%	39%	34%	8%	1%	0%	0%
PDX	PORTLAND	OR	0%	0%	0%	0%	4%	14%	32%	36%	13%	1%	0%	0%
RDM	REDMOND	OR	0%	0%	0%	0%	2%	14%	35%	32%	13%	4%	0%	0%
SLE	SALEM	OR	0%	0%	0%	0%	2%	14%	35%	37%	12%	1%	0%	0%
ABE	ALLENTOWN	PA	0%	0%	0%	1%	7%	18%	34%	27%	12%	2%	0%	0%
AOO	ALTOONA	PA	0%	0%	0%	1%	8%	17%	32%	27%	11%	3%	0%	0%
BFD	BRADFORD	PA	0%	0%	0%	0%	8%	17%	35%	27%	11%	2%	0%	0%
DUJ	DU BOIS	PA	0%	0%	0%	1%	8%	18%	34%	27%	11%	2%	0%	0%
ERI	ERIE	PA	0%	0%	0%	0%	8%	17%	30%	28%	14%	3%	0%	0%
CXY	HARRISBURG	PA	0%	0%	0%	1%	7%	19%	31%	26%	13%	3%	0%	0%
PHL	PHILADELPHIA	PA	0%	0%	0%	1%	7%	19%	30%	26%	14%	3%	0%	0%
PIT	PITTSBURGH	PA	0%	0%	0%	1%	9%	19%	30%	25%	13%	2%	0%	0%
AVP	SCRANTON	PA	0%	0%	0%	1%	8%	17%	34%	27%	12%	2%	0%	0%
IPT	WILLIAMSPORT	PA	0%	0%	0%	0%	7%	17%	34%	28%	12%	2%	0%	0%
PVD	PROVIDENCE	RI	0%	0%	0%	0%	5%	16%	36%	31%	12%	1%	0%	0%
CHS	CHARLESTON	SC	0%	1%	2%	4%	11%	18%	21%	20%	15%	7%	2%	0%
CAE	COLUMBIA	SC	0%	0%	1%	4%	11%	19%	23%	21%	15%	5%	1%	0%
FLO	FLORENCE	SC	0%	0%	1%	3%	11%	19%	23%	20%	15%	5%	1%	0%
GSP	GREENVILLE	SC	0%	0%	1%	2%	10%	20%	25%	23%	15%	4%	0%	0%
ABR	ABERDEEN	SD	0%	0%	0%	0%	5%	24%	36%	25%	10%	1%	0%	0%
HON	HURON	SD	0%	0%	0%	0%	5%	23%	34%	26%	13%	0%	0%	0%
PIR	PIERRE	SD	0%	0%	0%	0%	5%	17%	32%	27%	15%	3%	0%	0%
RAP	RAPID CITY	SD	0%	0%	0%	0%	1%	16%	40%	30%	12%	1%	0%	0%
FSD	SIOUX FALLS	SD	0%	0%	0%	0%	5%	24%	33%	25%	12%	1%	0%	0%
ATY	WATERTOWN	SD	0%	0%	0%	0%	4%	24%	36%	25%	11%	0%	0%	0%
TRI	BRISTOL	TN	0%	0%	1%	2%	9%	18%	25%	23%	15%	5%	1%	0%
CHA	CHATTANOOGA	TN	0%	0%	0%	2%	10%	20%	24%	23%	16%	5%	0%	0%
CSV	CROSSVILLE	TN	0%	0%	1%	3%	10%	17%	25%	22%	15%	6%	1%	0%
MKL	JACKSON	TN	0%	0%	0%	2%	10%	20%	25%	22%	14%	6%	1%	0%
TYS	KNOXVILLE	TN	0%	0%	0%	2%	10%	20%	25%	23%	15%	4%	0%	0%
MEM	MEMPHIS	TN	0%	0%	1%	3%	10%	19%	23%	22%	16%	5%	1%	0%
BNA	NASHVILLE	TN	0%	0%	0%	2%	10%	20%	25%	23%	15%	4%	0%	0%
ABI	ABILENE	TX	0%	0%	2%	4%	11%	18%	22%	22%	14%	6%	1%	0%
ALI	ALICE	TX	1%	2%	4%	7%	11%	14%	16%	16%	13%	9%	3%	1%
AMA	AMARILLO	TX	0%	0%	0%	2%	8%	21%	27%	25%	14%	3%	0%	0%
AUS	AUSTIN	TX	0%	1%	2%	5%	11%	17%	20%	20%	15%	7%	2%	0%
BRO	BROWNSVILLE	TX	1%	3%	5%	8%	11%	13%	14%	15%	12%	9%	5%	1%
CLL	COLLEGE STATION	TX	1%	1%	3%	5%	10%	15%	18%	19%	15%	9%	3%	1%
CRP	CORPUS CHRISTI	TX	1%	2%	4%	7%	11%	14%	16%	17%	14%	9%	3%	1%
DHT	DALHART	TX	0%	0%	1%	2%	7%	19%	26%	23%	15%	4%	1%	0%
DFW	DALLAS FT WORTH	TX	0%	0%	2%	4%	10%	18%	22%	22%	16%	6%	1%	0%
DRT	DEL RIO	TX	0%	1%	3%	7%	12%	16%	19%	19%	13%	7%	2%	0%
ELP	EL PASO	TX	0%	0%	1%	5%	12%	21%	22%	20%	14%	5%	0%	0%
GLS	GALVESTON	TX	1%	1%	3%	6%	11%	15%	17%	17%	15%	10%	3%	1%
IAH	HOUSTON	TX	0%	1%	3%	5%	11%	16%	19%	19%	14%	8%	2%	0%
LRD	LAREDO	TX	1%	2%	5%	8%	12%	15%	16%	16%	12%	8%	3%	1%
LBB	LUBBOCK	TX	0%	0%	1%	3%	10%	21%	25%	23%	14%	4%	0%	0%
LFK	LUFKIN	TX	0%	1%	2%	4%	11%	17%	20%	20%	15%	7%	2%	0%

Station Location			10-year Average Monthly Fraction of Annual CDD Data											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
MFE	MCALLEN	TX	2%	3%	5%	8%	11%	13%	15%	15%	12%	9%	4%	2%
MAF	MIDLAND ODESSA	TX	0%	0%	1%	5%	12%	19%	22%	21%	13%	6%	1%	0%
PSX	PALACIOS	TX	1%	1%	3%	6%	12%	16%	18%	18%	14%	8%	3%	1%
CXO	PORT ARTHUR	TX	0%	1%	2%	4%	11%	17%	20%	20%	15%	7%	2%	0%
SJT	SAN ANGELO	TX	0%	0%	2%	5%	11%	18%	22%	21%	14%	6%	1%	0%
SAT	SAN ANTONIO	TX	0%	1%	3%	5%	11%	16%	19%	19%	15%	8%	2%	0%
VCT	VICTORIA	TX	1%	1%	3%	6%	11%	16%	18%	18%	14%	8%	3%	1%
ACT	WACO	TX	0%	0%	1%	4%	10%	18%	22%	21%	15%	7%	1%	0%
SPS	WICHITA FALLS	TX	0%	0%	1%	3%	10%	19%	24%	23%	15%	5%	0%	0%
CDC	CEDAR CITY	UT	0%	0%	0%	0%	2%	20%	39%	29%	10%	0%	0%	0%
SLC	SALT LAKE CITY	UT	0%	0%	0%	0%	4%	19%	35%	28%	13%	1%	0%	0%
BTV	BURLINGTON	VT	0%	0%	0%	0%	7%	16%	35%	30%	11%	1%	0%	0%
MPV	MONTPELIER	VT	0%	0%	0%	0%	6%	16%	39%	29%	9%	1%	0%	0%
LYH	LYNCHBURG	VA	0%	0%	0%	2%	9%	19%	29%	24%	14%	3%	0%	0%
ORF	NORFOLK	VA	0%	0%	1%	3%	9%	19%	26%	23%	15%	5%	1%	0%
RIC	RICHMOND	VA	0%	0%	0%	2%	9%	19%	27%	24%	14%	3%	0%	0%
ROA	ROANOKE	VA	0%	0%	0%	2%	10%	19%	28%	24%	14%	3%	0%	0%
BLI	BELLINGHAM	WA	0%	0%	0%	0%	0%	16%	39%	40%	5%	0%	0%	0%
HQM	HOQUIAM	WA	0%	0%	0%	2%	4%	22%	10%	37%	25%	1%	0%	0%
OLM	OLYMPIA	WA	0%	0%	0%	0%	1%	17%	35%	40%	6%	0%	0%	0%
UIL	QUILLAYUTE	WA	0%	0%	0%	1%	2%	25%	11%	45%	16%	0%	0%	0%
SEA	SEATTLE TACOMA	WA	0%	0%	0%	0%	3%	14%	34%	37%	10%	0%	0%	0%
GEG	SPOKANE	WA	0%	0%	0%	0%	3%	14%	40%	36%	8%	0%	0%	0%
ALW	WALLA WALLA	WA	0%	0%	0%	1%	6%	16%	31%	29%	13%	4%	0%	0%
EAT	WENATCHEE	WA	0%	0%	0%	0%	5%	16%	37%	32%	8%	1%	0%	0%
YKM	YAKIMA	WA	0%	0%	0%	0%	5%	17%	39%	32%	7%	0%	0%	0%
BKW	BECKLEY	WV	0%	0%	0%	1%	9%	19%	30%	25%	13%	2%	0%	0%
CRW	CHARLESTON	WV	0%	0%	0%	2%	10%	19%	28%	25%	14%	3%	0%	0%
EKN	ELKINS	WV	0%	0%	0%	0%	7%	18%	33%	27%	13%	2%	0%	0%
HTS	HUNTINGTON	WV	0%	0%	0%	2%	10%	19%	27%	24%	14%	3%	0%	0%
MRB	MARTINSBURG	WV	0%	0%	0%	1%	8%	19%	32%	25%	12%	2%	0%	0%
MGW	MORGANTOWN	WV	0%	0%	0%	2%	10%	19%	29%	24%	14%	3%	0%	0%
PKB	PARKERSBURG	WV	0%	0%	0%	1%	11%	19%	28%	23%	14%	3%	0%	0%
EAU	EAU CLAIRE	WI	0%	0%	0%	0%	6%	22%	35%	26%	11%	0%	0%	0%
GRB	GREEN BAY	WI	0%	0%	0%	0%	7%	21%	35%	26%	10%	1%	0%	0%
LSE	LACROSSE	WI	0%	0%	0%	0%	7%	22%	32%	25%	12%	1%	0%	0%
MSN	MADISON	WI	0%	0%	0%	0%	8%	22%	33%	26%	11%	1%	0%	0%
MKE	MILWAUKEE	WI	0%	0%	0%	0%	5%	17%	32%	30%	14%	2%	0%	0%
AUW	WAUSAU	WI	0%	0%	0%	0%	7%	21%	36%	25%	10%	0%	0%	0%
CPR	CASPER	WY	0%	0%	0%	0%	1%	14%	44%	31%	10%	0%	0%	0%
CYS	CHEYENNE	WY	0%	0%	0%	0%	1%	16%	40%	31%	12%	0%	0%	0%
COD	CODY	WY	0%	0%	0%	0%	1%	13%	44%	30%	11%	1%	0%	0%
LND	LANDER	WY	0%	0%	0%	0%	1%	13%	37%	36%	13%	0%	0%	0%
RKS	ROCK SPRINGS	WY	0%	0%	0%	0%	0%	15%	48%	29%	7%	0%	0%	0%
SHR	SHERIDAN	WY	0%	0%	0%	0%	1%	12%	43%	34%	10%	0%	0%	0%
WRL	WORLAND	WY	0%	0%	0%	0%	1%	17%	40%	32%	9%	0%	0%	0%

7C.3.2 Monthly Average Outdoor Temperature Data by Weather Station

Table 7C.3.6 shows for each weather station the 30-year (1991-2020) monthly average outdoor temperature data based on NOAA data.[4]

Table 7C.3.6 Weather Station Monthly Average Outdoor Temperature (1991-2020)

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	City	State	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
BHM	BIRMINGHAM	AL	44.7	48.8	56.0	63.6	71.5	78.3	81.5	80.9	75.6	64.9	54.0	47.4
HSV	HUNTSVILLE	AL	42.7	46.7	54.2	62.9	71.3	78.6	81.3	80.5	74.9	63.9	52.5	45.5
MOB	MOBILE	AL	51.1	55.0	60.9	66.9	74.4	80.1	82.0	81.9	78.1	69.0	58.9	53.3
MGM	MONTGOMERY	AL	48.1	52.6	59.2	65.7	73.6	80.2	82.9	82.5	77.8	67.4	56.6	50.2
MSL	MUSCLE SHOALS	AL	42.9	46.7	54.4	62.9	71.3	78.4	81.5	80.5	74.7	63.6	52.5	45.6
TCL	TUSCALOOSA	AL	45.7	49.6	56.9	63.8	72.2	79.1	81.9	81.5	76.3	65.2	54.2	48.0
ANC	ANCHORAGE	AK	16.9	21.3	25.8	37.5	48.1	55.9	59.6	57.5	49.3	36.3	23.6	19.4
BRW	BARROW	AK	-11.5	-11.9	-10.5	4.0	22.7	36.0	41.7	39.8	33.7	21.2	5.7	-6.3
BET	BETHEL	AK	6.9	13.3	14.5	29.0	43.0	53.3	56.3	53.9	46.1	32.2	18.5	10.0
BTT	BETTLES	AK	-10.6	-3.4	3.7	24.6	45.0	58.6	59.8	52.7	41.2	21.3	0.3	-6.0
BIG	BIG DELTA	AK	-1.0	7.3	14.2	33.9	48.5	58.5	60.7	55.6	44.8	26.5	8.2	2.4
CDB	COLD BAY	AK	28.4	30.2	29.9	35.0	41.0	47.1	51.5	52.6	48.4	41.3	35.3	30.8
CDV	CORDOVA	AK	26.4	29.1	30.8	38.1	45.5	51.4	54.6	54.1	48.4	40.1	31.6	28.9
FAI	FAIRBANKS	AK	-8.3	0.2	10.7	33.7	50.3	61.0	62.9	57.0	45.8	26.2	4.1	-4.3
GKN	GULKANA	AK	-3.4	5.6	14.7	32.6	45.8	54.9	57.9	53.5	43.6	27.1	6.8	-0.2
HOM	HOMER	AK	25.4	28.3	30.1	38.7	46.0	52.0	56.1	55.3	49.5	40.2	31.2	27.7
JNU	JUNEAU	AK	28.5	30.1	32.9	40.8	49.0	54.6	57.0	56.0	50.1	42.2	33.8	30.3
ENA	KENAI	AK	14.9	19.9	23.6	36.0	45.4	52.1	56.0	54.8	47.8	35.9	23.2	18.1
KTN	KETCHIKAN	AK	35.6	36.2	38.0	43.5	50.1	55.3	58.8	59.0	53.6	46.2	39.7	36.4
AKN	KING SALMON	AK	16.6	22.1	23.5	36.0	45.6	52.8	56.7	55.7	48.7	36.4	25.0	18.6
ADQ	KODIAK	AK	31.2	32.4	33.2	39.1	45.8	51.4	56.2	56.5	50.6	42.2	35.7	31.9
OTZ	KOTZEBUE	AK	-1.9	1.4	1.5	16.3	33.1	47.5	55.3	52.1	43.1	26.9	10.8	2.4
MCG	MCGRATH	AK	-5.8	4.5	11.9	32.2	48.4	58.7	60.8	55.9	46.0	28.4	8.0	-2.3
OME	NOME	AK	5.6	9.0	9.6	22.7	37.3	48.3	52.0	50.2	43.1	30.4	18.2	9.1
ORT	NORTHWAY	AK	-13.3	-4.0	8.3	31.1	47.2	57.2	59.9	55.0	43.2	23.2	-0.7	-10.8
SNP	ST PAUL ISLAND	AK	25.3	25.3	25.1	30.1	36.6	43.1	47.9	49.5	46.0	39.5	33.9	28.9
SIT	SITKA	AK	36.5	36.7	37.5	42.6	48.1	53.0	56.5	57.3	53.2	46.4	40.0	37.5
TKA	TALKEETNA	AK	13.6	18.8	23.5	36.2	47.7	57.0	60.1	56.5	47.5	34.2	20.6	15.6
UNK	UNALAKLEET	AK	-4.0	4.1	9.7	27.6	45.1	57.4	59.3	54.3	44.5	27.8	9.4	0.1
VWS	VALDEZ	AK	23.9	26.7	29.9	39.2	47.7	54.4	56.6	54.5	48.3	39.5	29.4	26.2
YAK	YAKUTAT	AK	28.6	30.6	31.9	38.6	45.6	51.9	55.4	54.7	49.4	41.9	33.7	30.8
DUG	DOUGLAS	AZ	45.1	48.6	54.2	60.5	68.8	77.9	79.3	77.7	73.6	64.0	52.8	44.8
FLG	FLAGSTAFF	AZ	30.5	32.6	38.0	43.7	51.3	60.8	66.7	64.9	58.3	47.6	37.5	30.0
PHX	PHOENIX	AZ	56.8	59.9	66.3	73.2	82.0	91.4	95.5	94.4	89.2	77.4	65.1	55.8
TUS	TUCSON	AZ	53.6	56.2	61.9	68.1	76.8	86.1	88.2	86.9	82.8	72.6	61.5	53.0
INW	WINSLOW	AZ	35.9	41.0	48.2	54.9	63.7	73.8	79.1	77.1	69.7	57.1	44.6	35.2
NYL	YUMA	AZ	55.9	58.6	64.6	70.5	77.7	86.5	93.0	92.5	86.4	74.7	63.0	54.4
ELD	EL DORADO	AR	44.7	48.5	56.3	63.9	72.0	79.3	82.4	81.8	75.8	64.6	53.8	46.8
FYV	FAYETTEVILLE	AR	36.7	40.6	48.5	58.1	66.0	74.8	79.1	78.1	70.6	59.4	48.1	39.7
FSM	FORT SMITH	AR	40.4	45.0	53.5	62.1	70.4	78.8	83.1	82.3	74.8	63.5	51.7	42.8
HRO	HARRISON	AR	37.0	40.9	49.2	58.3	66.2	74.4	78.5	77.6	69.9	59.4	48.5	39.7
LIT	LITTLE ROCK	AR	40.7	44.7	52.7	61.4	69.9	78.0	81.4	80.8	74.0	62.6	51.1	43.0
TXK	TEXARKANA	AR	44.6	48.3	56.0	63.6	71.6	78.9	82.5	82.0	75.4	64.9	53.9	46.4
BFL	BAKERSFIELD	CA	49.5	53.8	58.6	63.3	71.1	78.7	84.8	83.4	78.2	67.7	56.3	49.2

Station Location			30-year Mean Temperature 1991-2020 NOAA											
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BLH	BLYTHE	CA	54.8	58.3	64.5	71.7	80.5	88.3	93.9	93.4	87.4	73.8	62.6	52.1
EKA	EUREKA	CA	47.9	48.4	49.2	50.8	53.7	56.0	57.7	58.5	57.2	54.3	50.5	47.4
FAT	FRESNO	CA	48.0	52.3	57.4	62.3	70.2	77.6	83.5	82.2	77.1	66.7	55.1	47.5
IPL	IMPERIAL	CA	56.0	59.4	65.3	70.9	78.2	86.8	93.1	93.6	87.2	75.2	63.3	54.9
LAX	LOS ANGELES	CA	57.9	57.9	59.1	61.1	63.6	66.4	69.6	70.7	70.1	67.1	62.3	57.6
MHS	MT SHASTA	CA	35.8	37.9	41.9	46.5	54.2	61.1	68.1	66.8	61.0	50.9	40.5	34.8
PRB	PASO ROBLES	CA	48.1	50.3	53.9	57.2	62.8	68.3	72.0	72.4	69.3	62.0	53.0	47.0
RBL	RED BLUFF	CA	47.4	50.8	54.7	59.6	68.0	76.4	82.0	79.9	75.4	65.1	53.4	46.8
RDD	REDDING	CA	47.5	50.5	54.4	59.4	68.2	77.1	83.4	81.0	75.3	64.8	52.9	46.6
SAC	SACRAMENTO	CA	47.6	51.4	55.4	59.5	66.1	72.2	75.9	75.3	72.5	64.5	53.9	47.3
SAN	SAN DIEGO	CA	58.4	59.0	60.7	62.9	64.8	67.2	70.7	72.4	71.7	68.1	62.7	57.9
SFO	SAN FRANCISCO	CA	51.3	53.5	55.5	57.3	59.9	62.5	64.0	64.9	65.3	62.9	56.4	51.4
SCK	STOCKTON	CA	48.0	52.1	56.4	60.9	67.7	74.0	78.1	77.3	73.9	65.5	54.7	47.7
AKO	AKRON	CO	29.1	31.3	40.5	47.2	56.9	68.2	74.5	72.5	64.1	50.2	38.3	29.3
ALS	ALAMOSA	CO	16.8	24.3	35.2	42.6	51.7	60.6	65.3	63.2	55.9	43.8	30.3	18.1
COS	COLORADO SPRINGS	CO	31.7	33.4	41.1	47.5	57.1	67.2	72.4	70.1	63.0	50.7	39.5	31.7
DEN	DENVER	CO	31.7	32.7	41.6	47.8	57.4	68.2	75.1	72.9	64.8	51.1	39.4	31.2
EGE	EAGLE	CO	17.5	21.1	29.2	36.6	45.7	53.5	59.2	57.4	50.3	39.7	26.4	17.6
GJT	GRAND JUNCTION	CO	27.7	35.3	45.0	51.9	62.0	73.0	79.2	76.3	67.1	53.2	39.6	28.4
LHX	LA JUNTA	CO	32.3	35.9	45.5	53.2	63.4	74.2	79.1	76.8	68.6	54.6	41.8	32.3
PUB	PUEBLO	CO	31.9	35.1	43.9	51.3	61.4	71.8	77.2	74.8	66.6	52.8	40.5	31.7
TAD	TRINIDAD	CO	35.7	37.9	45.3	51.7	60.8	70.3	74.3	72.2	66.0	54.6	43.4	35.4
BDR	BRIDGEPORT	CT	31.4	33.1	39.9	50.0	60.0	69.6	75.7	74.5	67.6	56.4	46.0	37.0
BDL	HARTFORD	CT	27.1	29.6	37.8	49.5	60.0	68.9	74.3	72.5	64.8	53.0	42.3	32.6
ILG	WILMINGTON	DE	33.5	35.5	43.2	53.9	63.5	72.6	77.6	75.8	68.9	57.2	46.6	38.2
DCA	WASHINGTON	DC	33.9	36.4	44.2	55.0	64.0	72.5	77.2	75.7	68.6	56.6	46.0	37.7
DAB	DAYTONA BEACH	FL	58.8	61.4	65.2	70.2	75.6	80.2	81.9	81.9	80.1	74.4	67.0	61.8
FLL	FT LAUDERDALE	FL	68.3	70.3	72.6	76.4	79.7	82.5	83.8	84.0	82.7	79.9	74.6	71.2
FMY	FORT MYERS	FL	64.7	67.3	70.3	74.8	79.3	82.3	83.2	83.4	82.2	78.0	71.5	67.3
GNV	GAINESVILLE	FL	54.8	58.4	62.7	68.5	75.0	79.9	81.4	81.3	78.8	71.4	62.7	57.3
JAX	JACKSONVILLE	FL	54.9	58.0	62.6	68.3	74.4	79.9	82.2	81.7	78.8	71.9	63.3	57.6
EYW	KEY WEST	FL	70.6	72.3	74.4	77.9	81.1	84.1	85.4	85.5	84.1	81.3	76.6	73.0
MLB	MELBOURNE	FL	63.3	65.4	68.6	73.1	78.1	81.9	83.1	83.4	82.1	77.5	70.7	66.2
MIA	MIAMI	FL	68.6	70.7	73.1	76.7	80.1	82.8	84.1	84.2	83.0	80.1	74.8	71.2
MCO	ORLANDO	FL	60.6	63.6	67.3	72.2	77.3	81.2	82.6	82.6	81.0	75.5	68.2	63.3
PNS	PENSACOLA	FL	53.2	56.8	62.3	68.3	76.0	81.7	83.5	83.0	80.0	71.3	61.4	55.5
TLH	TALLAHASSEE	FL	52.2	55.6	61.4	67.3	75.2	80.8	82.5	82.4	79.1	70.3	60.2	54.4
TPA	TAMPA	FL	61.2	64.0	67.5	72.3	77.2	81.0	82.2	82.4	81.2	75.9	68.5	63.9
VRB	VERO BEACH	FL	62.8	65.0	68.0	72.1	76.7	80.6	81.9	82.1	80.9	76.9	70.4	65.7
PBI	WEST PALM BEACH	FL	66.3	68.4	71.1	74.9	78.7	81.7	83.1	83.2	81.9	78.7	73.0	69.0
ABY	ALBANY	GA	50.5	54.0	60.3	67.0	75.3	80.9	83.1	82.7	78.1	68.9	58.7	52.7
AHN	ATHENS	GA	44.3	47.9	54.9	62.3	70.5	77.7	81.0	79.8	73.9	63.5	53.3	46.5
ATL	ATLANTA	GA	44.8	48.5	55.6	63.2	71.2	77.9	80.9	80.2	74.9	64.7	54.2	47.3
AGS	AUGUSTA	GA	47.4	50.8	57.5	64.6	72.7	79.7	82.8	81.8	76.4	66.0	55.6	49.4
BQK	BRUNSWICK	GA	53.0	56.1	61.7	68.0	75.6	81.0	83.6	82.8	79.1	71.3	62.0	55.7
CSG	COLUMBUS	GA	48.5	52.3	58.9	65.8	74.1	80.4	83.2	82.4	77.6	67.6	57.3	50.6
MCN	MACON	GA	47.6	51.2	57.7	64.5	72.9	79.5	82.5	81.4	76.2	66.0	55.8	49.5

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SAV	SAVANNAH	GA	50.7	54.0	60.0	66.7	74.1	80.1	83.0	82.1	77.7	68.8	59.1	53.2
AYS	WAYCROSS	GA	50.3	54.1	59.9	66.2	74.0	80.4	82.7	81.9	77.4	68.1	59.4	53.0
ITO	HILO-HAWAII	HI	71.4	71.2	71.9	72.5	74.0	75.2	76.3	76.6	76.5	75.7	74.0	72.2
HNL	HONOLULU-OAHU	HI	73.6	73.8	74.7	76.6	78.2	80.3	81.6	82.2	81.6	80.4	78.0	75.5
OGG	KAHULUI-MAUI	HI	72.9	73.0	74.0	75.5	77.1	79.3	80.5	81.1	80.6	79.4	77.1	74.6
LIH	LIHUE-KAUAI	HI	72.3	72.2	72.9	74.6	76.3	78.3	79.6	80.2	80.0	78.7	76.2	73.9
BOI	BOISE	ID	32.2	37.5	45.2	50.9	59.9	67.8	77.3	75.8	66.3	53.2	40.3	32.1
BYI	BURLEY	ID	29.2	33.3	41.4	47.1	55.8	63.4	71.5	69.9	60.8	49.1	37.6	29.2
IDA	IDAHO FALLS	ID	20.4	24.9	36.2	44.4	52.8	60.4	68.0	66.5	57.7	45.0	32.4	21.9
LWS	LEWISTON	ID	36.2	39.3	45.4	51.5	60.0	66.5	75.8	75.2	65.9	52.5	41.6	35.2
PIH	POCATELLO	ID	25.6	29.7	39.1	45.7	54.2	62.2	70.8	69.3	59.7	47.1	34.9	25.8
ORD	CHICAGO	IL	25.2	28.8	39.0	49.7	60.6	70.6	75.4	73.8	66.3	54.0	41.3	30.5
MLI	MOLINE	IL	23.3	27.7	39.7	51.4	62.5	72.1	75.5	73.4	66.1	53.7	40.4	28.9
PIA	PEORIA	IL	25.6	30.0	41.4	52.9	63.5	72.8	76.3	74.5	67.4	54.9	41.9	30.9
UIN	QUINCY	IL	26.6	31.2	42.1	53.3	63.6	72.8	76.3	74.5	67.0	55.1	42.3	31.6
RFD	ROCKFORD	IL	21.8	25.6	37.3	49.1	60.4	70.1	73.8	71.9	64.4	52.0	38.8	27.3
SPI	SPRINGFIELD	IL	27.9	32.4	43.2	54.4	65.1	73.7	76.5	74.9	68.0	56.0	43.5	32.9
EVV	EVANSVILLE	IN	33.6	37.6	46.6	57.2	66.9	75.5	78.7	77.3	70.3	58.6	46.3	37.5
FWA	FORT WAYNE	IN	25.5	28.7	38.6	50.2	61.3	70.7	73.8	71.6	64.8	53.2	41.1	30.9
IND	INDIANAPOLIS	IN	28.5	32.5	42.4	53.6	63.6	72.5	75.8	74.7	67.8	55.5	43.3	33.3
SBN	SOUTH BEND	IN	24.1	27.1	36.7	48.1	59.1	68.8	72.4	70.7	63.7	52.0	39.8	29.6
LAF	WEST LAFAYETTE	IN	25.8	29.7	40.0	51.1	61.6	70.7	73.6	72.2	65.5	53.7	41.3	31.0
BRL	BURLINGTON	IA	24.3	28.8	40.7	52.3	63.0	72.5	75.6	73.8	66.7	54.2	41.0	29.9
CID	CEDAR RAPIDS	IA	19.6	24.1	36.5	48.9	60.3	69.9	72.8	70.8	63.3	50.7	37.0	25.2
DSM	DES MOINES	IA	22.3	26.9	39.4	51.3	62.4	72.2	76.0	73.9	66.2	53.2	39.3	27.7
DBQ	DUBUQUE	IA	18.8	22.9	35.2	47.4	58.8	68.5	71.7	69.8	62.3	49.9	36.4	24.5
MCW	MASON CITY	IA	15.7	20.0	32.9	46.0	58.2	68.5	71.5	68.9	61.4	48.2	33.9	21.6
OTM	OTTUMWA	IA	22.9	27.4	39.6	51.1	62.0	71.6	75.1	73.0	65.3	52.9	39.6	28.4
SUX	SIOUX CITY	IA	20.0	24.5	36.7	48.9	60.5	70.7	74.2	71.7	63.9	50.3	35.9	24.1
SPW	SPENCER	IA	16.9	21.4	34.2	47.2	59.4	69.8	73.4	70.6	63.0	49.4	34.6	22.2
ALO	WATERLOO	IA	19.4	23.9	36.7	49.4	61.5	71.5	74.5	71.9	64.6	51.6	37.4	25.3
CNU	CHANUTE	KS	33.7	38.3	48.3	57.7	66.9	76.2	80.6	79.6	71.1	59.4	47.1	37.1
CNK	CONCORDIA	KS	28.8	32.8	43.5	53.1	63.5	74.4	78.9	76.4	68.5	55.6	42.1	31.5
DDC	DODGE CITY	KS	33.0	36.2	45.4	54.3	64.8	75.1	80.1	78.1	70.0	56.8	43.7	33.9
GCK	GARDEN CITY	KS	31.2	34.7	44.0	52.7	63.4	73.8	78.4	76.2	68.6	55.1	41.9	32.3
GLD	GOODLAND	KS	30.2	32.3	41.4	49.3	59.6	70.7	76.1	73.6	65.3	51.8	39.6	30.8
RSL	RUSSELL	KS	30.5	33.9	44.1	53.4	63.9	75.1	79.9	77.5	69.2	55.9	42.5	32.1
SLN	SALINA	KS	30.8	34.9	45.3	54.6	65.1	76.2	80.9	78.6	70.1	57.0	43.6	32.9
TOP	TOPEKA	KS	30.2	34.9	45.6	55.5	65.7	75.5	79.8	77.9	69.2	57.0	44.2	33.9
ICT	WICHITA	KS	33.2	37.6	47.4	56.5	66.7	76.9	81.5	79.9	71.7	59.0	45.8	35.6
BWG	BOWLING GREEN	KY	35.7	39.7	48.2	58.4	66.4	73.3	76.4	75.8	69.7	59.1	48.0	39.5
JKL	JACKSON	KY	35.8	39.7	47.8	58.2	65.6	72.6	75.7	74.9	69.1	58.7	48.1	39.7
LEX	LEXINGTON	KY	33.9	37.5	45.9	56.2	65.4	73.3	76.7	75.7	69.1	57.8	46.1	37.8
SDF	LOUISVILLE	KY	35.7	39.5	48.4	59.0	68.3	76.4	79.9	78.9	72.0	60.3	48.5	39.6
PAH	PADUCAH	KY	36.0	40.1	49.0	59.0	68.4	76.5	79.7	78.2	71.0	59.7	48.0	39.5
BTR	BATON ROUGE	LA	52.0	55.9	62.0	68.0	75.5	81.0	82.9	82.8	78.8	69.5	59.4	53.8
LFT	LAFAYETTE	LA	52.8	56.8	62.9	69.2	76.5	81.6	83.3	83.5	79.7	70.7	60.8	54.9
LCH	LAKE CHARLES	LA	53.2	56.9	63.1	69.1	76.4	82.1	83.9	84.0	80.1	71.3	61.4	55.3
MLU	MONROE	LA	46.8	50.7	58.1	65.5	73.8	80.3	82.8	82.5	77.1	66.3	55.6	48.8

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MSY	NEW ORLEANS	LA	54.3	58.0	63.8	70.1	77.1	82.4	83.9	84.0	80.8	72.5	62.4	56.6
SHV	SHREVEPORT	LA	47.9	51.8	59.0	65.9	74.0	80.9	83.9	84.0	78.3	67.4	56.6	49.5
AUG	AUGUSTA	ME	20.4	23.2	32.0	43.8	55.3	64.2	70.1	68.9	61.0	49.2	38.0	27.2
BGR	BANGOR	ME	18.5	21.0	30.6	42.8	54.5	63.6	69.5	68.2	59.9	48.2	37.3	25.9
CAR	CARIBOU	ME	11.7	14.2	25.0	38.5	52.2	61.4	66.7	64.9	56.6	44.5	32.6	19.9
HUL	HOULTON	ME	12.9	14.8	25.5	38.6	51.2	60.2	66.1	64.4	56.2	44.3	33.1	20.9
PWM	PORTLAND	ME	24.0	26.2	34.1	44.6	54.9	64.3	70.4	69.2	61.6	50.3	40.0	30.3
BWI	BALTIMORE	MD	34.3	36.6	44.3	55.0	64.4	73.5	78.3	76.2	69.2	57.4	46.9	38.6
SBY	SALISBURY	MD	36.8	38.7	45.3	55.1	63.8	72.7	77.9	75.8	69.7	58.5	48.2	40.6
BOS	BOSTON	MA	29.9	31.8	38.3	48.6	58.4	68.0	74.1	72.7	65.6	54.8	44.7	35.7
CHH	CHATHAM	MA	32.1	32.7	37.6	45.6	55.0	64.3	71.4	70.6	64.3	54.3	45.4	37.3
ORH	WORCESTER	MA	24.7	27.0	34.5	46.1	56.7	65.2	70.8	69.3	61.9	50.6	40.2	30.5
APN	ALPENA	MI	20.0	20.7	29.3	41.2	53.4	63.2	68.2	66.6	59.0	47.4	36.6	26.6
DTW	DETROIT	MI	25.8	28.0	37.2	48.9	60.3	69.9	74.1	72.3	64.9	53.0	41.2	31.3
FNT	FLINT	MI	23.0	24.7	34.2	46.0	57.4	67.1	70.9	69.1	61.7	50.2	38.8	28.7
GRR	GRAND RAPIDS	MI	24.8	26.6	35.7	47.6	59.2	68.9	72.8	71.1	63.5	51.5	40.0	30.4
CMX	HANCOCK	MI	16.1	17.0	25.2	37.2	50.2	59.7	65.0	64.2	56.4	44.0	32.0	21.9
HTL	HOUGHTON LAKE	MI	19.1	20.3	29.7	42.2	54.7	63.9	67.8	65.8	58.3	46.8	35.5	25.6
JXN	JACKSON	MI	24.4	26.6	36.0	47.8	58.8	68.0	71.6	69.9	62.6	51.2	39.9	29.9
LAN	LANSING	MI	23.9	25.9	35.2	47.0	58.4	68.0	71.8	70.0	62.5	50.8	39.5	29.5
SAW	MARQUETTE	MI	18.5	19.7	28.2	38.4	49.8	59.0	66.2	66.2	59.4	47.0	34.5	24.4
MKG	MUSKEGON	MI	26.6	27.7	35.7	46.8	57.9	67.4	71.9	70.8	63.5	51.9	41.0	31.9
MBS	SAGINAW	MI	23.0	24.5	34.0	45.9	58.2	68.1	71.7	69.7	62.5	50.8	39.0	28.9
ANJ	SAULT ST MARIE	MI	16.2	17.8	26.7	39.4	52.1	61.1	66.0	65.6	58.4	46.3	34.8	23.8
TVC	TRAVERSE CITY	MI	23.1	23.8	32.2	43.4	55.3	65.6	70.3	69.2	61.9	49.9	38.7	29.1
AXN	ALEXANDRIA	MN	10.7	14.9	28.0	42.5	55.9	66.0	70.6	68.5	60.0	45.7	30.3	16.9
DLH	DULUTH	MN	11.2	15.4	27.0	39.5	52.0	61.2	67.0	65.5	57.2	44.1	29.8	17.1
HIB	HIBBING	MN	6.2	10.5	23.8	37.1	49.5	58.9	63.5	61.6	53.0	40.2	25.6	12.3
INL	INT'L FALLS	MN	5.0	9.5	23.6	38.1	51.1	60.8	64.9	62.8	54.2	41.1	26.3	11.8
MSP	MINNEAPOLIS	MN	16.2	20.6	33.3	47.1	59.5	69.7	74.3	71.8	63.5	49.5	34.8	22.0
RST	ROCHESTER	MN	14.7	18.7	31.7	45.2	57.6	67.5	70.5	68.2	61.1	47.9	33.6	20.8
STC	SAINT CLOUD	MN	11.8	16.1	29.2	43.3	56.2	66.0	70.3	67.7	59.5	45.7	30.9	17.8
GWO	GREENWOOD	MS	44.4	48.3	56.1	64.0	72.3	79.0	81.5	81.1	75.6	64.9	53.8	47.1
JAN	JACKSON	MS	47.0	50.9	57.9	64.9	72.9	79.6	82.1	81.8	76.9	66.2	55.4	49.1
MCB	MCCOMB	MS	49.1	53.0	59.5	65.5	73.1	79.2	81.1	81.0	76.9	67.5	56.9	51.1
MEI	MERIDIAN	MS	47.7	51.7	58.5	65.4	73.3	80.0	82.7	82.2	77.3	66.6	55.8	49.9
TUP	TUPELO	MS	43.4	47.3	55.1	63.3	71.8	79.2	82.3	81.6	75.5	64.4	53.0	45.9
COU	COLUMBIA	MO	31.0	35.7	46.0	56.4	65.8	74.6	78.5	77.2	69.2	57.5	45.3	35.2
JLN	JOPLIN	MO	33.7	37.9	47.8	57.0	65.4	74.2	78.2	76.9	68.6	57.8	46.4	36.5
MCI	KANSAS CITY	MO	29.0	33.6	44.5	54.6	64.6	74.1	78.2	76.7	68.4	56.4	43.6	33.1
STL	SAINT LOUIS	MO	32.1	36.7	46.6	57.5	67.5	76.5	80.4	78.8	71.0	59.1	46.5	36.5
SGF	SPRINGFIELD	MO	34.3	38.7	47.6	57.0	66.0	74.9	79.2	78.2	70.3	58.6	46.7	37.4
BIL	BILLINGS	MT	27.0	29.4	38.0	45.8	55.3	64.7	73.3	71.6	61.4	47.9	36.2	27.6
BTM	BUTTE	MT	20.0	22.2	31.6	38.7	47.6	55.5	63.6	61.8	52.8	40.6	27.8	19.0
CTB	CUT BANK	MT	21.8	23.1	31.1	40.2	49.6	57.6	64.9	63.9	54.4	42.0	30.6	22.8
GGW	GLASGOW	MT	14.6	18.7	31.6	44.8	55.5	64.5	72.0	71.0	59.9	45.2	30.2	18.5
GTF	GREAT FALLS	MT	25.2	26.2	34.1	42.4	51.5	59.4	67.9	66.7	57.2	44.8	33.6	26.0
HVR	HAVRE	MT	17.7	21.3	32.0	44.0	53.9	62.1	69.8	68.4	57.7	44.1	30.9	21.1
HLN	HELENA	MT	23.0	27.2	36.1	44.5	53.9	61.7	70.6	68.8	58.9	45.5	32.8	23.4
FCA	KALISPELL	MT	23.7	26.8	34.5	42.7	51.6	57.6	64.9	63.7	54.3	41.6	31.4	24.1

Station Location			30-year Mean Temperature 1991-2020 NOAA											
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LWT	LEWISTOWN	MT	24.9	24.0	31.5	37.3	46.3	53.7	60.9	60.6	52.2	40.6	31.2	24.0
MLS	MILES CITY	MT	19.5	23.6	34.7	45.5	55.5	65.6	74.2	72.5	61.2	46.4	32.7	22.4
MSO	MISSOULA	MT	24.8	29.0	37.4	44.2	53.0	59.7	68.4	67.2	57.5	44.1	32.3	24.4
GRI	GRAND ISLAND	NE	25.9	29.7	40.7	51.0	62.0	72.8	77.0	74.6	66.6	53.1	39.6	28.9
LNK	LINCOLN	NE	25.0	29.5	41.2	52.0	63.1	73.7	78.1	75.6	67.2	53.8	39.8	28.8
OFK	NORFOLK	NE	22.3	26.3	37.8	48.9	60.1	70.4	74.8	72.4	64.4	50.8	36.8	25.7
LBF	NORTH PLATTE	NE	26.3	29.4	39.6	48.2	58.5	69.7	75.6	73.0	64.2	50.2	37.0	27.5
OMA	OMAHA	NE	24.4	28.9	41.0	52.6	63.6	73.9	78.1	75.7	67.6	54.4	40.2	28.7
BFF	SCOTTSBLUFF	NE	28.3	30.8	39.9	47.5	57.7	68.7	75.3	73.0	63.5	49.3	37.2	28.0
VTN	VALENTINE	NE	24.5	27.6	37.6	47.2	58.1	69.0	75.7	73.6	64.2	49.3	36.2	26.3
EKO	ELKO	NV	27.0	31.6	39.9	45.6	54.2	63.2	71.9	69.6	60.3	47.4	35.9	26.7
ELY	ELY	NV	26.7	30.0	37.7	43.2	51.5	61.3	69.3	67.5	58.4	46.4	35.1	26.2
LAS	LAS VEGAS	NV	49.5	53.5	60.8	67.7	77.3	87.6	93.2	91.7	83.6	70.4	57.2	48.2
LOL	LOVELOCK	NV	31.2	36.6	43.3	49.3	58.9	67.8	75.9	72.9	63.6	50.8	38.2	30.2
RNO	RENO	NV	36.9	40.6	46.6	51.6	60.3	69.2	77.2	75.1	67.0	55.1	43.8	36.2
TPH	TONOPAH	NV	33.9	37.2	43.8	49.9	59.0	69.1	75.7	73.7	65.7	53.5	41.0	32.5
WMC	WINNEMUCCA	NV	32.2	36.6	42.6	47.6	56.4	65.4	74.5	71.6	62.1	49.4	38.6	30.7
CON	CONCORD	NH	22.3	24.7	33.4	45.4	56.7	65.8	71.1	69.5	61.4	49.3	38.6	28.3
LEB	LEBANON	NH	19.8	22.4	31.9	44.3	56.7	65.1	70.3	68.6	60.7	48.6	37.2	26.8
MWN	MT WASHINGTON	NH	5.8	5.9	12.9	23.7	36.3	45.5	49.9	48.7	43.1	31.3	20.8	11.8
ACY	ATLANTIC CITY	NJ	34.1	36.0	42.6	52.5	61.9	71.4	76.9	75.0	68.4	57.1	46.8	38.7
EWR	NEWARK	NJ	32.8	35.1	42.5	53.3	63.3	72.7	78.2	76.4	69.2	57.5	47.0	38.0
ABQ	ALBUQUERQUE	NM	37.4	41.9	49.5	56.8	66.1	76.1	78.9	76.9	70.3	58.4	45.7	36.9
CNM	CARLSBAD	NM	43.9	48.4	55.6	63.7	72.6	81.0	82.3	81.0	73.9	63.3	51.4	43.5
CAO	CLAYTON	NM	35.5	37.5	44.9	52.0	61.5	71.2	75.4	73.1	66.4	54.7	43.7	35.3
GUP	GALLUP	NM	29.8	34.4	40.6	47.0	55.6	65.7	71.7	69.7	62.2	49.7	38.0	29.5
ROW	ROSWELL	NM	42.7	47.8	55.2	63.2	72.3	81.0	83.2	81.6	74.4	63.2	51.0	42.4
CVN	TUCUMCARI	NM	38.6	42.5	50.0	57.7	67.1	77.2	80.6	78.6	71.4	59.2	47.3	38.6
ALB	ALBANY	NY	24.4	26.8	35.7	48.1	59.6	68.4	73.1	71.4	63.5	51.4	40.5	30.4
BGM	BINGHAMTON	NY	22.5	24.5	32.3	44.6	56.2	64.4	68.9	67.3	60.0	48.8	37.9	28.1
BUF	BUFFALO	NY	25.5	26.4	34.1	45.6	57.9	66.9	71.7	70.4	63.4	51.7	41.0	31.4
GFL	GLENS FALLS	NY	19.7	21.9	31.7	44.6	56.5	65.0	69.7	67.8	59.7	48.0	37.2	26.6
MSS	MASSENA	NY	15.6	17.8	28.5	42.9	55.9	64.8	69.5	67.5	59.5	47.5	35.8	23.8
LGA	NEW YORK	NY	34.4	36.3	43.1	53.6	63.7	73.4	79.2	77.7	70.8	59.6	49.1	40.0
ROC	ROCHESTER	NY	26.2	27.4	35.2	46.8	58.8	67.6	72.3	70.7	63.6	52.2	41.5	32.0
SYR	SYRACUSE	NY	24.1	25.5	33.8	46.3	58.2	67.0	71.8	70.4	62.9	51.3	40.5	30.4
UCA	UTICA	NY	21.7	23.6	31.8	44.6	56.8	65.5	70.0	68.4	61.3	50.0	38.5	28.2
ART	WATERTOWN	NY	19.9	21.1	30.4	43.1	55.0	63.8	69.0	67.5	60.0	48.8	38.0	27.3
AVL	ASHEVILLE	NC	38.7	42.1	48.4	57.0	64.8	71.8	75.1	74.0	68.3	57.9	47.8	41.4
HAT	CAPE HATTERAS	NC	48.0	49.1	53.8	61.8	69.7	77.5	81.3	80.7	76.9	68.2	58.7	52.1
CLT	CHARLOTTE	NC	42.1	45.7	52.7	61.1	69.0	76.6	80.1	78.6	72.7	61.9	51.4	44.7
GSO	GREENSBORO	NC	46.4	50.1	56.5	63.3	71.0	77.8	80.6	80.2	75.3	65.2	54.4	48.1
HKY	HICKORY	NC	39.7	43.0	50.1	58.8	66.8	74.3	77.7	76.4	70.4	59.6	49.3	42.2
EWN	NEW BERN	NC	44.5	47.1	53.2	61.8	69.5	77.0	80.4	78.9	74.2	64.2	54.2	47.7
RDU	RALEIGH DURHAM	NC	41.9	45.0	51.8	60.8	68.8	76.7	80.5	78.8	72.6	61.7	51.5	44.6
ILM	WILMINGTON	NC	46.8	49.3	55.3	63.6	71.1	78.2	81.5	80.0	75.3	65.9	56.1	49.7
BIS	BISMARCK	ND	12.8	17.5	30.1	43.2	55.3	65.4	71.3	69.6	59.7	44.8	29.9	17.9
P11	DEVIL'S LAKE	ND	7.2	11.2	24.1	41.1	54.6	64.6	69.4	68.0	58.8	43.6	26.5	13.3
DIK	DICKINSON	ND	14.6	18.6	29.1	41.2	52.7	62.4	69.1	67.9	57.5	42.9	29.6	18.4

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FAR	FARGO	ND	9.2	13.4	27.2	43.0	56.6	66.8	70.7	68.8	60.0	45.5	29.5	15.7
GFK	GRAND FORKS	ND	6.3	10.6	24.4	40.7	54.1	64.6	68.9	67.0	57.9	43.2	26.7	12.8
JMS	JAMESTOWN	ND	9.4	13.0	26.3	39.9	52.7	62.8	68.6	67.1	57.7	42.7	27.8	15.1
MOT	MINOT	ND	13.8	17.3	29.2	43.5	56.1	65.6	71.2	70.1	60.1	45.6	30.2	18.3
ISN	WILLISTON	ND	11.6	16.1	28.8	42.4	53.8	63.5	70.4	69.0	58.0	43.2	27.8	16.1
CAK	AKRON CANTON	OH	27.9	30.2	38.9	50.8	61.3	69.9	73.9	72.3	65.4	53.7	42.5	33.0
CLE	CLEVELAND	OH	29.6	32.5	41.6	53.2	63.3	71.9	75.4	74.0	67.2	55.2	43.6	34.5
CMH	COLUMBUS	OH	29.6	32.5	41.6	53.2	63.3	71.9	75.4	74.0	67.2	55.2	43.6	34.5
CVG	CINCINNATI	OH	29.1	32.2	41.2	52.7	62.5	70.9	73.6	72.0	65.6	54.5	42.9	34.0
DAY	DAYTON	OH	29.4	32.8	42.1	53.7	64.0	72.7	76.0	74.5	67.7	56.0	44.1	34.3
FDY	FINDLAY	OH	27.8	30.5	39.7	51.4	62.5	71.7	74.9	72.9	66.4	54.8	42.9	33.0
MFD	MANSFIELD	OH	26.5	29.1	37.8	49.7	60.3	69.0	72.6	71.0	64.4	53.0	41.5	31.8
TOL	TOLEDO	OH	27.5	29.9	39.2	50.9	62.1	71.6	75.4	73.5	66.4	54.6	42.8	32.8
YNG	YOUNGSTOWN	OH	26.8	29.0	37.2	49.1	59.3	67.5	71.5	69.9	63.2	52.2	41.5	32.1
LHQ	ZANESVILLE	OH	30.1	32.9	41.6	52.8	62.3	70.5	74.2	72.7	65.9	54.3	43.4	34.7
GAG	GAGE	OK	36.6	40.0	49.7	58.3	68.0	77.5	82.0	80.6	72.4	59.8	47.2	37.4
HBR	HOBART	OK	39.4	43.4	51.9	60.1	70.4	80.2	84.7	83.4	75.1	62.9	50.2	40.9
MLC	MCALESTER	OK	41.1	45.5	53.9	61.7	69.9	78.2	82.6	81.9	74.3	63.3	52.1	43.3
OKC	OKLAHOMA CITY	OK	38.2	42.3	51.2	59.3	68.2	76.9	81.7	80.7	72.7	61.1	49.2	40.0
PNC	PONCA CITY	OK	35.9	40.1	49.5	58.5	68.1	77.6	82.4	80.9	72.7	60.5	48.1	38.1
TUL	TULSA	OK	38.5	42.8	52.0	60.8	69.6	78.6	83.4	82.2	73.8	62.3	50.4	41.0
AST	ASTORIA	OR	43.7	44.2	46.0	48.7	53.4	57.3	60.6	61.3	59.0	52.8	46.9	43.2
BKE	BAKER	OR	28.8	33.5	40.8	45.9	54.2	60.6	68.5	67.7	59.1	47.1	36.2	28.6
BNO	BURNS	OR	26.5	31.0	38.7	43.9	52.8	59.7	68.6	66.5	57.8	45.6	34.7	25.9
EUG	EUGENE	OR	41.4	43.3	46.9	50.7	56.1	60.9	67.8	67.9	62.9	53.4	45.5	40.6
MFR	MEDFORD	OR	40.4	44.1	48.3	52.8	60.4	66.9	75.1	74.5	67.7	56.1	45.2	39.4
OTH	NORTH BEND	OR	47.3	47.6	48.5	50.4	54.2	57.4	59.8	60.4	59.0	54.9	50.2	46.7
PDT	PENDLETON	OR	34.9	38.0	44.4	50.1	57.9	64.6	73.0	71.8	63.5	51.5	40.7	34.2
PDX	PORTLAND	OR	41.9	44.1	48.3	52.8	59.4	64.2	70.2	70.6	65.4	55.6	47.1	41.6
RDM	REDMOND	OR	34.8	36.6	41.3	45.5	53.4	60.0	68.0	66.8	59.6	48.6	39.1	32.8
SLE	SALEM	OR	42.1	44.0	47.5	51.3	57.7	62.7	69.3	69.2	64.0	54.3	46.3	41.3
ABE	ALLENTOWN	PA	30.1	32.4	40.7	51.8	62.0	70.9	75.6	73.6	66.3	54.6	43.9	35.0
AOO	ALTOONA	PA	28.4	30.7	38.7	50.4	60.3	68.5	72.4	70.6	63.7	53.0	42.3	33.1
BFD	BRADFORD	PA	23.1	24.9	33.0	44.9	55.4	63.2	66.9	65.5	58.9	48.3	37.8	28.5
DUJ	DU BOIS	PA	24.5	26.8	35.2	47.2	57.4	65.1	69.1	67.7	61.0	50.1	39.2	29.8
ERI	ERIE	PA	28.2	28.9	36.1	47.4	58.8	68.2	72.7	71.5	65.2	54.3	43.6	34.1
CXY	HARRISBURG	PA	32.6	34.7	43.2	54.1	64.0	73.0	77.5	75.4	68.5	56.7	46.0	37.0
PHL	PHILADELPHIA	PA	33.7	35.9	43.6	54.5	64.3	73.5	78.7	76.8	69.9	58.2	47.4	38.6
PIT	PITTSBURGH	PA	28.8	31.4	39.7	51.5	61.2	69.4	73.2	71.8	64.9	53.4	42.6	33.7
AVP	SCRANTON	PA	28.0	30.3	38.3	50.2	60.9	69.0	73.7	71.8	64.6	53.2	42.7	33.3
IPT	WILLIAMSPORT	PA	27.7	30.1	38.7	50.3	60.8	69.4	73.7	72.0	64.7	53.0	41.9	32.8
PVD	PROVIDENCE	RI	30.2	32.0	38.9	49.3	59.1	68.2	74.4	73.0	65.6	54.4	44.5	35.5
CHS	CHARLESTON	SC	49.5	52.7	58.7	65.8	73.3	79.4	82.5	81.4	76.9	67.8	58.3	52.2
CAE	COLUMBIA	SC	45.7	49.1	55.9	64.1	72.2	79.1	82.4	81.0	75.5	64.6	54.0	47.7
FLO	FLORENCE	SC	46.6	49.7	56.3	64.4	72.2	79.1	82.2	80.9	75.6	65.5	55.3	48.9
GSP	GREENVILLE	SC	44.1	47.7	54.7	63.3	71.3	78.1	81.3	80.1	74.4	63.7	53.7	46.6
ABR	ABERDEEN	SD	12.8	17.5	30.5	44.5	57.3	67.6	72.3	69.7	60.9	46.3	30.9	18.3
HON	HURON	SD	16.0	20.5	32.9	45.7	57.9	68.3	73.7	71.3	62.6	47.9	33.1	20.6
PIR	PIERRE	SD	19.1	23.2	34.3	45.9	57.2	67.8	74.9	73.0	63.6	48.5	34.1	22.8
RAP	RAPID CITY	SD	24.3	26.1	35.4	43.9	54.1	64.6	72.4	70.8	61.3	47.1	34.6	25.6
FSD	SIOUX FALLS	SD	17.9	22.3	34.7	47.2	59.1	69.9	74.4	72.0	63.8	49.6	34.8	22.5

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ATY	WATERTOWN	SD	12.2	16.3	29.1	42.8	55.7	66.1	71.0	68.5	60.1	45.7	30.6	17.8
TRI	BRISTOL	TN	36.4	40.0	47.4	56.4	64.7	72.3	75.6	74.5	68.6	57.3	46.4	39.3
CHA	CHATTANOOGA	TN	41.7	45.6	53.2	61.7	70.0	77.4	80.7	80.0	73.9	62.7	51.2	44.3
CSV	CROSSVILLE	TN	35.3	38.8	46.0	55.4	63.2	70.2	73.8	72.9	67.0	56.4	46.0	38.8
MKL	JACKSON	TN	39.0	42.7	50.9	60.3	68.9	76.4	79.5	78.3	71.7	60.7	49.3	41.8
TYS	KNOXVILLE	TN	39.1	42.9	50.6	59.6	67.9	75.3	78.5	77.6	71.8	60.3	49.0	41.9
MEM	MEMPHIS	TN	42.1	46.1	54.2	63.2	72.1	79.9	82.8	82.1	76.0	64.6	52.7	44.8
BNA	NASHVILLE	TN	39.6	43.4	51.5	60.8	69.3	77.1	80.7	79.7	73.1	61.7	50.3	42.7
ABI	ABILENE	TX	46.3	50.1	58.1	66.0	74.1	81.1	84.7	84.2	76.8	67.0	55.5	47.3
ALI	ALICE	TX	57.0	61.3	67.3	73.5	79.4	84.0	85.4	86.0	81.5	74.3	65.3	58.8
AMA	AMARILLO	TX	38.6	41.8	49.8	57.5	66.8	76.1	79.6	78.1	70.9	59.2	47.4	38.8
AUS	AUSTIN	TX	50.1	54.2	61.0	68.1	76.0	82.2	84.5	84.8	79.1	69.9	59.3	51.8
BRO	BROWNSVILLE	TX	62.8	66.5	71.3	76.7	82.0	85.6	86.4	87.0	83.4	77.9	70.5	64.4
CLL	COLLEGE STATION	TX	51.5	55.3	62.1	68.7	76.4	82.6	85.1	85.7	80.6	71.1	60.4	53.1
CRP	CORPUS CHRISTI	TX	58.0	61.9	67.4	73.4	79.0	83.2	84.6	85.4	81.9	75.1	66.2	59.7
DHT	DALHART	TX	36.3	39.5	47.2	55.0	64.9	74.9	78.7	76.9	69.5	57.1	45.1	36.1
DFW	DALLAS FT WORTH	TX	46.3	50.5	58.2	65.6	74.0	81.9	85.7	85.7	78.5	67.7	56.4	48.1
DRT	DEL RIO	TX	53.1	58.2	65.6	72.7	79.7	85.2	87.2	87.4	81.4	72.5	61.1	53.5
ELP	EL PASO	TX	46.5	51.5	58.7	66.6	75.4	83.9	84.4	82.9	76.9	66.7	54.5	46.1
GLS	GALVESTON	TX	56.0	59.3	65.2	71.5	78.2	83.8	85.5	85.9	82.4	75.3	65.5	58.5
IAH	HOUSTON	TX	53.8	57.7	63.8	70.0	77.4	83.0	85.1	85.2	80.5	71.8	62.0	55.4
LRD	LAREDO	TX	57.5	62.5	69.2	76.1	82.1	87.0	88.1	88.9	83.0	76.3	66.3	58.6
LBB	LUBBOCK	TX	41.1	45.1	53.0	61.2	70.4	78.6	81.2	79.9	72.3	61.8	50.0	41.7
LFK	LUFKIN	TX	48.6	52.8	59.4	66.0	73.8	79.9	82.5	82.4	77.3	67.4	57.0	50.2
MFE	MCALLEN	TX	62.8	67.2	72.9	78.4	83.6	87.7	88.6	89.3	85.0	79.0	70.2	64.0
MAF	MIDLAND ODESSA	TX	45.7	50.2	58.0	66.2	75.4	82.6	84.4	83.2	76.2	66.5	54.3	46.4
PSX	PALACIOS	TX	55.6	59.3	65.0	71.4	78.1	83.6	85.4	85.6	81.5	73.9	64.6	58.0
CXO	PORT ARTHUR	TX	53.7	57.5	63.3	69.3	76.5	82.0	83.6	83.8	80.0	71.6	61.9	55.6
SJT	SAN ANGELO	TX	47.4	51.5	59.4	67.1	75.5	82.2	84.8	84.1	77.0	67.1	55.9	48.4
SAT	SAN ANTONIO	TX	52.2	56.3	62.8	69.4	76.5	82.6	84.8	85.5	79.9	71.3	60.7	53.5
VCT	VICTORIA	TX	54.4	58.4	64.4	70.4	77.3	82.7	84.5	84.8	80.4	72.6	62.8	56.2
ACT	WACO	TX	47.4	51.6	58.8	66.2	74.3	81.9	85.6	85.5	78.7	68.4	57.2	49.2
SPS	WICHITA FALLS	TX	42.4	46.3	54.7	62.8	71.8	80.1	84.7	84.1	76.0	64.6	52.7	43.7
CDC	CEDAR CITY	UT	30.4	34.3	41.5	47.2	56.4	66.6	74.0	72.1	63.1	50.5	38.5	29.2
SLC	SALT LAKE CITY	UT	31.4	36.6	45.8	51.8	61.5	71.6	81.1	79.1	68.4	54.6	41.7	32.2
BTV	BURLINGTON	VT	20.9	22.9	32.3	45.6	58.4	67.5	72.4	70.7	62.7	50.3	39.3	28.2
MPV	MONTPELIER	VT	16.6	18.9	27.9	40.9	53.3	61.8	66.5	64.9	57.4	45.5	34.4	23.2
LYH	LYNCHBURG	VA	35.9	38.8	46.4	56.1	64.2	72.0	76.0	74.5	68.0	57.0	46.5	38.9
ORF	NORFOLK	VA	42.2	44.2	50.7	60.1	68.3	76.7	81.1	79.2	74.0	63.7	53.3	46.1
RIC	RICHMOND	VA	38.3	41.0	48.4	58.4	66.7	75.0	79.4	77.5	71.2	60.0	49.6	41.8
ROA	ROANOKE	VA	37.9	40.8	48.3	58.0	66.1	73.8	77.8	76.2	69.6	58.9	48.4	40.9
BLI	BELLINGHAM	WA	40.2	41.7	45.1	49.6	55.5	59.8	63.9	63.9	58.9	51.1	44.5	39.8
HQM	HOQUIAM	WA	42.8	43.6	45.8	48.7	53.4	57.1	60.3	61.0	59.1	52.5	45.9	42.0
OLM	OLYMPIA	WA	39.6	40.7	44.1	48.2	54.5	59.1	64.2	64.2	59.1	50.3	43.2	38.9
UIL	QUILLAYUTE	WA	41.7	42.1	43.9	46.9	51.7	55.5	59.3	60.0	57.1	50.6	44.7	41.0
SEA	SEATTLE TACOMA	WA	42.8	44.0	47.1	51.3	57.5	62.0	67.1	67.4	62.6	53.8	46.5	42.0
GEG	SPOKANE	WA	29.6	32.9	40.0	47.0	56.0	62.3	71.0	70.3	61.1	47.9	36.3	29.1

Station Location			30-year Mean Temperature 1991-2020 NOAA											
Code	**City**	**State**	**JAN**	**FEB**	**MAR**	**APR**	**MAY**	**JUN**	**JUL**	**AUG**	**SEP**	**OCT**	**NOV**	**DEC**
ALW	WALLA WALLA	WA	36.3	39.7	46.8	52.5	60.4	67.0	76.3	75.2	66.2	53.7	42.4	35.6
EAT	WENATCHEE	WA	28.9	34.5	43.1	51.1	60.1	66.5	74.7	73.7	64.6	50.7	37.4	29.0
YKM	YAKIMA	WA	31.7	36.6	43.4	49.9	58.8	65.1	72.4	70.9	62.2	49.8	38.0	30.6
BKW	BECKLEY	WV	32.2	35.4	42.8	53.5	61.3	68.2	71.6	70.5	64.7	54.3	44.0	36.0
CRW	CHARLESTON	WV	35.0	38.2	46.0	56.9	64.7	72.3	75.8	74.6	68.3	57.0	46.4	38.7
EKN	ELKINS	WV	30.8	33.5	41.0	51.5	60.2	67.8	71.4	70.2	64.1	52.7	42.3	34.7
HTS	HUNTINGTON	WV	34.8	38.2	46.4	57.2	65.2	72.9	76.4	75.2	68.7	57.4	46.6	38.6
MRB	MARTINSBURG	WV	32.4	35.0	42.8	53.6	62.5	71.1	75.7	73.8	66.7	55.2	44.6	36.0
MGW	MORGANTOWN	WV	32.0	34.8	42.6	53.8	62.6	70.3	74.1	72.8	66.5	55.3	44.9	36.4
PKB	PARKERSBURG	WV	32.0	35.0	43.6	54.6	63.3	71.0	74.7	73.5	66.9	55.4	44.7	36.3
EAU	EAU CLAIRE	WI	14.6	18.8	31.2	44.8	57.4	67.1	71.3	69.1	60.8	47.5	33.4	20.6
GRB	GREEN BAY	WI	18.3	21.1	32.1	44.3	56.5	66.4	70.5	68.6	61.0	48.7	36.2	24.5
LSE	LACROSSE	WI	18.9	23.3	35.8	49.0	61.0	71.0	75.0	72.8	64.8	51.7	37.6	25.1
MSN	MADISON	WI	19.4	23.0	34.4	46.3	58.1	68.0	71.9	69.7	62.0	49.7	36.7	25.3
MKE	MILWAUKEE	WI	24.0	27.1	36.4	46.3	57.1	67.6	73.3	72.3	65.0	53.0	40.4	29.5
AUW	WAUSAU	WI	14.8	18.5	30.1	43.1	55.8	65.4	69.5	67.4	59.2	46.3	32.8	20.7
CPR	CASPER	WY	25.1	26.6	35.8	42.3	52.0	62.5	71.0	69.0	58.9	45.3	34.0	24.8
CYS	CHEYENNE	WY	29.2	29.5	37.1	42.8	52.3	63.1	70.1	68.1	59.6	46.5	36.1	28.7
COD	CODY	WY	27.5	28.6	37.7	44.2	53.1	62.4	70.6	68.9	59.7	46.9	35.2	27.3
LND	LANDER	WY	21.3	25.0	36.0	43.2	52.8	62.8	71.5	69.8	59.6	45.4	32.1	21.6
RKS	ROCK SPRINGS	WY	21.5	24.3	34.0	41.2	50.8	61.0	69.4	67.3	57.3	44.5	31.2	21.4
SHR	SHERIDAN	WY	24.0	26.0	35.7	43.2	52.4	61.8	70.7	69.1	59.1	45.4	33.3	24.5
WRL	WORLAND	WY	17.2	23.3	36.8	45.9	56.2	66.2	73.9	71.2	60.2	46.4	31.3	19.4

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1. U.S. Department of Energy–Energy Information Administration. *2020 Residential Energy Consumption Survey (RECS)*. 2020. (Last accessed April 1, 2024.) https://www.eia.gov/consumption/residential/data/2020/.

2. U.S. Department of Energy–Energy Information Administration. *2018 Commercial Buildings Energy Consumption Survey (CBECS)*. 2018. (Last accessed April 1, 2024.) https://www.eia.gov/consumption/commercial/data/2018/.

3. National Oceanic and Atmospheric Administration. *Degree Days Archives - Weekly/Monthly Heating/Cooling Degree Days by City/State*. Weekly/Monthly Heating/Cooling Degree Days by City/State. (Last accessed December 1, 2023.) https://ftp.cpc.ncep.noaa.gov/htdocs/products/analysis_monitoring/cdus/degree_days/archives/.

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APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET MODEL

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APPENDIX 8A. USER INSTRUCTIONS FOR THE LIFE-CYCLE COST ANALYSIS SPREADSHEET MODEL

8A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel spreadsheets available on the U.S. Department of Energy's (DOE's) consumer water heater rulemaking website: https://www.energy.gov/eere/buildings/consumer-water-heaters. From that page, follow the links to the final rule and then to Analytical Tools.

8A.2 STARTUP

DOE's spreadsheets enable users to perform life-cycle cost (LCC) and payback period (PBP) analyses for each product class. Two spreadsheets exist for gas-fired instantaneous water heaters: a spreadsheet labeled LCC and another labeled "LCC Results". The LCC Results spreadsheet summarizes the LCC results as well as provides the LCC outputs for the NIA spreadsheet.

The main LCC spreadsheet can be downloaded and run independently. To change the input of the main LCC, the user will need to manually make edits in the main LCC spreadsheet. To populate the results in the LCC Results spreadsheet, the user will need to manually copy/paste the updated extracted forecast cells from the main LCC spreadsheet into the LCC Results spreadsheet.

To examine the spreadsheets, DOE assumed that the user has access to a personal computer with hardware capable of running Windows XP or later. All spreadsheets require Microsoft Excel 2003 or later installed under the Windows operating system. Crystal Ball[a] (a commercially available Excel add-on program) is also needed to regenerate the LCC results and to view the statistical distributions that are used to define certain variables inside the spreadsheets.

8A.3 DESCRIPTION OF LIFE-CYCLE COST WORKSHEET

8A.3.1 LCC Worksheet

For gas-fired instantaneous water heaters, DOE created a single LCC spreadsheet containing a collection of worksheets. Each worksheet represents a conceptual component within the LCC calculation. To facilitate navigability and identify how worksheets are related, each worksheet contains an area on the extreme left showing variables imported to and exported from the current worksheet. The LCC spreadsheet contains the following worksheets:

[a] See www.oracle.com/applications/crystalball/

Introduction	The *Introduction* worksheet contains an overview of each worksheet and a flow chart of the inputs and outputs of the spreadsheet.
Statistics	The *Statistics* worksheet contains the statistics of key parameters from the outcome of the Monte Carlo simulations for the sample of households or buildings.
Summary	The *Summary* worksheet contains a user interface to manipulate energy price trend and product price trend, and to run the Crystal Ball simulation. LCC and PBP simulation results for each efficiency level are also displayed here.
LCC&PB Calcs	The *LCC&PB Calcs* worksheet shows LCC calculation results for different efficiency levels for a single Energy Information Administration's (EIA's) *2020 Residential Energy Consumption Survey* (RECS 2020)[1] household and EIA's *2018 Commercial Building Energy Consumption Survey* (CBECS 2018)[2] building. During a Crystal Ball simulation, the spreadsheet records the LCC and PBP values for every sampled household or building.
Rebuttable PBP	The *Rebuttable Payback* worksheet contains the total and incremental manufacturer costs, retail prices, installation costs, repair and maintenance costs, energy use calculations, and the simple PBP calculations for each efficiency level. DOE's gas-fired instantaneous water heater test procedure is used to calculate parameters used in energy use calculations.
Prod Price	The *Prod Price* worksheet calculates retail price values used as inputs in the LCC calculations in the *Summary* worksheet.
Markups	The *Markups* worksheet calculates markup values used as inputs in the *Prod Price* worksheet. DOE applied baseline and incremental markups to calculate final retail prices. DOE calculated the markups differently for replacement units and new units.
Price Trend	The *Price Trend* worksheet calculates projected product price trend scenarios used to adjust the manufacturer's cost over the entire analysis period as inputs in the *Prod Price* worksheet.
Installation Cost	The *Installation Cost* worksheet provides the estimated installation cost for each design option for the sampled household or building. These results are used to calculate the total installed prices of the design options.
Installation Cost Data	The *Installation Cost Data* worksheet provides the data inputs to the installation cost calculations.
Maint & Repair Cost	The *Maint & Repair Cost* worksheet provides the maintenance and repair costs for each design option for the sampled household and building. These results are used to determine operating costs for the design options.
Labor Costs	The *Labor Cost* worksheet provides the labor cost by region as used to determine the installation and repair/maintenance costs.

Bldg Sample	The *Bldg Sample* worksheet contains the RECS 2020 and CBECS 2018 data and statistics about the sampled household and building. During a Crystal Ball simulation, DOE uses these characteristics to determine the analysis parameters.
No-New Standards Case UEF	The *No-New Standards Case UEF* worksheet includes the gas-fired instantaneous water heater efficiency distribution for 2030.
Energy Use	The *Energy Use* worksheet calculates annual energy use by ELs. The annual energy use calculations for each design option are inputs to the *LCC&PB Calcs* worksheet to calculate the annual operating cost of the LCC.
Energy Price (Base Year)	The *Energy Price (Base Year)* worksheet shows the estimated monthly natural gas/LPG and electricity prices.
Energy Price Trends	The *Energy Price Trends* worksheet shows the future price trends of the different heating fuels and electricity. DOE used energy price data and forecasts from the Energy Information Administration's (EIA's) Annual Energy Outlook 2023 and extrapolated beyond 2050.[3]
Discount Rate	The *Discount Rate* worksheet contains the distributions of discount rates for residential and commercial applications.
Lifetime	The *Lifetime* worksheet contains the distribution of lifetimes for gas-fired instantaneous water heaters.
Temperatures	The *Temperatures* worksheet contains the estimated monthly air temperature and water temperature data used in the energy use analysis.
Weather Data	The *Weather Data* worksheet contains weather data for each weather station mapped to a household or building.
Labels	The *Labels* worksheet contains labels used in graphical user interface.
Forecast Cells	The *Forecast Cells* worksheet contains the outcome of the Monte Carlo simulations for the sample of 10,000 households and commercial buildings for many parameters used in the analysis and the documentation.

8A.3.2 LCC Results Spreadsheet

The *LCC Results* spreadsheet contains all the LCC results, as well as intermediate inputs used for DOE's National Impact Analysis. These inputs include fuel and electricity use, total installed price, and operating cost for each product class and efficiency level. The inputs are presented for replacement and new construction housing markets, as well as residential and commercial applications.

8A.4 BASIC INSTRUCTIONS FOR OPERATING THE LCC SPREADSHEETS

Basic instructions for operating the LCC spreadsheet are as follows:

1. Once the LCC spreadsheet has been downloaded, open the file using Excel. Click "Enable Macro" when prompted and then click on the tab for the *Summary* worksheet.
2. Use Excel's View/Zoom commands at the top menu bar to change the size of the display to fit your monitor.
3. The Analysis User Variables listed on the *Summary* worksheet are:
    a. Start Year: Default is "2030." Changing the start year does not update the inputs, and thus only gives an approximation of the results for a different start year. To change the value, type in the desired year.
    b. # of Trials: Default is "10,000." To change the value, type in the desired number of trials for Crystal Ball to run. Decreasing the number of runs will increase the speed of the simulation but decrease the representativeness of the results.
4. The user can change the parameters listed under Scenarios in the *Summary* worksheet. There are two drop-down boxes and one command button. The default parameters are:
    a. Energy Price Trend: set to "AEO 2023 - Reference Case." To change the input, use the drop-down menu and select the desired trend (Reference, Low, or High).
    b. Product Price Trend: set to "No Learning (Constant)." To change the value, use the drop-down menu and select the desired product price trend ("No Learning (Constant)", "Decreasing", or "Increasing").

5. To run the Crystal Ball simulation, click the "Run" button (you must re-run after changing any parameters). The spreadsheet will then be minimized. You can monitor the progress of the simulation by watching the count of iterations at the left bottom corner. When the simulation is finished, the worksheet named *Summary* will reappear with the results.

To populate the LCC Results spreadsheet, click on "Crystal Ball" menu and then on "Extract Forecast Cells". Select in the "Data" tab: 1) Select data to extract: "Trial values"; 2) Forecast cells: "Choose…"; and 3) Assumptions: "None". Then click ok, which will generate a new spreadsheet with the forecast cells. Proceed to copy and paste the forecast cells into the "Data" worksheet of the LCC Results spreadsheet.

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

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APPENDIX 8B. UNCERTAINTY AND VARIABILITY IN THE LIFE-CYCLE COST AND PAYBACK PERIOD ANALYSIS

8B.1 INTRODUCTION

This appendix discusses uncertainty and variability and describes how the U.S. Department of Energy (DOE) incorporated these into the life-cycle cost (LCC) and payback period (PBP) analysis in this technical support document (TSD) for the consumer gas-fired instantaneous water heater energy conservation standards (ECS) rulemaking. The two key approaches are (1) to use distributions to capture uncertainties and variations in input variables when such distributions are reasonably well defined, and (2) to use scenarios that capture the bounds of uncertainty when the bounds are less well defined.

8B.2 UNCERTAINTY AND VARIABILITY

DOE develops mathematical models to analyze the impacts of proposed energy conservation standards. The models generate outputs (e.g., the LCC impact of proposed standards) based on inputs that are often uncertain, variable, or both.

Variability means that the quantity of interest takes on different values at different times or under different conditions. Variability may be caused by many factors. For example, the hot water use depends on environmental factors (e.g., inlet water temperature) and behavioral factors (e.g., the schedules and preferences of the inhabitants of a house). Manufacturing irregularities can also cause variability. For example, 10 water heaters of the same model may each have slightly different power consumptions. DOE attempts to account for major sources of variability in its analyses.

Uncertainty has many sources. Variability may lead to uncertainty in model inputs, because analysts frequently must estimate the values of interest based on samples of a variable quantity (for example, the hot water use in a home). Measurement uncertainty is another source of uncertainty, which may result from instrumental uncertainties (resulting, for example, from drift, bias, and precision of resolution) and human factors (e.g., variations in experimental setup, errors in instrument readings or recordings). Uncertainty can also arise when there is limited data available to estimate a particular parameter. DOE attempts to address the major sources of uncertainties in its analyses.

8B.2.1 Approaches to Uncertainty and Variability

This section describes two approaches to address uncertainty and variability in numerical modeling that in practice are often used in tandem, as they are in this rulemaking: (1) probability analysis and (2) scenario analysis.

Probability analysis considers the probability that a variable has a given value over its range of possible values. For quantities with variability (e.g., electricity rates in different households), data from surveys or other forms of measurement can be used to generate a frequency distribution of numerical values to estimate the probability that the variable takes a given value. By sampling values from the resulting distribution, it is possible to quantify the impact of known variability in a particular variable on the outcome of the analysis. In this analysis, DOE used probability distributions to estimate consumer gas-fired instantaneous water heater lifetime, discount rates, and other variables.

Unlike probability analysis, which considers the impact of known variability, scenario analysis estimates the sensitivity of an analysis to sources of uncertainty and variability whose probability distribution is not well known. Certain model inputs are modified to take a number of different values, and models are re-analyzed, in a set of different model scenarios. Because only selected inputs are changed in each scenario, the variability in the results for each scenario helps to quantify the impact of uncertainty in the input parameters. Whereas it is relatively simple to perform scenario analyses for a range of scenarios, scenario analyses provide no information regarding the likelihood of any given scenario's actually occurring.

Scenario and probability analysis provide some indication of the robustness of the policy given the uncertainties and variability. A policy is robust when the impacts are acceptable over a wide range of possible conditions.

8B.3 PROBABILITY ANALYSIS AND THE USE OF MONTE CARLO SIMULATION IN THE LCC AND PBP ANALYSES

To quantify the uncertainty and variability that exist in inputs to the LCC and PBP analyses, DOE used Monte Carlo simulation and probability distributions to conduct probability analyses.

Simulation refers to any analytical method meant to imitate a real-life system, especially when other analyses are too mathematically complex or too difficult to reproduce. Without the aid of simulation, a model will only reveal a single outcome, generally the most likely or average scenario. Probabilistic risk analysis uses both a spreadsheet model and simulation to automatically analyze the effect of varying inputs on the outputs of a modeled system. One type of simulation is Monte Carlo simulation, which repeatedly generates random values for uncertain variables, drawn from a probability distribution, to simulate a model.

For each uncertain variable, the range of possible values is controlled by a probability distribution. The type of distribution selected is based on the conditions surrounding that variable. Probability distribution types include normal, triangular, uniform, and Weibull distributions, as well as custom distributions where needed. Example plots of these distributions are shown in Figure 8B.3.1.

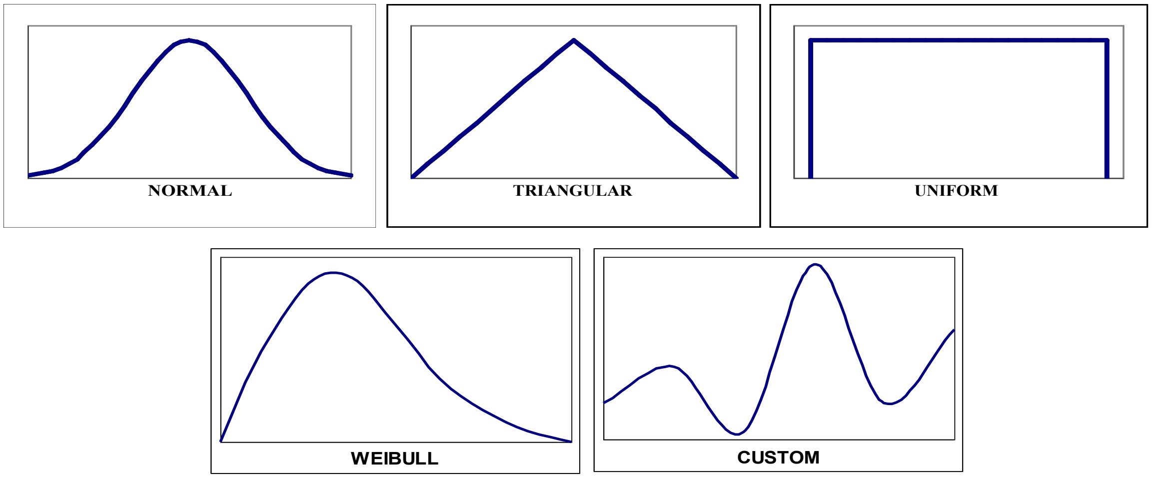

Figure 8B.3.1 Normal, Triangular, Uniform, Weibull, and Custom Probability Distributions

During a simulation, multiple scenarios of a model are calculated by repeatedly sampling values from the probability distributions for the uncertain variables and using those values for that input. Monte Carlo simulations can consist of as many trials as desired, with larger numbers of trials yielding more accurate average results. During a single trial, the simulation randomly selects a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculates the result for that trial.

DOE conducted probability analyses using Microsoft Excel spreadsheets combined with Crystal Ball, a commercially available add-in software. Crystal Ball simulations can consist of as many trials (or scenarios) as desired—hundreds or even thousands. To calculate the LCC and PBP for gas-fired instantaneous water heaters, DOE performed 10,000 Monte Carlo simulations for each variable. During a single trial, Crystal Ball randomly selected a value from the defined possibilities (the range and shape of the probability distribution) for each uncertain variable and then recalculated the spreadsheet.

APPENDIX 8C. FORECAST OF PRODUCT PRICE TRENDS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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APPENDIX 8C. FORECAST OF PRODUCT PRICE TRENDS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

8C.1 INTRODUCTION

DOE obtained historical PPI data for water heating equipment from the U.S. Bureau of Labor Statistics' (BLS). The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for heating equipment manufacturing was calculated by dividing the PPI series by the implicit price deflator for Gross Domestic Product Chained Price Index. Based on the past price data and given the uncertainty regarding the magnitude and direction of potential future price trends, DOE decided to use constant prices as the default price assumption to project future consumer gas-fired instantaneous water heater prices.

Examination of historical price data for certain appliances and equipment that have been subject to energy conservation standards indicates that the assumption of constant real prices and costs may, in many cases, over-estimate long-term appliance and equipment price trends. Economic literature and historical data suggest that the real costs of these products may in fact trend downward over time according to "learning" or "experience" curves, or alternatively that the price trends for certain sectors of the US economy may be different than the price trends for the economy as a whole. Desroches et al. (2013) summarizes the data and literature currently available that is relevant to price projections for selected appliances and equipment.[1]

The extensive literature on the "learning" or "experience" curve phenomenon is typically based on observations in the manufacturing sector.[a] In the experience curve method, the real cost of production is related to the cumulative production or "experience" with a manufactured product. This experience is usually measured in terms of cumulative production. A common functional relationship used to model the evolution of production costs in this case is:

$$Y = a\,X^{-b}$$

Eq. 8C.1

Where:

a = an initial price (or cost),
b = a positive constant known as the learning rate parameter,
X = cumulative production, and
Y = the price as a function of cumulative production.

Thus, as experience (production) accumulates, the cost of producing the next unit decreases. The percentage reduction in cost that occurs with each doubling of cumulative production is known as the learning rate (LR), given by:

[a] In addition to Desroches (2013), see Weiss, M., Junginger, H.M., Patel, M.K., Blok, K., (2010). A Review of Experience Curve Analyses for Energy Demand Technologies. Technological Forecasting & Social Change. 77:411-428.

$$LR = 1 - 2^{-b}$$

Eq. 8C.2

In typical experience curve formulations, the learning rate parameter is derived using two historical data series: cumulative production and price (or cost).

8C.2 PRICE, COST AND MARKET STRUCTURE

DOE uses a cost-based analysis in estimating equipment prices. To estimate equipment prices in both the standards and the baseline or no-new-standard case, DOE develops engineering cost estimates that DOE then uses to estimate manufacturer selling price. The manufacturer selling price includes direct manufacturing production costs (labor, material, and overhead estimated in DOE's manufacturer production costs) and all non-production costs (SG&A, R&D, and interest), along with profit. The process of the cost-based method for developing the manufacturer selling prices is described in the engineering analysis in chapter 5 of this TSD. To convert the manufacturer selling price to an equipment price for the consumer, DOE performs an analysis of distribution chain markups and estimates markups on both the baseline and incremental manufacture selling prices to determine equipment prices after distribution to the consumer.

In analyzing experience curves to estimate price trends, DOE uses producer price indices as a key data input and analyzes this data to estimate the experience curve exponent. This approach has only one model parameter to describe the price trend and assumes a simple relationship between producer price and retail equipment price. Specifically, the approach assumes that producer prices, distribution chain markups and equipment prices all scale proportionally over time for the same product.

DOE could have developed a more complex price trend forecasting model with more parameters that could explain different trends in different equipment price and cost components over time. But the relatively few available data points present a risk that a fit with multiple parameters would "overfit" the data. Overfitting occurs when there are too many degrees of freedom in a statistical model compared to the data and the fits are sensitive to random noise unrelated to long term trends. Due to the risk of overfitting the available data, DOE has decided to not develop a more complex multi-parameter price trend estimation model at this time.

Due to the simple nature of the price trend estimation model, there are several well-known economic and market phenomena that will not be captured in detail by the price trend forecast. Some effects might lead to an overestimate of the long-term price trend and other effects may lead to an underestimate. For example, if there has been increasing market concentration historically on the part of manufacturers, this may have resulted in increasing manufacturer and wholesale markups over time. This would result in an observed historical producer price trend that did not decrease as fast as the underlying industrial learning rate. Depending on if market concentration accelerated or decelerated into the future this could lead to an over- or under-estimation of future price trends.

Similarly, if there are cost components that have relatively slow long-term price trends that have an increasing impact on price over time, the decreasing share of costs that are declining rapidly can result in a change in the empirically estimated experience curve exponent over time.

8C.3 DERIVATION OF LEARNING RATES

To develop price trends for gas-fired instantaneous water heaters, DOE obtained historical PPI data from 1967-1973 and 1977-2022 for all other consumer water heaters from the Bureau of Labor Statistics' (BLS).[b] The PPI data reflect nominal prices, adjusted for product quality changes. An inflation-adjusted (deflated) price index for heating equipment manufacturing was calculated by dividing the PPI series by the implicit price deflator for Gross Domestic Product Chained Price Index (see Figure 8C.3.1).

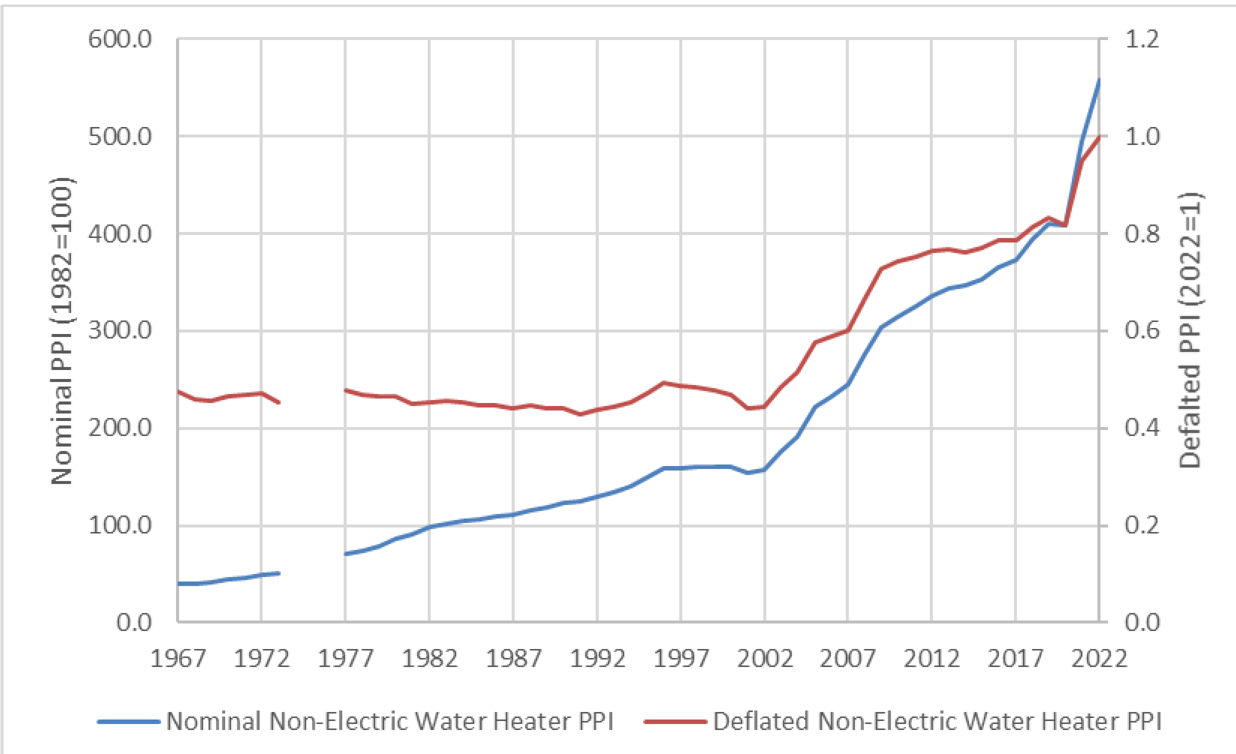

Figure 8C.3.1 Historical Nominal and Deflated Producer Price Indexes for Non-Electric Consumer Water Heaters

DOE assembled a time-series of annual shipments for consumer water heaters during the period of 1945-2022 mainly using data from the Appliance Magazine, and Air-Conditioning, Heating, and Refrigeration Institute (AHRI), and BRG Consulting shipments data.[2,3,4] Chapter 9 in this final rule TSD describes the data sources in more details. Consumer water heater shipments prior to 1945 were extrapolated backward based on a linear trend to the historical shipments. The annual shipments data were used to estimate cumulative shipments (production). Projected shipments after 2022 were obtained from the base case projections made for the NIA (see chapter 9 of this TSD). Figure 8C.3.2 shows the shipments time series used in the analysis.

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[b] Series ID PCU33522833522083; www.bls.gov/ppi/

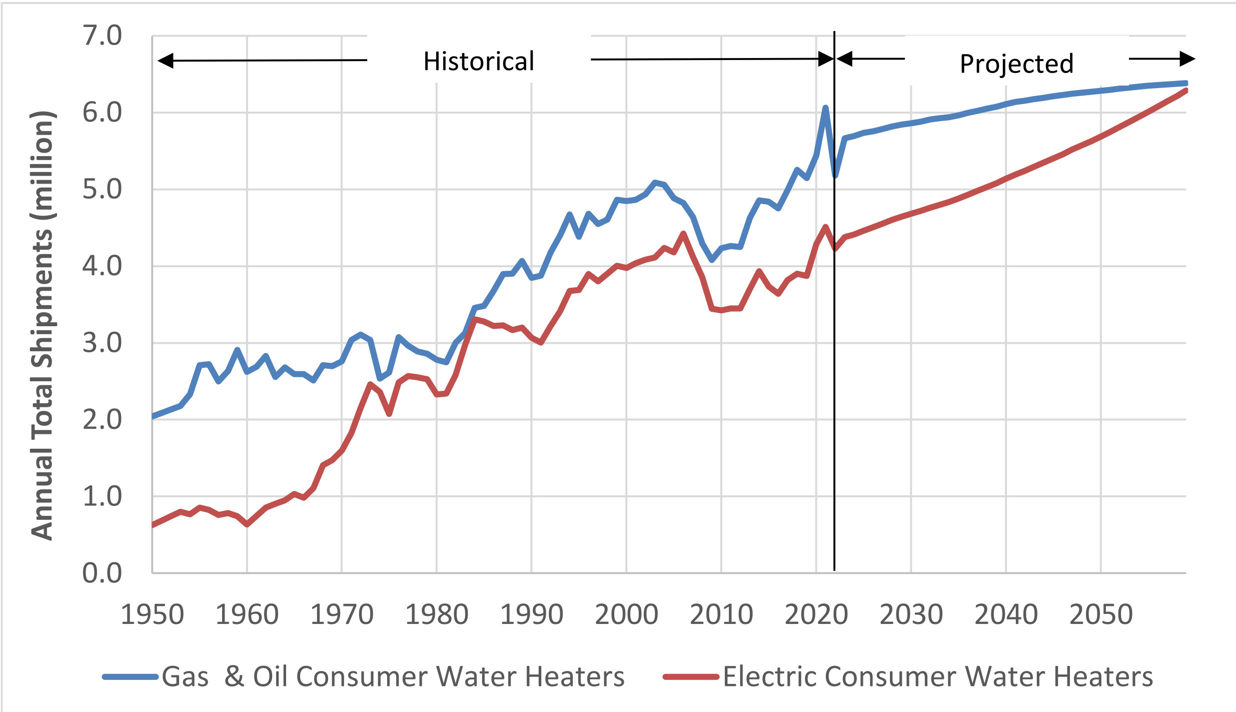

Figure 8C.3.2 Extrapolated, Historical and Projected Shipments of Consumer Water Heaters

From 1977 to 2002, the deflated price index for consumer water heaters was mostly decreasing, or staying flat. Since then, the index has risen, primarily due to rising prices of copper, aluminum, and steel products which are the major raw material used in water heating equipment (as shown in Figure 8C.3.3). The rising prices for copper and steel products were attributed to a series of global events, from strong demand from China and other emerging economies to the recent severe delay in commdotiy shipping due to the covid pandemic. Given the slowdown in global economic activity in recent years and the lingering impact from the global pandemic, DOE believes that the extent to which the trends of the past five years will continue is very uncertain. Therefore, DOE decided to use constant prices as the default price assumption to project future gas-fired instantaneous water heater prices. Thus, projected prices for the LCC and PBP analysis are equal to the 2023 values for each efficiency level. The no price trend scenario assumes zero percent learning rate, implying constant real prices over the entire forecast period.

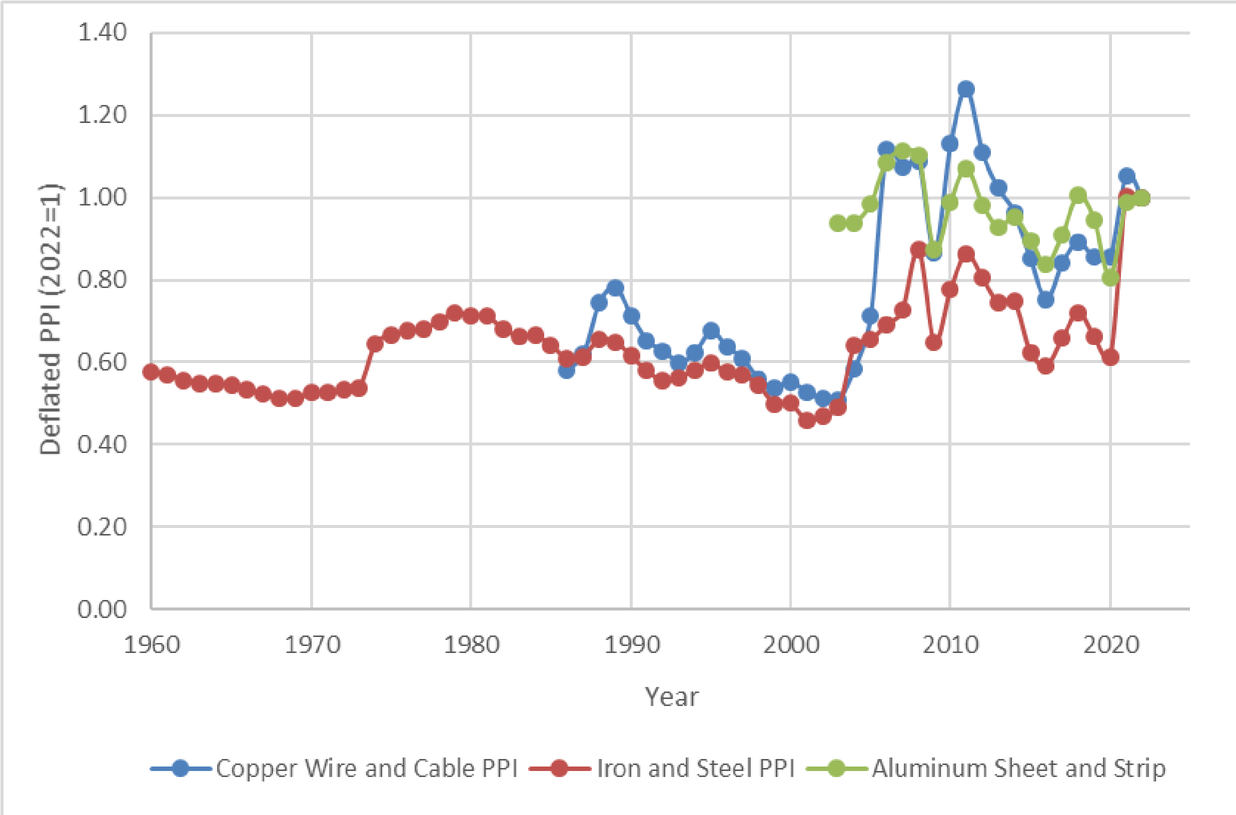

Figure 8C.3.3 Historical Deflated Copper, Iron and Aluminum Sheet PPI

8C.4 ALTERNATIVE GAS-FIRED INSTANTANEOUS WATER HEATER PRICE TREND SCENARIOS

DOE also investigated the impact of different product price trends on the life-cycle cost (LCC) results for the considered TSLs for gas-fired instantaneous water heaters. DOE considered two alternative price trends for the sensitivity analysis, one with increasing price trend and the other with decreasing price trend. The decreasing price trend scenario used the power-law function as described above to fit the gas-fired instantaneous water heater PPI during the period of 1977 to 1991 for gas instantaneous water heaters. The increasing price trend scenario is set equal to be symmetric to the decreasing trend.

8C.4.1 Determination of Decreasing Price Trend Scenario

DOE examined the consumer water heater PPI series from the Bureau of Labor Statistics (BLS) during the period of 1997 to 1991 for gas-fired water heaters, which demonstrates a steeper downward trend than the full set of data. DOE fit this segment of the data to a power-law function to derive the decreasing price trend. To estimate a learning rate parameter, a least-squares power-law fit was performed on the deflated price index versus corresponding cumulative shipments (Figure 8C.4.1).

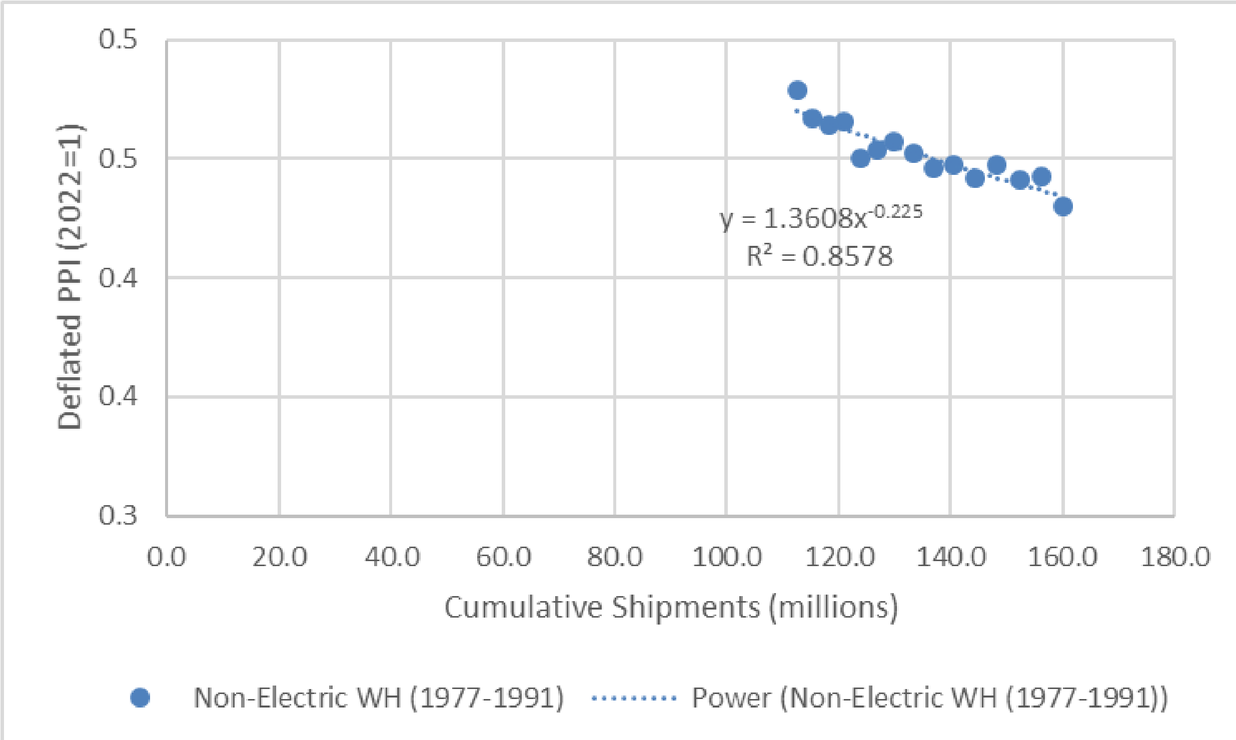

Figure 8C.4.1 Relative Price versus Cumulative Shipments of Non-Electric Consumer Water Heaters from 1977 to 1991, with Power Law Fit

8C.5 SUMMARY OF PRODUCT PRICE TRENDS FORECAST

Table 8C.5.1 shows the summary of the estimated learning rate in each price trend scenario used for gas-fired instantaneous water heaters. Figure 8C.5.1 show the resulting price forecast indexes.

Table 8C.5.1 Price Trend Sensitivities

Sensitivity	Price Trend	Estimated Learning Rate %	Learning Rate Factor in 2030 (2023=1)
Default	Constant price projection	0.00	1.000
Decreasing Price Trend Scenario (Gas & Oil)	Power-law fit to the non-electric water heater PPI from 1977 to 1991	14.44	0.973
Increasing Price Trend Scenario (Gas & Oil)	Symmetric to Power-law fit to the non-electric water heater PPI from 1977 to 1991	16.87	1.028

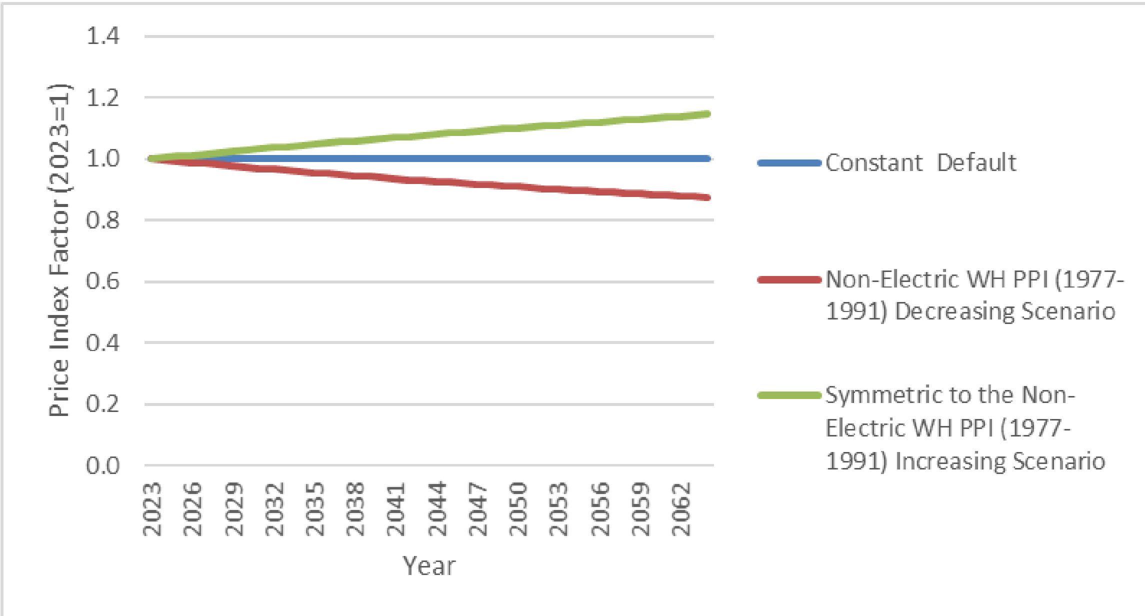

Figure 8C.5.1 Price Forecast Indexes for Non-Electric Consumer Water Heaters

8C.6 PRODUCT PRICE TRENDS SENSITIVITIY RESULTS

DOE produced results with a constant price (default) trend and with a decreasing and increasing price trend. The results are presented in Table 8C.6.1 to Table 8C.6.4.

Table 8C.6.1 Constant Product Price Trend (Default) Scenario LCC Results by Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,087	303	4,571	6,659	NA	NA	NA
	1	2,304	285	4,339	6,644	12.6	(1)	17%
	2	2,318	277	4,210	6,528	8.9	112	15%
	3	2,334	273	4,154	6,487	8.3	90	25%
	4	2,424	270	4,107	6,531	10.3	39	56%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.2 Decreasing Product Price Trend Scenario LCC Results by Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,060	303	4,571	6,632	NA	NA	NA
	1	2,269	285	4,339	6,609	12.1	7	17%
	2	2,283	277	4,210	6,493	8.6	118	15%
	3	2,298	273	4,154	6,452	8.0	93	24%
	4	2,386	270	4,107	6,493	9.9	44	55%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.3 Increasing Product Price Trend Scenario LCC Results by Product Class and Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,115	303	4,571	6,686	NA	NA	NA
	1	2,340	285	4,339	6,680	13.0	(9)	18%
	2	2,355	277	4,210	6,564	9.2	105	16%
	3	2,370	273	4,154	6,524	8.6	86	26%
	4	2,463	270	4,107	6,571	10.6	33	57%

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

Table 8C.6.4 Product Price Trend Scenario Comparison of LCC, PBP and Net Cost Results for Gas-fired Instantaneous Water Heaters

Product Class	EL	Average LCC Savings** 2023$			Simple Payback Period* *years*			Net Cost** *%*		
		Decr.	Const.	Incr.	Decr.	Const.	Incr.	Decr.	Const.	Incr.
GIWH	1	7	(1)	(9)	12.1	12.6	13.0	17	17	18
	2	118	112	105	8.6	8.9	9.2	15	15	16
	3	93	90	86	8.0	8.3	8.6	24	25	26
	4	44	39	33	9.9	10.3	10.6	55	56	57

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

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1. Desroches, L.-B., K. Garbesi, C. Kantner, R. Van Buskirk, and H.-C. Yang. Incorporating Experience Curves in Appliance Standards Analysis. *Energy Policy*. 2013. 52 pp. 402–416.

2. Appliance Magazine. *Appliance Historical Statistical Review: 1954-2012*. 2014. UBM Canon.

3. BRG Building Solutions. *The North American Heating & Cooling Product Markets (2022 Edition)*. 2022. (Last accessed April 1, 2024.) https://www.brgbuildingsolutions.com/solutions/market-reports/.

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APPENDIX 8D. INSTALLATION COST DETERMINATION FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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APPENDIX 8D. INSTALLATION COST DETERMINATION FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

8D.1 INTRODUCTION

This appendix provides details about the derivation of installation costs for gas-fired instantaneous water heaters. The installation cost is the price to the consumer of labor and materials (other than the cost of the actual product) needed to install a gas-fired instantaneous water heater product.

The Department of Energy (DOE) estimated installation costs for gas-instantaneous water heaters based on RSMeans, a well-known and respected construction cost estimation method, as well as manufacturer literature and information from expert consultants. Table 8D.1.1 offers an example of the installation cost calculation. All labor costs are derived using 2023 RSMeans residential labor costs by crew type.[1] Replacement installation cost tables include a trip charge, which is often charged by contractors and estimated to be equal to one half hour of labor per crew member. Labor hours (or person-hours) are based on RSMeans data, expert data, or engineering judgment. Bare costs are all the costs without any markups. Material costs are based on RSMeans data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RSMeans. Values reported in this appendix are based on national average labor costs. In its analysis, DOE used regional labor costs to more accurately estimate installation costs by region. Section 8D.4 describes the derivation of regional labor costs. DOE then applied the appropriate regional labor cost to each Energy Information Administration's (EIA) 2020 Residential Energy Consumption Survey (RECS 2020) sample household or EIA's 2018 Commercial Building Energy Consumption Survey (CBECS 2018) sample building. Section 8D.5 includes the full consultant report with more detailed information and cost examples.

Table 8D.1.1 Example Installation Cost Table

Description	Crew	Labor Hours	Unit	Bare Costs *(2023$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	CREW1	0.5	-	0.00	23.00	23.00	1	35.00
Description of Installation Item	CREW1	0.5	Ea.	15.00	23.00	48.00	1	51.50
Total								**86.50**

The installation cost calculations for gas-fired instantaneous water heaters encompass:

- new construction, new owner, and replacement markets;
- residential and commercial markets;
- single-family (detached), single-family (attached), multi-family, and mobile home dwellings as well as commercial building types;
- basement, crawlspace, garage, attic, indoor water heater installation, and outdoor installation;

- Category III (non-condensing) and Category IV (condensing) venting systems, including concentric pipe for a fraction of installations, and
- condensate withdrawal piping and drainage, including adding a condensate pump, freeze protection (heat tape), condensate neutralizers, and an electrical connection for a condensate pump or heat tape.

Applying the RSMeans installation costs to a gas-fired instantaneous water heater installation requires knowledge of its physical parameters, including the installation location, vent length, venting material, *etc*. DOE reviewed relevant literature, data, and installation manuals to estimate these quantities as a distribution of values. A Crystal Ball Monte Carlo simulation[a] was used to model the resultant costs for each individual household or building.

8D.2 INSTALLATION COST INPUTS

The following information about market shares, housing types, and installation locations set the base for installation cost calculations.

Residential and Commercial Market Shares. As determined in the shipment analysis (see chapter 9), for gas-fired instantaneous water heaters, approximately 94 percent of the market will be residential and 6 percent will be commercial in 2030.

Table 8D.2.1 Estimated Fraction of Gas-fired Instantaneous Water Heaters in Residential and Commercial Applications in 2030

Product Class	Rated storage volume and input rating	Residential	Commercial
Gas-fired Instantaneous Water (GIWH)	<2 gal and >50 kBtu/h	94%	6%

New Construction, New Owner, and Replacement Market Shares. As determined in the shipment analysis (see chapter 9), for gas-fired instantaneous water heaters, approximately 15 percent of the market will be new construction and 85 percent will be replacements in 2030.

Table 8D.2.2 Estimated Fraction of Gas-fired Instantaneous Water Heaters in Replacement and New Construction in 2030

Product Class	Rated storage volume and input rating	Residential		Commercial	
		Repl./New Owner	New Construction	Repl./New Owner	New Construction
GIWH	<2 gal and >50 kBtu/h	52%	48%	83%	17%

Building Types. DOE calculated costs for gas-fired instantaneous water heaters installed in various building types. Table 8D.2.3 shows the percentages of water heaters installed in different building types.

[a] See chapter 8 for a description of the Monte Carlo simulation methodology.

Table 8D.2.3 Estimated Fraction of Gas-fired Instantaneous Water Heaters by Building Type in 2030

Product Class	Rated Storage Volume and Input Rating	Mobile Home	Single-Family		Multi-Family		Commercial Buildings
			Detached	Attached	2-4 Units	5+ Units	
GIWH	<2 gal and >50 kBtu/h	1%	82%	4%	1%	6%	6%

Installation Locations. Consumer water heaters are installed in different parts of the house or building. DOE reviewed references that examined consumer water heater installation locations such as the 2013, 2016, 2019, and 2022 Decision Analysts, Inc. survey based on a representative sample[2] and based on the 1991 GTI Water Heater Survey.[3] DOE derived the installation location in residential households using RECS 2020 housing characteristics with the following assumptions, which is also applicable to GIWHs:[4]

1) If the consumer water heater is reported to be installed in the main living space, it is assumed to be installed in an indoor closet.
2) If the consumer water heater is reported to be installed in the basement, it is assumed to be installed in the basement.
3) If the consumer water heater is reported to be installed in the garage, it is assumed to be installed in the garage.
4) If the consumer water heater is reported to be installed outside, it is assumed to be installed in a set of locations including an outdoor closet, crawl space, and outdoor.
5) If the installation location is not specified –
    a. If a household has an *attic*, then the consumer water heater is assumed to be installed in the attic;
    b. If the household has a *crawl space*, then the consumer water heater is assumed to be installed in the crawl space.
6) For mobile homes and multi-family buildings, 40% and 75%, respectively, of the water heaters are assumed to be installed in an indoor closet with the rest installed in an outdoor closet or outdoor. For all other cases, the consumer water heater is assumed to be installed in an indoor location (such as an indoor closet or utility room). All consumer water heater installations in commercial buildings are assumed to be in indoor locations.

Table 8D.2.4 shows a summary of the distribution of the installation locations.

Table 8D.2.4 Distribution of Installation Location for Gas-Fired Instantaneous Water Heaters

ID	Installation Location	GIWH
1	Basement	22%
2	Garage	26%
3	Attic	5%
4	Indoors	23%
5	Other*	24%

* Includes outdoor closet, crawlspace, and outside of the house. DOE estimates that 12% of the installations are outdoor installation.

8D.3 INSTALLATION COST METHODOLOGY

8D.3.1 Overview

There are two main types of gas-fired instantaneous water heater designs: non-condensing, and condensing. Non-condensing GIWHs usually use Category III venting systems, while condensing GIWHs are vented using Category IV venting systems. Non-condensing GIWHs require stainless steel venting system, while condensing GIWHs use plastic venting (PVC, CPVC, or polypropylene).

DOE developed installation costs for gas-fired instantaneous water heater using consultant report available in section 8D.5, RSMeans cost data, as well as the 2010 heating products technical support document.[5] The installation cost are divided into the following components:

- basic installation,
- flue venting,
- condensate management,
- additional costs.

8D.3.2 Basic Installation Costs

For gas-fired instantaneous water heaters, DOE estimated basic installation costs that are applicable to both replacement and new home installations. These costs include:

- trip charge (replacement only),
- removal of existing water heater (replacement only),
- putting in place and setting up the water heater,
- unit start-up, check, and clean up,
- gas piping,
- water piping,
- T&P valve drain piping,
- permit, removal or disposal fees,
- when applicable, wall mount and asbestos abatement.

See consultant report in section 8D.5 for more detailed discussion about these costs, as well as basic installation cost examples using national labor costs for new construction replacement cases. The actual costs in the spreadsheet vary for each household depending primarily on the regional labor costs.

8D.3.3 Flue Venting

Condensing heating appliances condense the water vapor in a secondary heat exchanger, thus increasing the heating appliance efficiency by reducing latent heat loss. The condensate is fed to a drain. Because the flue gas temperature is relatively low, condensing heating appliances can be vented through plastic piping (such as PVC).

DOE calculated venting costs for each sampled household and building from RECS 2020 and CBECS 2018. To determine venting costs for both new construction and replacement installations, DOE used a number of parameters that have an impact on the venting installation cost, including vent location, installation type (replacement, new owner, or new construction), region, vent material, and vent length. The methodologies for determining these costs and the vent length are discussed in the following sections.

8D.3.3.1 Flue Venting Types

There are two primary vent configurations for gas-fired instantaneous water heaters.

(1) Single-pipe with room air intake or Two-pipe system. For some direct vent models, one plastic pipe is used for air intake from outside, consisting of the two-pipe system.
   a. For non-condensing gas instantaneous water heaters, 4” stainless steel vent pipe is commonly used.
   b. For condensing gas instantaneous water heaters, PVC is used for venting. Other equivalent materials include CPVC and polypropylene.

(2) Concentric pipe system. Concentric pipe use is also commonly seen with gas tankless water heater, for it requires only one wall penetration and that it potentially can be more cost efficient than running two pipes especially for non-condensing models.
   a. For non-condensing gas instantaneous water heaters, 3”/5” concentric pipe is commonly used. On the current market, there are multiple material options: all stainless steel, stainless steel/galvanized steel, and aluminum/PVC.
   b. For condensing gas instantaneous water heaters, concentric PVC pipe is used for venting. Other equivalent materials include CPVC and polypropylene.

For the analysis, DOE estimated that 41% of non-condensing GIWH and 22% of condensing GIWH utilizing concentric pipe. DOE applied the material prices accordingly.

Besides the two primary venting configurations above, gas instantaneous water heaters are also sometimes installed on the outside wall of the house. In this scenario, vent pipe is not needed. In the analysis, DOE accounted for a cost of $80 (before markup) for the outdoor installation conversion kit, which is a protection box commonly offered on the market.

8D.3.3.2 Vent Pipe Length

Figure 8D.3.1 shows the vent pipe length determination methodology. DOE separately determined the vent length for vertical (through the roof) or horizontal (through the wall) vent applications taking into consideration the number of floors, installation location, and presence of a cathedral ceiling or high ceiling (peach-colored items) as well as data from National Association of Home Builders (NAHB) on floor height (see Figure 8D.3.2).[6]

For GIWHs, DOE assumed that both non-condensing and condensing can vent horizontally or vertically, depending on which provides the shorted vent run. When the situation allows, it is economic to vent tankless water heaters horizontally through the side wall. DOE estimated that the minimum length needed for the straight vent pipe is as short as 1 ft.

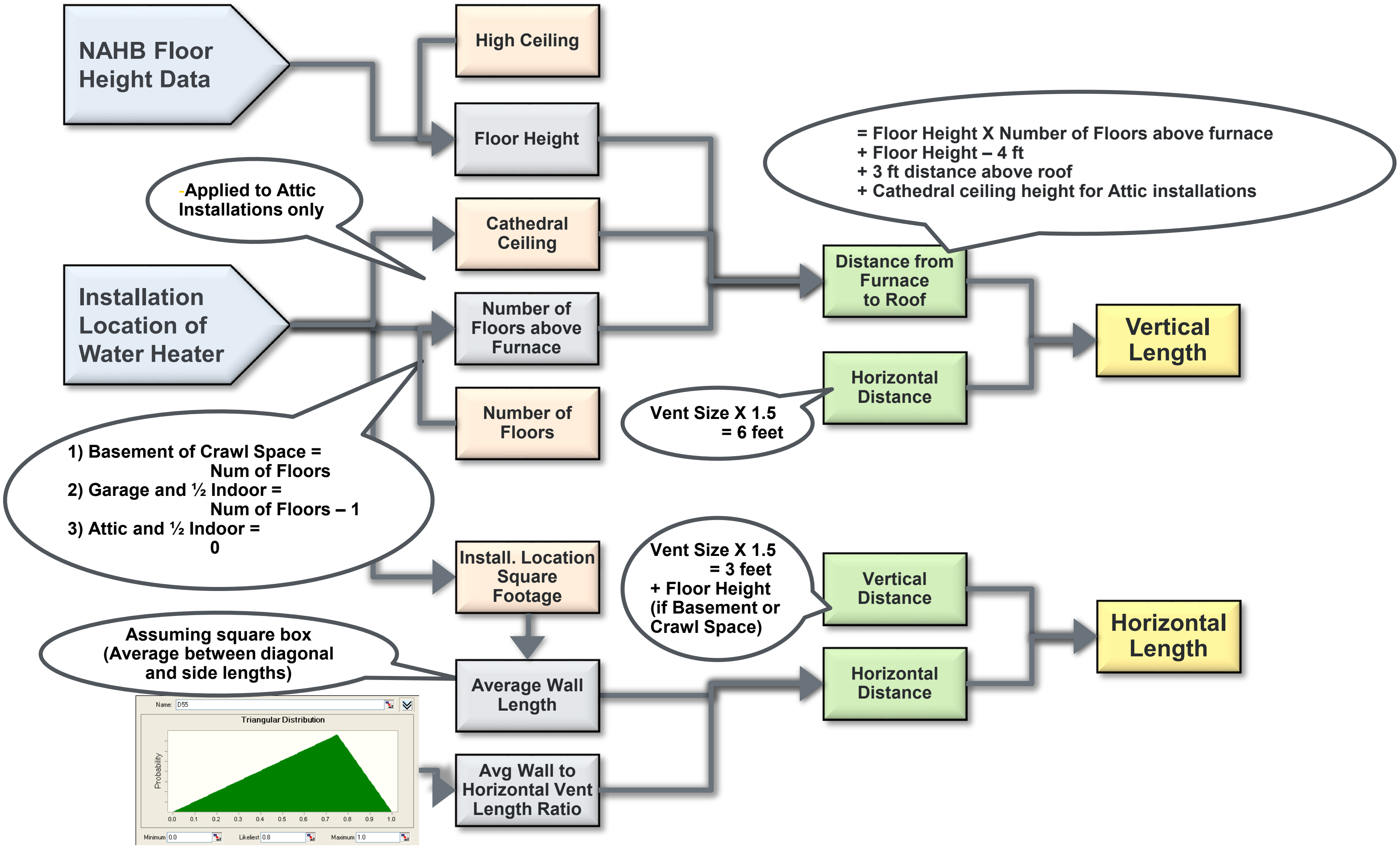

Figure 8D.3.1 Vent Pipe Length Determination

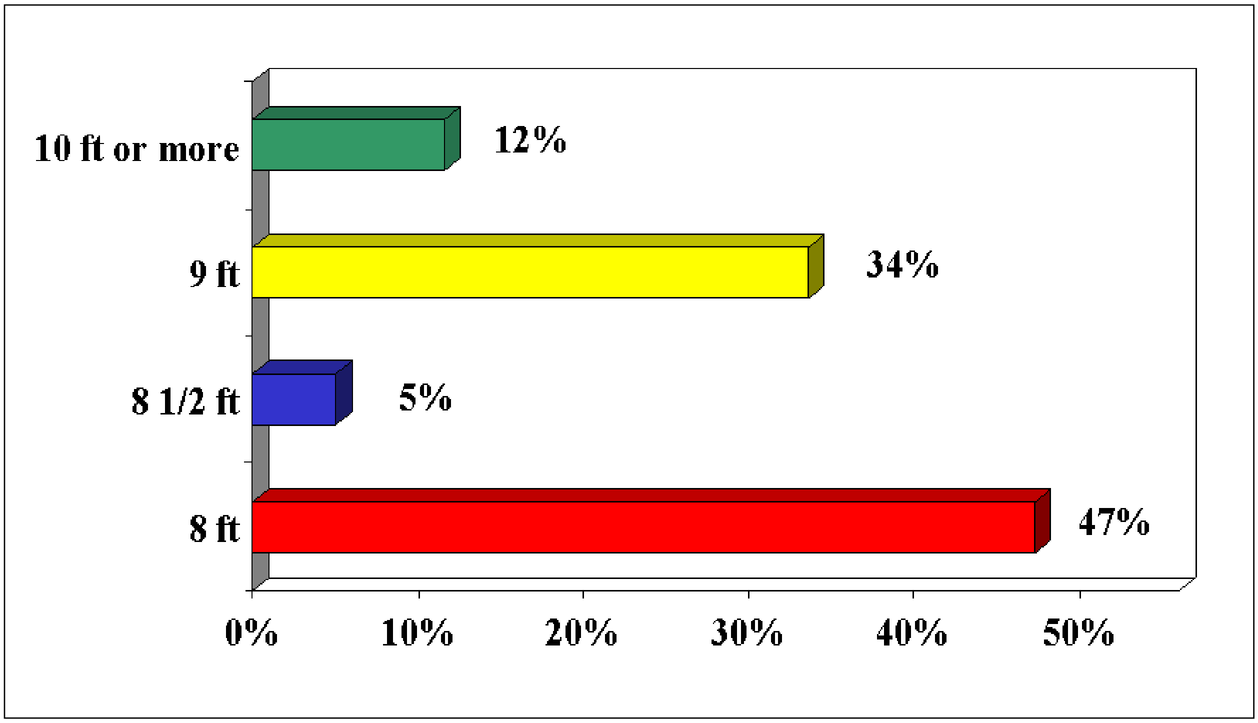

Figure 8D.3.2 First Floor Height Fractions from 2001 NAHB Survey

DOE used the square footage of the house reported in RECS 2020 or business reported in CBECS 2018 to determine the average wall length. DOE used a triangular probability distribution to represent the average ratio between the wall length and horizontal vent length (see Figure 8D.3.3 and Figure 8D.3.4 for replacement and new construction distributions, respectively). The average wall length and ratio of wall length to horizontal vent length were used to determine the pipe horizontal length. DOE also considered the vertical vent length that is required based on the floor height and whether the water heater is in a basement or crawlspace. The vertical vent height is assumed to be high enough to be above the snow level in the winter months.

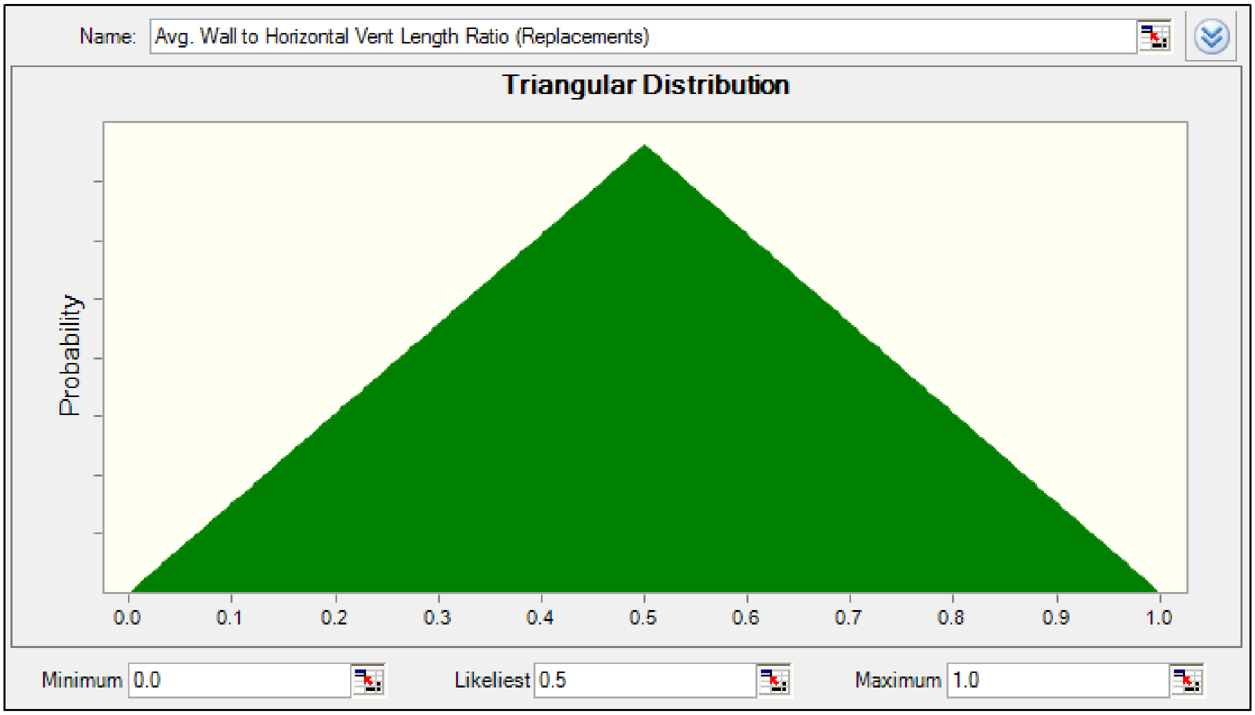

Figure 8D.3.3 Average Wall to Horizontal Vent Length Ratio (Replacements)

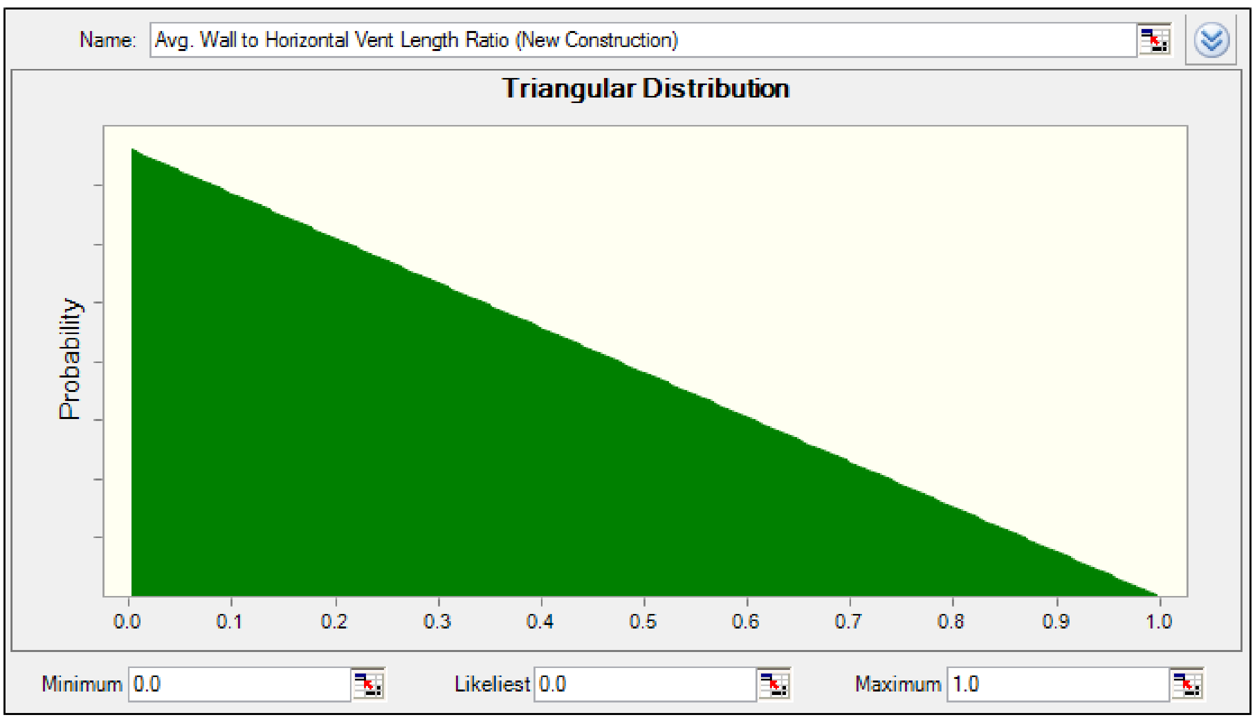

Figure 8D.3.4 Average Wall to Horizontal Vent Length Ratio (New Construction)

In addition to the vent pipe length, DOE account for various vent pipe components, including number of elbows and different cost vent wall penetration depending on wall type.

Table 8D.3.1 show the 5th percentile, average, and 95th percentile vent length results from the sample and the fraction of installations with vertical or horizontal for GIWHs. The length accounts for the straight extension pipe, not including elbows and terminations.

Table 8D.3.1 Non-condensing and Condensing Gas-fired Instantaneous Water Heater Vent Length

Vent Run	Vent Length, ft			Fraction of Installations
	5th Percentile	Average	95th Percentile	
Horizontal	2	10	22	86%
Vertical	13	19	32	14%

8D.3.3.3 Combustion Air Vent

A fraction of the GIWH installations are direct-vent installations, which uses combustion air supplied from the outdoor air. For each sampled household or building, DOE considered the following factors when calculating the installation cost of the combustion air vent for GIWHs:

- combustion air vent installation fraction, which depends on the installation location.
- combustion air vent length, which is the same as flue pipe length.
- use of concentric pipe (only applicable to a fraction of GIWHs), where a standalone PVC pipe is no longer needed.

Table 8D.3.2 shows the fraction of direct vent installations by installation location, based on a 2010 consultant report.[7] DOE estimated that 46 percent of the GIWH installations are direct vent.

Table 8D.3.2 Fraction of Direct Vent Installations by Installation Location

ID	Installation Location	Fraction of Direct Vent Installations
1	Basement (Conditioned)	**25%**
2	Garage	**67%**
3	Attic	**33%**
4	Indoor (Closet, Alcove, Utility Room)	**67%**
5	Other	**25%**

8D.3.3.4 Concealing Vent Pipes

For a fraction of indoor installations, DOE added an installation cost to conceal the vent pipes—putting in place structures to mask vents that pass through the living space. DOE assumed that half of the indoor installed GIWHs that are horizontally vented would require such modifications.

8D.3.4 Condensate Management

Condensate removal is required for all condensing gas-fired instantaneous water heater. DOE considered the following when assessing the cost of condensate removal:

- *Condensate Pipe:* Excess condensate must be deposited in a drain. Therefore, for all installations DOE applied the cost of adding condensate pipe (5 to 20 feet).
- *Condensate Pump:* If a drain is not near the gas-fired instantaneous water heater, then the condensate must be pumped to a remote drain. DOE assumed that 12.5% of the replacement installations where there is no central air conditioner or heat pump installed will require the additional cost of a condensate pump. Additionally, for those that need a condensate pump, DOE estimated that the cost of $20 for a condensate drain would be applicable.
- *Condensate Freeze Protection:* If the condensate is exposed to freezing temperatures, then heat tape and pipe insulation is required. DOE assumed that heat protection is required for 50% of the installations in an unconditioned attic for replacements.
- *Additional Electrical Outlet:* DOE assumed that 25% of replacement installations requiring a condensate pump or heat tape would also require an additional electrical outlet.
- *Condensate Neutralizer:* DOE assumed that 12.5% of all installations would require condensate neutralizer.

8D.3.5 Additional Costs

Besides the basic installation cost, venting cost, and cost for condensate management, given the complexities of the higher efficiency product, DOE applied a distribution of extra labor hours needed for installing a condensing GIWHs.

8D.4 RSMEANS 2023 REGIONAL LABOR COSTS

DOE used regional material and labor costs to more accurately estimate installation costs by region. RSMeans provides average national labor costs for different trade groups as shown in Table 8D.4.1. Bare costs are given in RSMeans, while labor costs including overhead and profit (O&P) are the bare costs multiplied by the RSMeans markups by trade shown in Table 8D.4.2.

Table 8D.4.1 RSMeans 2023 National Average Labor Costs by Crew (2023$)

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	Incl. O&P*
Residential Labors Costs				
Q1	1 Plumber, 1 Plumber Apprentice	2	$38.92	$63.50
Q9	1 sheet metal worker, 1 sheet metal worker apprentice	2	$37.90	$62.40
Q10	2 sheet metal worker, 1 sheet metal worker apprentice	3	$39.30	$64.70
1 Plum	1 Plumbers	1	$43.25	$70.55
1 Plum Apprentice	1 Plumber Apprentice	1	$34.60	$56.45
1 Elec	1 Electrician	1	$44.45	$72.30
1 Sheet	1 Sheet metal worker	1	$42.10	$69.30
1 Sheet Apprentice	1 Sheet metal worker apprentice	1	$33.70	$55.50
1 Carp	1 Carpenter	1	$38.65	$62.95
Commercial Labors Costs (Standard Union)				
Q1	1 Plumber, 1 Plumber Apprentice	2	$64.85	$96.70
Q9	1 sheet metal worker, 1 sheet metal worker apprentice	2	$63.13	$95.10
Q10	2 sheet metal worker, 1 sheet metal worker apprentice	3	$65.47	$98.63
1 Plum	1 Plumbers	1	$72.05	$107.45
1 Plum Apprentice	1 Plumber Apprentice	1	$57.65	$85.95
1 Elec	1 Electrician	1	$67.35	$100.10
1 Sheet	1 Sheet metal worker	1	$72.55	$108.20
1 Sheet Apprentice	1 Sheet metal worker apprentice	1	$58.05	$86.55
1 Carp	1 Carpenter	1	$58.60	$87.25

* O&P includes markups from Table 8D.4.2.

Table 8D.4.2 RSMeans 2023 Labor Costs Markups by Trade

Trade	Workers Comp.	Aver Fixed Overhead	Overhead	Profit	Total
Residential Labor Costs Markups					
Plumber	4.6%	18.5%	30.0%	10.0%	63.1%
Electrician	4.1%	18.5%	30.0%	10.0%	62.6%
Sheet Metal	6.2%	18.5%	30.0%	10.0%	64.7%
Carpenter	9.4%	18.5%	25.0%	10.0%	62.9%
Steamfitter	4.6%	18.5%	30.0%	10.0%	63.1%
Commercial Labor Costs Markups					
Plumber	4.6%	18.5%	16.0%	10.0%	49.1%
Electrician	4.1%	18.5%	16.0%	10.0%	48.6%
Sheet Metal	6.2%	18.5%	16.0%	10.0%	50.7%
Carpenter	9.4%	18.5%	11.0%	10.0%	48.9%
Steamfitter	4.6%	18.5%	16.0%	10.0%	49.1%

RSMeans also provides material and labor cost factors for 295 cities and towns in the U.S. To derive average labor cost values by state, DOE weighted the price factors by 2021 population for the different cities. DOE used the material and labor cost factors for cost associated with fire suppression, plumbing, and HVAC. Table 8D.4.3 shows the final regional material and labor price factors used in the analysis by state for residential and commercial installations.

Table 8D.4.3 Material and Labor Cost Factors by State

State	Plumbing, HVAC		Electrical		Weighted Average	
	Material	Labor	Material	Labor	Material	Labor
Alabama	1.00	0.62	0.99	0.65	0.99	0.70
Alaska	1.00	1.07	1.04	1.02	1.17	1.09
Arizona	1.00	0.76	0.99	0.63	0.99	0.73
Arkansas	0.98	0.51	0.97	0.56	0.96	0.62
California	0.99	1.39	0.96	1.34	1.01	1.34
Colorado	0.99	0.71	0.98	0.74	1.00	0.73
Connecticut	1.00	1.17	0.97	1.02	0.99	1.14
Delaware	1.00	0.93	1.00	0.99	1.02	0.89
District of Columbia	1.00	1.18	1.00	1.06	1.01	1.08
Florida	0.99	0.62	0.97	0.63	1.00	0.67
Georgia	0.99	0.67	0.99	0.64	0.98	0.72
Hawaii	1.00	1.07	1.02	1.15	1.16	1.14
Idaho	1.00	0.76	0.93	0.73	1.01	0.80
Illinois	1.00	1.32	0.98	1.30	0.98	1.40
Indiana	0.99	0.77	0.95	0.83	0.97	0.81
Iowa	0.99	0.79	0.96	0.75	0.98	0.81
Kansas	0.99	0.74	0.99	0.72	0.97	0.76
Kentucky	0.99	0.75	0.98	0.72	0.96	0.77
Louisiana	1.00	0.59	1.01	0.61	0.97	0.66
Maine	0.98	0.74	1.01	0.73	0.97	0.84
Maryland	0.98	0.81	0.99	0.87	0.99	0.82
Massachusetts	1.00	1.13	1.01	1.10	0.98	1.19
Michigan	1.00	0.90	0.98	0.91	0.98	0.92
Minnesota	0.99	1.11	1.00	1.12	1.00	1.13
Mississippi	0.99	0.54	0.99	0.52	0.97	0.62
Missouri	0.99	0.94	0.97	0.89	0.97	0.95
Montana	0.99	0.69	0.96	0.67	1.01	0.74
Nebraska	0.99	0.76	0.98	0.73	0.98	0.78
Nevada	1.00	0.95	1.00	1.00	1.03	0.98
New Hampshire	0.99	0.85	1.02	0.74	0.98	0.90
New Jersey	1.00	1.34	0.96	1.35	0.98	1.33
New Mexico	1.00	0.68	0.86	0.70	0.98	0.72
New York	1.00	1.64	1.01	1.68	0.99	1.62
North Carolina	1.00	0.61	0.98	0.62	1.00	0.67
North Dakota	0.99	0.70	0.98	0.68	1.00	0.76
Ohio	1.00	0.86	0.99	0.82	0.96	0.85
Oklahoma	0.99	0.63	0.98	0.69	0.96	0.66
Oregon	0.99	1.07	0.94	1.03	1.04	1.02
Pennsylvania	0.98	1.20	0.99	1.31	0.98	1.18
Rhode Island	1.00	1.11	1.01	0.95	1.00	1.11
South Carolina	0.99	0.54	0.96	0.65	0.98	0.66
South Dakota	0.99	0.68	0.96	0.61	0.99	0.74
Tennessee	1.00	0.69	1.01	0.63	0.99	0.69
Texas	0.99	0.59	0.97	0.57	0.98	0.64
Utah	1.00	0.72	0.95	0.69	1.00	0.72
Vermont	0.96	0.68	1.01	0.53	0.96	0.82
Virginia	0.98	0.69	0.96	0.73	0.99	0.71
Washington	1.00	1.10	1.00	1.09	1.03	1.03
West Virginia	0.97	0.86	0.97	0.83	0.98	0.86
Wisconsin	0.99	0.98	0.98	0.97	0.97	1.02

8D.5 CONSULTANT REPORT (CDS CONSULTING)

The following is the consumer water heaters installation cost report was prepared by CDS Consulting,[b] for Lawrence Berkeley National Laboratory (LBNL) on October 19, 2021.

8D.5.1 Introduction

This report is based on a request from LBNL to provide installation costs examples for different water heater types and technologies, as well as information about installation practices and issues based on my 40+ year experience in the water heater industry and recent research. The following sections are first divided into major product classes (i.e., gas-fired storage water heaters, electric storage water heaters, oil-fired storage water heaters, and gas-fired instantaneous water heaters). Each section is then divided into subsections for the new construction and replacement markets, if applicable. For each of these subsections typical installation steps, typical installation cost items, and example cost tables are shown. Note that installation situations vary greatly case to case and that the presented cost tables for each water heater model are based on certain assumptions and a likely installation scenario.

The installation costs are developed using the following common assumptions:

- Many of the material costs are derived from a survey of retail water heaters and related installation parts suppliers such as Home Depot and Lowe's. Contractors actively installing water heaters were also contacted to derive typical labor hours or material costs.[c] Data was also used from HomeAdvisor.com and RSMeans.

- For all the cost tables below a national average labor rate of $60 per hour is assumed except for mobile home manufacturing plant labor and mobile home service companies. Those labor rates are shown in the specific mobile home sections. There are significant regional labor cost differences that need to be taken into account when considering regional installation costs.[d]

- All cost values are rounded to the nearest whole dollars.

- Most recent building codes and safety requirements are considered in these estimates.

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[b] Drew Smith is founder of CDS Consulting and has more than 40 years of experience in the consumer water heater industry (including sixteen years in sales and marketing and nineteen years in engineering design and development). He was previously Director of Residential Engineering and Product Safety, Certification and Standards at A.O. Smith until 2007 and previously Vice President of Product Development and Research at State Industries until 2001.
[c] Mainly contractors from Chicago, Nashville, and Dallas areas.
[d] Note that some labor hours are based on dividing the reported labor cost from surveying contractors and other sources by labor rate.

8D.5.2 Gas-Fired Storage Water Heater

8D.5.2.1 Gas-fired Storage Water Heater Technology Description

Gas-fired storage water heaters (GSWHs) are typically separated into three distinct groups or product classes:

- models with rated volume at or above 20 gallons and at or below 55 gallons,
- models with rated volume above 55 gallons, and
- models with rated volume below 20 gallons.

Currently, models with rated volume above 20 gallons and less than 55 gallons are the most common. There are currently no residential certified gas-fired models available at or above 55 gallons. There are also no models below 20 gallons covered by federal efficiency standards. The existing models below 20 gallons are primarily specialized water heaters for recreation vehicles, which are not currently covered by the federal efficiency standards.

For gas-fired storage water heaters with rated volumes ≥ 20 gallons and ≤ 55 gallons, the following water heater designs are considered:

- **Baseline GSWHs (meeting minimum efficiency standards)** - Non-Condensing with standing pilot. Atmospheric, standard Category I vent system, and draft hood equipped.
- **Baseline Direct Vent GSWHs (meeting minimum efficiency standards)**[e] - Non-condensing with standing pilot, atmospheric, designed for use with the water heater manufacturer specified vent system to allow intake combustion air and flue product exhaust from/to outdoors. This system does not use combustion air from inside the house structure.
- **GSWHs with Automatic Flue Damper**[f] - Atmospheric burner, draft hood equipped, standard Category I vent system. Tank flue outlet is equipped with a closure device to close when the burner is shut off. Reduced standby heat loss when the burner is off.
- **GSWHs with Induced Draft or Fan-assisted** - Atmospheric burner with high efficiency baffling in the combustion chamber and/or flue. Better heat transfer and lower flue temperature thereby necessitating a small fan at the flue outlet to insure proper draft in the vent system. Acceptable for common, double wall, Category I, B-Vent. Electronic ignition.
- **GSWHs with Power Vent**[g] - Atmospheric burner with forced (fan) draft venting such that flue products temperature is reduced from blower dilution air. Vent system temperature acceptable for PVC vent pipe. Burner system includes electronic ignition.

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[e] The atmospheric direct vent design option is utilized in a small fraction of installations where the combustion air in the space is not adequate.

[f] There have been prototypes tested with bimetal and other vane type, unpowered dampers in the past. But there was no way to shut-off the water heater (mechanical) gas valve/control if the flue is shut off accidentally which creates a safety issue. In the past there was no interlock between damper and gas valve/control. I am not aware of any that have fostered a revision to the water heater Z21.10.1 safety standard. Nor am I aware of any unpowered dampers brought to market.

[g] Manufacturers also offer GSWHs with power direct vent for baseline GSWH design option, for installations where the combustion air in the space is not adequate.

For some power vent models that are designed for direct vent applications, an intake air connection is provided for piping combustion air from outside the structure.

- **Condensing GSWHs** - High efficiency burner system and flue with enhanced heat transfer surface. Some utilize a secondary heat exchanger. Flue outlet temperature is sufficiently low, with a dilution air blower, to allow PVC, ABS or CPVC vent pipe to be used. Electronic ignition. This higher efficiency condensing water heaters generate corrosive condensate as a byproduct of combustion and may necessitate treatment before disposal.
- **Mobile Home GSWHs** - There are currently two main types of water heater designs certified exclusively for mobile homes. Standard atmospheric, which must be installed in an outdoor access closet with louvered air openings and a direct vent, which is atmospheric but acquires its combustion air from outdoors. Both systems are meeting the minimum efficiency (baseline) designs and require specific vent systems certified with the water heater.

8D.5.2.2 New Construction

Typical Installation Steps. Typical installation steps for GSWHs that a plumber usually follows are shown in Table 8D.5.1. Assumption is that all gas and water lines in the house have been leak tested and that utilities are "OFF" in house. Leak test is done with an air charge in all piping with a pressure gage to determine any leaks that occur over an appropriate period of time.

For water heaters installed in new construction, the installation costs typically include putting in place and setting up the new water heater, adding a drain pan and piping, adding flue venting, connecting to a gas line branch, adding water piping, and adding T&P valve drain piping. Some installations may also require the installation of a water heater stand, the installation of an expansion tank, additional labor to install in up or down stairs location, and/or additional labor for special handling of GSWH with capacity over 55 gallons. Higher efficiency water heaters might also require an electrical outlet[h] and condensate disposal (including condensate drain and/or neutralizer filter).

[h] Assumption for the report is that the water heater needs to be no more than 6 ft. from the electrical outlet. Local codes and the design of the water heater (i.e., cord length) may impact the overall length.

Table 8D.5.1 Typical Installation Steps for GSWHs in New Construction

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Install water heater stand (if required)	Water heater stand (optional)
2	Install drain pan and any code or builder required accessories	Drain pan and piping
3	Uncarton new water heater and move to install location	Install water heater
4	Install electrical outlet (if required)	Electrical outlet (optional)
5	Lift and place water heater into drain pan at install location and line up fittings to existing stubbed piping	Install water heater
6	Install vent system (may be done in advance)	Flue vent system
7	Install air intake vent piping (if direct vent, may be done in advance)	Air intake vent piping
8	Make gas pipe connection to water heater gas control (note: install shutoff valve if nonexistent)	Gas piping
9	Make hot and cold water connections to water heater fittings (note: install shutoff valves if nonexistent)	Water piping
10	Install expansion tank (if required)	Expansion tank (optional)
11	Install T&P valve drain line	T&P valve drain piping
12	Install condensate pump (only if water heater is below the closest drain)	Condensate pump (optional)
13	Install condensate drain (if required)	Condensate drain (optional, only for condensing models)
14	Put in condensate neutralizer (if required)	Condensate neutralizer (optional, only for condensing models)
15	Install insulation jacket (if supplied with water heater)	Insulation jacket (used only if supplied from the water heater manufacturer in the water heater box)

At this point, the installation is done. When the house utilities are turned "ON", the following check-up steps apply as shown in Table 8D.5.2. This checklist is a list of essential steps to take for ensuring that the water heater is operating appropriately and in good condition. Some steps can be done concurrently. The additional labor hours to conduct this checkup could range from 30 minutes to 1 hour and are included as part of the installation of the water heater. These steps could occur before occupation as part of commissioning of the new construction. Once this check-up is complete, the next startup will be by either a plumber or gas company when the house is sold or fully operable and this cost is not included as part of the water heater installation costs.

Table 8D.5.2 Typical Post-Installation (Check-up) Steps for GSWHs in New Construction

No.	Typical Post-Installation Step
1	Remove access covers to burner area for burner start up process
2	Turn on gas supply to water heater and leak test all fittings
3	Turn on water supply to house
4	Open hot water faucet in house and fill water heater until water runs from faucet
5	Shutoff hot water faucet
6	Check all water connections for leaks
7	Initiate gas burner startup and check for proper burner operation
8	Clean install area and recheck for any leaks
9	Observe burner operation again and replace any removed covers
10	Turn off water heater gas control and close cold water inlet shutoff valve

Typical Installation Cost Items. In most cases, when plumbers quote plumbing for a new home, they include all water supply, waste and vent piping, gas piping, toilets, sinks, appliance connections, tubs, showers and all other plumbing related items including water heaters. For this report, costs of each water heater installation is estimated based on labor hours and materials needed. Table 8D.5.3 shows the engineering specifications for each installation line item.

Table 8D.5.3 Engineering Specifications for Typical New Construction Installation Items

Installation Items	Specifications/Requirements
Install water heater	Labor for setting up and putting into place a new water heater.
Drain pan and piping	22″ assumed, min. 2" deep, aluminum with drain opening and drain connector.
Flue vent system	20′ length assumed for vertical venting, but vent pipe material type, length, and diameter vary by water heater type. The cost could also include other vent components such as the vent termination. (See example tables below for more details)
Air intake vent piping (if direct vent model)	20′ length assumed for vertical venting, but vent pipe material type, length, and diameter vary by water heater installation instructions. The diameter is usually the same or larger than the flue vent piping. A manufacturer may allow a smaller intake pipe diameter but this would have to be outlined in the installation instructions provided with the water heater. The cost could also include other vent components such as the vent termination. (See example tables below for more details)
Gas piping	Threaded black gas pipe* and fittings, ½″ diameter for below 75 kBtu/h models, Schedule 40, 3′ length assumed off branch. (Sediment trap has been required in building codes for many years, so the assumption is that it is included as part of gas supply pipe installation).
Water piping	Copper pipe and fittings, most commonly ¾″ in diameters (½″ also used sometimes), 3′ length each for hot and cold water, 6′ length in total.
T&P valve drain piping	Plastic pipe and fittings, 4′ to floor drain or adequate drainage from water heater, ¾" PVC Schedule 40 water pipe.
Electrical outlet (120V)	Only when electricity is needed to power (induced draft, flue damper, power vent, and condensing models). 15 A, 120 V, duplex receptacle, can be a branch of an existing circuit (power requirements are typically 5 amps or less).
Power vent assembly	For some power vent water heaters.
Assisted fan assembly	For some induced draft/ fan assisted water heaters.
Condensate drain	Only for condensing and some power vent water heaters. Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Condensate pump	Only for condensing and some power vent water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater. The pump may require more piping.
Condensate neutralizer	Only for condensing water heaters. Specifications vary widely and manufacturers make reference to these products in their installation manual.
Insulation jacket	To meet the Federal water heater efficiency standards, some water heaters must be installed with an insulation jacket, which is supplied in the box with the water heater.
Water heater stand	Metal "knock down" design with four bolt-on legs. Other designs and materials are available.
Expansion tank	2 gallon, pre-charged, bladder type tank for tee mounting in the cold water line.
Up or down stairs	Plumbing contractors charge extra to move a water heater up or down a stairway. Some use a special motorized lift for this job.
Capacity over 55 gal. - special handling	Large water heaters are difficult to maneuver and lift. There may be extra cost to accommodate these large units.

*Flexible gas tubing (flexible copper tubing with outer plastic) is also used especially as part of an installation kit or building code requirement for earthquake areas.

The installation costs for each line item are based on the following assumptions:

- Install water heater (setting up and putting in place a new water heater) - Estimated by assuming that installing a standard size 40 gallon GSWH takes about 2 hours.[i] In general, the installation costs for 30 gallon to 50 gallon water heater sizes are very similar.
- Drain pan and piping - 22″ drain pan is assumed for a standard size 40 gallon water heater. Assumption is that an adequate drain is provided at the water heater installation location. Code requirements that mandate drain to outside or adequate floor drain may impose added costs not accounted for in the report.
- Flue vent system - In all cost tables below the average developed vent length (including vertical and horizontal components) is assumed to be 20 ft. The vent length varies significantly between different household types, water heater design options, and water heater installation locations. Plumbers are guided by a manufacturer installation manual, National Fuel Gas Code vent tables, and other building and safety codes to determine the exact flue vent length, diameter, and type of material needed.
- Gas piping - For gas piping, 3 feet length is assumed.[j] The length is developed considering all elbows, tees, valves, etc.
- Water piping - For water piping, the assumption is that there are "stubbed" hot and cold supply pipes in the area of the installation location. To join those stubs to the hot and cold fittings of the water heater would take an average of 3 feet equivalent of pipe each.
- Electrical outlet (120V) - In new construction, the electrical work is assumed to already be done as part of the overall building electrical work, so the cost of additional electrical outlets is not included in the new construction cost tables.
- T&P valve drain piping - For a 40 gallon tall gas water heater, the T&P valve is approximately 54" from the floor. Codes require the end of the drain pipe to be 6" off the floor drain. Thus 48" is assumed.
- Condensate drain - 6′ PVC pipe length is assumed based on the manufacturer not providing the pipe and the pipe going from the condensate outlet of the water heater to a drain close to the water heater.
- Condensate pump - Only for condensing and some power vent water heaters. A condensate pump may be necessary if the water heater is located below an adequate drain.
- Condensate neutralizer - Currently there is a wide spectrum of neutralizer filter products available on the market. The water heater manufacturer may make reference to specified products, criteria, or recommendations. The costs for the neutralizer filter assumes ½" PVC piping, fittings, and typical neutralizer unit from different sources.

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[i] For storage tank water heaters there are three standard sizes that are commonly installed in residential applications: 30 gallon, 40 gallon, or 50 gallon. For gas-fired storage tank water heaters 40 gallon is the most common (e.g., represents the most installed equipment or fraction of shipments). The standard sizes are rounded gallon capacities and don't represent a nominal or rated volume for a specific manufacturer.

[j] Note that natural gas and propane gas piping is the same for standard water heaters used in single family, since they are factory built either for natural gas or propane installations. Mobile home water heaters gas piping is different as discussed in the mobile home section.

- Expansion tank - Installation of expansion tanks has become more and more popular in the market, but not yet typical or common. Expansion tanks are needed in some cases to address water heater thermal expansion and water hammer issues. When shutting the faucet, because of the sudden change of the water flow, there will be vibration in the long runs of pipe. The expansion tank absorbs the water force. It usually requires a minimal labor hour. In common practice, anchoring the pipe also helps minimize the impact. The tank also absorbs any water expansion due to the water being heated by the water heater. This prevents seepage at the T&P valve if the heated water cannot expand and be relieved, anywhere else. All utility water meters are equipped with a check valve to prevent expanding water from entering the main water supply.

GSWH New Construction Installation Cost Examples. Based on the assumptions above, the following tables include an installation costs example for each of the GSWH designs. Plumbing materials such as solder, torch gas, flux, pipe dope, plastic pipe prep and glue, leak test liquid, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are included in the individual cost items such as drain pan and piping, water piping, flue vent system, and T&P valve drain piping.

Baseline GSWH Installation Cost Example. Table 8D.5.4 shows an example of an installation cost breakdown for baseline GSWH models in new construction. These water heaters require a Category I venting system using single wall or double wall Type B venting materials. No electrical work is required.

Table 8D.5.4 Example of Installation Costs for Baseline GSWHs: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	2.08	Ea.	$125	$0	1	$125
Flue vent system*	1 Plumber	-	per ft.	$9		20	$180
Water piping	1 Plumber	-	per ft.	$8		6	$48
Gas piping	1 Plumber	-	per ft.	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
						Total	**$472**
Additional Installation Costs (specific to Baseline GSWHs)							
Insulation jacket (if provided in water heater box)	1 Plumber	0.50	Ea.	$30	--	1	$30
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Roof vent cap and attach vent connector to water heater draft hood (4", type B galvanized vent pipe). Note that flue venting installation costs can vary significantly and the direct vent option requires a specialized vent kit.

Manufactures have developed some baseline water heater models with a smaller storage tank diameter that fit through tight spaces (such as small closet doors) that are installed onsite with an insulation blanket to be able to meet Federal water heater efficiency standards. The overall installation costs are similar to the baseline GSWHs costs but the insulation jacket (packaged with the water heater) takes approximately 1/2 hour to install. The other installation cost items in Table 2.4 are applicable to all GSWH designs but may not be applicable for all installation situations.

Baseline Direct Vent GSWH Installation Cost Example. There is a small fraction of installations where the combustion air in the space is not adequate (or is contaminated). In such cases, an atmospheric direct vent design offers the ability to draw combustion air from the outside utilizing a one-pipe dual-channel closed vent system. The overall installation costs are similar to the baseline GSWHs cost, but flue vent installation requirements are different. Please note that the opening through the wall used for the vent system would be part of the house construction and the plumber would install the vent system through that pre-constructed opening.

Table 8D.5.5 shows an example of an installation cost breakdown for Baseline Direct Vent GSWH models in new construction. The water heater and the vent system kit are sold together and there are direct vent kit size options. No electrical work is required.

Table 8D.5.5 Example of Installation Costs for Baseline Direct Vent GSWHs: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	2.08	Ea.	$125	$0	1	$125
Flue vent system	1 Plumber	2.00	per ft.	$120	NA*	1	$120
Water piping	1 Plumber	-	per ft.	$8		6	$48
Gas piping	1 Plumber	-	per ft.	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
						Total	**$412***
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Note this cost does not include the flue vent material, which is included as part of the equipment costs as a vent kit.

GSWHs with Flue Dampers Cost Example. Table 8D.5.6 shows the installation costs for new construction for gas-fired water heaters with an electrical flue damper. These water heaters require a Category I flue venting system using Type B vent and an electrical outlet for the flue vent damper. In new construction, the electrical work is assumed to already be done as part of the overall building electrical work. The installation costs and requirements are essentially the same as a baseline GSWH with added 120V, 15A duplex receptacle at site of installation (flue dampers operation typically require less than 5 amps). The flue damper must be an integral part of the water heater, as certified. The vent installation labor would be the same as a standard atmospheric (draft hood) type water heater since the vent connector is simply attached to the flue damper assembly.

Table 8D.5.6 Example of Installation Costs for GSWHs w/ Flue Damper: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	2.08	Ea.	$125	$0	1	$125
Flue vent system*	1 Plumber	-	per ft.	$9		20	$180
Water piping	1 Plumber	-	per ft.	$8		6	$48
Gas piping	1 Plumber	-	per ft.	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$472**
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Roof vent cap and attach vent connector to water heater draft hood (4" ID, galvanized, Type B vent (Category I)). Essentially the same parameters as a standard GSWH. Note that flue vent system installation costs can vary significantly.

GSWHs with Assisted Fan (Induced Draft) Cost Example. Installation costs for water heaters with assisted fans are summarized in Table 8D.5.7. These water heaters require a Category I flue venting system using double wall Type B vent and an electrical outlet for the induced draft fan. The purpose of the induced draft fan is to facilitate the flue venting through higher efficiency baffle and flue design, while still being able to vent using a Category I flue vent system. In new construction, the electrical work is assumed to already be done as part of the overall building electrical work. The installation costs and requirements are essentially the same as a baseline GSWH with added 120V, 15A duplex receptacle at site of installation (fan inducers typically require less than 5 amps).[k] The induced draft fan is an integral part of the water heater, as certified.[l] The vent installation labor would be the same as a standard atmospheric (draft hood) type water heater, since the vent connector is simply attached to the inducer outlet.

[k] If not included as part of the overall building electrical work, the additional cost for 120V in new construction could be up to one hour labor for an electrician and about $10 in material (10' 14-2 WG Romex wire - $3, 1 duplex wall box - $3, 1 15A duplex receptacle - $2, 1 duplex receptacle wall plate - $2).
[l] A lower efficiency design option from Bradford White uses an assisted fan and a draft hood.

Table 8D.5.7 Example of Installation Costs for GSWHs w/ Assisted Fan: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	2.08	Ea.	$125	$0	1	$125
Flue vent system*	1 Plumber	-	per ft.	$9		20	$180
Water piping	1 Plumber	-	per ft.	$8		6	$48
Gas piping	1 Plumber	-	per ft.	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$472**
Additional Installation Costs (specific to GSWHs w/ Assisted Fan)							
Assisted fan mounting (if required)	1 Plumber	0.25	Ea.	$15	--	1	$15
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Roof vent cap and attach vent connector to induced draft fan (4", galvanized, Type B vent (Category I)). Note that flue venting piping installation costs can vary significantly.

GSWHs with Power Vent Cost Example. Power Vent GSWHs require either a Category III (stainless steel vent system) or a Category IV flue venting system[m] using PVC venting materials and an electrical outlet. Almost all newer power vent systems are installed with a Cat. IV venting. These GSWHs are designed for use with PVC, ABS, CPVC venting materials by use of vent blower assemblies that introduce ambient air to dilute the flue products to lower temperatures. The flue gases temperature is reduced to under 200°F with dilution air. Power Vent GSWHs can have either a vertical or horizontal vent termination, which increases the amount of vent path possibilities that can be associated with a power vent GSWH unit (from shorter side wall venting to longer vertical vent lengths). The vent installation instructions are much more detailed than those of the baseline and fan assisted models. For the cost example tables, two installation cases are considered. 1) Vertical vent path (following the same vertical flue vent path as a Category I GSWH), with a total vent path length of 20 feet; and 2) a horizontal flue vent path, following a shorter horizontal vent path of 10 feet. Typically, contractors will choose the easiest and most cost effective flue vent path, but that there are several factors that they need to

[m] Note that some manufacturers label power vent water heaters as Category III, but for the purposes of this study the flue venting material is the same as a typical Category IV.

consider including existing building codes, any limitations of being able to have a vent termination through a horizontal wall, etc.

Table 8D.5.8 shows an installation cost example for new construction for vertically power vented water heaters. Table 8D.5.9 shows it for horizontally power vented water heaters. The labor hours needed to put in place and set up a power vented water heater is estimated to be around 3 hours, which is longer than baseline due to more complicated installation including access to electrical power, making any wiring connections, checking the correct function of control system and blower assembly, and handling an overall larger water heater.

In new construction, the electrical work is assumed to already be done as part of the overall building electrical work. Some models require the blower assembly to be mounted to the top of the water heater and the wiring connections to be made. Units that leave the factory mounted on top of the water heater require inspection of all electrical connections and ensuring a proper seal of the blower to the water heater. Some models have an external shroud that once attached covers the blower assembly. Many models also have a condensate drain tube (even though the condensate is not as acidic as a condensing water heater).[n]

[n] AO Smith's model includes the tubing to the drain condensate (which could terminate at the same place as the T&P drain). No neutralizer filter is necessary.

Table 8D.5.8 Example of Installation Costs for GSWHs w/ Power Vent (Vertically Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	3.00	Ea.	$180	$0	1	$180
Flue vent system*	1 Plumber	-	per ft	$7		20	$140
Water piping	1 Plumber	-	per ft	$8		6	$48
Gas piping	1 Plumber	-	per ft	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$487**
Additional Installation Costs (specific to GSWHs w/ Power Vent)							
Air intake vent piping (if direct vent model)**	1 Plumber	-	per ft.	$7		20	$140
Power vent assembly mounting (if required)	1 Plumber	0.50	Ea.	$30	--	1	$30
Condensate drain piping*** (if required)	1 Plumber	-	per ft.	$4		6	$24
Condensate pump (if no gravity drain available)****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* 3" PVC, suitable for water heater Category IV venting. Note that flue venting piping installation costs can vary significantly. 2”, 3”, and 4” PVC pipe diameter can be used, depending on input rate, equivalent vent length, and other considerations. I chose 3” because all the residential power vent models will work on 3” pipe.
** 3" PVC, assumed to be the same as the flue vent piping. It can be larger than 3”, but not smaller according to most installation manuals. There is a risk of “throttling” the burner for combustion air.
*** ½" PVC pipe for condensate drain where necessary.
**** The material cost includes $45 for the pump and $15 for piping.

Table 8D.5.9 Example of Installation Costs for GSWHs w/ Power Vent (Horizontally Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	3.00	Ea.	$180	$0	1	$180
Flue vent system*	1 Plumber	-	per ft	$7		10	$70
Water piping	1 Plumber	-	per ft	$8		6	$48
Gas piping	1 Plumber	-	per ft	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$417**
Additional Installation Costs (specific to GSWHs w/ Power Vent)							
Air intake vent piping (if direct vent model)**	1 Plumber	-	per ft.	$7		10	$70
Power vent assembly mounting (if required)	1 Plumber	0.50	Ea.	$30	--	1	$30
Condensate drain piping*** (if required)	1 Plumber	-	per ft.	$4		6	$24
Condensate pump (if no gravity drain available)****	1 Plumber	1.20	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* 3" PVC, suitable for water heater Category IV venting. Note that flue venting piping installation costs can vary significantly. 2”, 3”, and 4” PVC pipe diameter can be used, depending on input rate, equivalent vent length, and other considerations. I chose 3” because all the residential power vent models will work on 3” pipe.
** 3" PVC, assumed to be the same as the flue vent piping. It can be larger than 3”, but not smaller according to most installation manuals. There is a risk of “throttling” the burner for combustion air.
*** ½" PVC pipe for condensate drain where necessary.
**** The material cost includes $45 for the pump and $15 for piping.

When the combustion air in the space is not adequate (or is contaminated), a power direct vent design offers the ability to draw combustion air from the outside. Typically, these systems require a two pipe system (one for air intake and one for the combustion venting). The overall installation costs are similar to the power vent GSWH cost, but there is additional installation cost associated with the separate pipe for intake air. Thus, you must install a second pipe system for intake air, which is assumed to be similar to the flue venting cost for the standard power vent.

Condensing GSWHs Cost Example. Table 8D.5.10 and Table 8D.5.11 show the installation costs in new construction for condensing GSWHs. These water heaters require a Category IV flue venting system using PVC venting materials, an electrical outlet, condensate drain piping, and possibly a condensate neutralizer filter. Similar to power vent models, the labor hour needed to put in place and set up a condensing water heater is estimated to be around 3 hours, which is longer than the baseline. It is because of the larger size of condensing units, provision for treatment and drain of condensation, checking function of more complicated control system, and a more complex design overall. In new construction, the electrical work is assumed to already be done as part of the overall building electrical work. 20 ft flue venting is assumed for vertical through-the-roof venting and 10 ft flue venting is assumed for horizontal through-the-wall venting.

Installation of this type of water heaters is similar to that of power vent water heaters except that the blower assembly is factory installed. However, because this product has enhanced heat transfer technology for improved efficiency and low flue outlet temperatures, accumulating condensation must be piped to an acceptable drain. Many local codes require neutralizing of the corrosive condensate before it can be drained into city sewer. Even though some manufacturers provide a small diameter vinyl drain tube, ⅜ or ½" PVC pipe may be required with an acid neutralizer module to comply with codes. That is assumed with this installation.

Table 8D.5.10 Example of Installation Costs for Condensing GSWHs (Vertically Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	3.00	Ea.	$180	$0	1	$180
Flue vent system*	1 Plumber	-	per ft	$7		20	$140
Water piping	1 Plumber	-	per ft	$8		6	$48
Gas piping	1 Plumber	-	per ft	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft	$4		4	$16
Condensate drain**	1 Plumber	-	per ft.	$4		6	$24
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$511**
Additional Installation Costs (specific to GSWHs Condensing)							
Air intake vent piping (if direct vent model)***	1 Plumber	-	per ft.	$7		20	$140
Condensate neutralizer (if required)	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* 3" PVC, suitable for water heater Category IV vent. Note that flue venting piping installation costs can vary significantly. 2”, 3”, and 4” PVC pipe diameter can be used, depending on input rate, equivalent vent length, and other considerations. I chose 3” because all the residential condensing models will work on 3” pipe.
** ½" PVC pipe for condensate drain with connected neutralizer.
*** 3" PVC, assumed to be the same as the flue vent piping. It can be larger than 3”, but not smaller according to most installation manuals. There is a risk of “throttling” the burner for combustion air.
**** The material cost includes $45 for the pump and $15 for piping.

Table 8D.5.11 Example of Installation Costs for Condensing GSWHs (Horizontally Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	3.00	Ea.	$180	$0	1	$180
Flue vent system*	1 Plumber	-	per ft	$7		10	$70
Water piping	1 Plumber	-	per ft	$8		6	$48
Gas piping	1 Plumber	-	per ft	$11		3	$33
T&P valve drain piping	1 Plumber	-	per ft	$4		4	$16
Condensate drain**	1 Plumber	-	per ft.	$4		6	$24
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$30	1	$70
Electrical outlet (120V)	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$441**
Additional Installation Costs (specific to GSWHs w/ Power Vent)							
Air intake vent piping (if direct vent model)***	1 Plumber	-	per ft.	$7		10	$70
Condensate neutralizer (if required)	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)****	1 Plumber	1.20	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* 3" PVC, suitable for water heater Category IV venting. Note that flue venting piping installation costs can vary significantly. 2”, 3”, and 4” PVC pipe diameter can be used, depending on input rate, equivalent vent length, and other considerations. I chose 3” because all the residential power vent models will work on 3” pipe.
** ½" PVC pipe for condensate drain where necessary.
*** 3" PVC, assumed to be the same as the flue vent piping. It can be larger than 3”, but not smaller according to most installation manuals. There is a risk of “throttling” the burner for combustion air.
**** The material cost includes $45 for the pump and $15 for piping.

Similar to baseline direct vent GSWHs and power direct vent models, many condensing models can be installed with the piping for intake air. This offers the ability to draw combustion air from the outside for installations where the combustion air in the space is not adequate (or is contaminated). Some models are direct ventable and some are not. Concentric vent termination may be used.

Mobile Home GSWHs Cost Examples. GSWHs installed in new construction mobile homes follow a similar set of installation steps as a stick built new construction home. During the mobile home construction process, often the water heater is connected with the water piping when the floor of the home is without walls. The walls are added around the water heater, roof sections applied and the vent assembly is then added on top of the heater and the roof penetration is made and the roof jack installed. Keep in mind that this is an assembly line process starting with a fabricated framework/carriage assembly and progresses to a finished home so the people who install the water heaters are not necessarily licensed plumbers but line workers. This labor cost ($30/hr) is reflected in Table 8D.5.12 and Table 8D.5.13.

There are two baseline design options that are installed in mobile homes - atmospheric and direct vent:

- **Atmospheric design** is installed in about 60% of new mobile homes. It is installed in a closet with an outside door provided with louvers for ventilation. Water heater manufacturers installation instructions are strictly followed.
- **Direct vent design** is installed in about 40% of new mobile homes. They are installed in indoor space such as an indoor closet.

The mobile home new construction industry is a very cost sensitive industry. The home is built off a "bill of material" on an assembly line, in a very specific design. And the water heaters are certified to specific safety standards outlined in ANSI Z21.10.1. Space constraints, home design ,and requirements for convertibility from propane to natural gas and vice versa, limit the options for water heating types. All currently available mobile home water heaters are sold with a requirement to use a certified and approved venting kit. Propane is very common in mobile home installations, particularly in rural areas. Therefore, mobile home water heaters are shipped to the mobile home manufacturer set up for one type gas but have a gas control that is convertible and the conversion orifices for the main burner and pilot burner are attached to the water heater gas control. They all have to be field convertible. The flue vent kit, the dual fuel orifice kit and the convertible gas control makes the water heater more expensive than a standard GSWH for "stick built" homes.

An example of the installation costs for atmospheric mobile home GSWHs is shown in Table 8D.5.12. These water heaters require a Category I flue venting system with a roof jack certified for use with the water heater. The roof jack is available with telescoping tubes of different lengths, depending on the roof type and height.

Table 8D.5.12 Example of Installation Costs for Mobile Home (Atmospheric) GSWHs: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Line worker	1.10	Ea.	$33	--	1	$33
Flue vent system*	1 Line worker	0.70	Ea.	$21	$80	1	$101
Water piping**	1 Line worker	-	per ft.	$4		6	$24
Gas piping***	1 Line worker	-	per ft.	$8		2	$16
T&P valve drain piping	1 Line worker	-	per ft.	$2		4	$8
Drain pan and piping	1 Line worker	0.50	Ea.	$15	$30	1	$45
						Total	**$227**

Note: Labor rates for mobile home assembly line workers are on average $30/Hr.
* 3" Vent/Roof jack system specified in water heater certification. Purchased separately from the vent supplier.
** Polybutylene with crimp ring connections
*** ½" black steel threaded pipes

The installation costs for direct vent mobile home GSWHs are shown in Table 8D.5.13. These water heaters require a Category I flue venting system certified as part of the water heater and purchased from the water heater manufacturer. In addition, all combustion air is drawn from underneath the floor using a tube through the floor attached to the water heater base. No drain pan needed.

Table 8D.5.13 Example of Installation Costs for Mobile Home (Direct Vent) GSWHs: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Line worker	1.50	Ea.	$45	--	1	$45
Flue vent system*	1 Line worker	0.70	Ea.	$21	$0**	1	$21
Water piping***	1 Line worker	-	per ft.	$4		6	$24
Gas piping	1 Line worker	-	per ft.	$8		2	$16
T&P valve drain piping	1 Line worker	-	per ft.	$2		4	$8
						Total	**$114**

* 3" Vent/roof jack system specified in water heater certification. Purchased with direct vent water heater from the manufacturer.
** The certified vent/roof jack assembly comes with the water heater.
*** Polybutylene with crimp ring connections

Summary. Table 8D.5.14 through Table 8D.5.16 show the summary of the new construction installation costs for each of the gas-fired storage water heater technologies.

Table 8D.5.14 Summary Installation Items Checklist for GSWHs: New Construction

Installation Items	Baseline GSWH	Baseline Direct Vent	Flue Damper	Induced Draft	Power Vent	Condensing	Atmospheric (MH)	Direct Vent (MH)
Install water heater	X	X	X	X	X	X	X	X
Flue vent system	X	X	X	X	X	X	X	X
Water piping	X	X	X	X	X	X	X	X
Gas piping	X	X	X	X	X	X	X	X
T&P valve drain piping	X	X	X	X	X	X	X	X
Drain pan and piping	X	X	X	X	X	X	X	-
Electrical outlet (120V)*	-	-	X	X	X	X	-	-
Assisted fan or power vent assembly mounting	-	-	-	O	O	-	-	-
Condensate drain piping	-	-	-	-	O**	X**	-	-
Condensate neutralizer	-	-	-	-	-	O	-	-
Air intake vent piping	-	O***	-	-	O	O	-	-
Insulation jacket onsite	O	-	-	-	-	-	-	-

X = Required; O = Optional
* Electrical outlet (120V) required, but the cost in new construction is assumed to be zero, since the electrical work is assumed to already be done as part of the overall building electrical work.
** For power vent, condensate drain is not always required. For condensing some manufacturers provide a vinyl tubing, but PVC tube is usually needed to comply with codes.
*** Air intake and flue vent piping part of a concentric vent system.

Table 8D.5.15 Summary Installation Costs for GSWHs: New Construction

Water Heater Technology or Type	Total	Differential
Baseline GSWH	$472	-
with Insulation Jacket Option	$502	$30
Baseline Direct Vent GSWH**	$412**	-$60**
GSWH with Flue Damper*	$472	$0
GSWH with Assisted Fan (Induced Draft)*	$472	$0
+ Assisted Fan Mounting Required	$487	$15
GSWH with Power Vent (Vertical Flue Venting)*	$487	$15
+ Power Vent Mounting Required	$517	$45
+ Condensate Drain Piping Required	$511	$39
+ Power Vent Mounting and Condensate Drain Piping Required	$541	$69
with Direct Vent Option	$627	$155
+ Power Vent Mounting Required	$657	$185
+ Condensate Drain Piping Required	$651	$179
+ Power Vent Mounting and Condensate Drain Piping Required	$681	$209
Condensing GSWH (Vertical Flue Venting)*	$511	$39
+ Condensate Neutralizer Required	$606	$134
with Direct Vent Option	$651	$179
+ Condensate Neutralizer Required	$746	$274

* Electrical outlet (120V) required, but the cost in new construction is assumed to be zero, since the electrical work is assumed to already be done as part of the overall building electrical work.
** Note this cost does not include flue vent material. The vent system is supplied with, and is part of the purchase price of, the water heater and is specifically designed for the water heater. The atmospheric direct vent design option is utilized in a small fraction of installations where the combustion air in the space is not adequate. The assumption here is that the vent goes through the adjacent wall not vertically through the roof. Note that for all other models in this table, the costs represent the cases where the vent system goes vertically through the roof.

Table 8D.5.16 Summary Example of Installation Costs for Mobile Home GSWHs: New Construction

Water Heater Technology or Type	Total
Baseline Mobile Home GSWH (atmospheric)	$227
Baseline Mobile Home GSWH (direct vent)	$114*

* No drain pan. Vent/roof jack cost included with price of water heater.

8D.5.2.3 Replacement

Typical Replacement Steps. Typical replacement steps for installing new GSWHs in replacement applications (where the existing water heater is also a GSWH[o]) that a plumber usually follows are shown in Table 8D.5.17. For water heaters installed in replacements, the installation costs typically include basic trip charge, disconnecting and removing the existing water heater, putting in place and setting up the new water heater, municipal permit if required,

[o] Some of the assumptions and cost estimates are related to the replacement of existing 40 gallon standard size GSWH.

and haul away charge. Higher efficiency water heaters might also require an electrical outlet and condensate treatment and/or drainage. Some installations may also require the installation of a water heater stand, the installation of an expansion tank, additional labor to install in up or down stairs locations, and/or additional labor for special handling of GSWH with capacity over 55 gallons. Higher efficiency water heaters might also require a new flue vent system.

Table 8D.5.17 Typical Installation Steps for GSWHs: Replacement

No.	Typical Installation Steps	Corresponding Installation Cost Item
1	Check and clean space around old water heater	Install water heater
2	Confirm adequate space and utilities for new water heater	
3	Shutoff gas to the water heater and water supply to the house	Remove existing water heater
4	Connect drain hose to water heater, open cold water faucet in house and start draining water heater	
5	Disconnect vent connector pipe from draft hood	
6	Disconnect gas supply pipe from water heater gas control	
7	Disconnect cold and hot water pipe connections at water heater	
8	Disconnect T&P valve drain line, if existing	
9	Determine if existing drain pan is reusable	
10	After draining, disconnect drain hose and lift water heater out of drain pan and remove from house	
11	Determine the need for water heater stand, new vent connector, expansion tank, code req'd changes, etc.	Install water heater
12	Install an electrical outlet (if replacing with flue damper, assisted fan, power vent, or condensing models)	Electrical outlet (optional)
13	Uncarton new water heater and move to install location	Install water heater
14	Lift and place water heater into drain pan at install location and line up fittings to existing piping	
15	Remove access covers to burner area for later burner start up process	
16	Make gas pipe connection to water heater gas control (note: install shutoff valve if nonexistent)	
17	Make hot and cold water connections to water heater fittings (note: install shutoff valves if nonexistent)	
18	Install T&P valve drain line	
19	Install condensate drain (if replacing with condensing models)	Condensate drain (optional)
20	Put in condensate neutralizer (if replacing with condensing models)	Condensate neutralizer (optional)
21	Shutoff cold water faucet in house	Install water heater
22	Turn on water supply to house	
23	Open hot water faucet in house and fill water heater until water runs from faucet	
24	Shutoff hot water faucet	
25	Check all new water connections for leaks	
26	Install a new flue vent system (if replacing with power vent or condensing models)	Flue vent system (optional)

No.	Typical Installation Steps	Corresponding Installation Cost Item
27	Attach vent connector to water heater draft hood (for non-condensing options with draft hood)	
28	Initiate gas burner startup and check for proper burner operation	Install water heater (startup, post- installation checks and interaction with homeowner)
29	Clean install area and recheck for any leaks	
30	Observe burner operation again and replace any removed covers	
31	Instruct homeowner on pilot lighting instructions for the water heater	
32	Instruct homeowner to wait at least two hours before using hot water	

Typical Replacement Cost Items. Table 8D.5.18 shows the engineering specifications for typical installation items when replacing a water heater.

Table 8D.5.18 Engineering Specifications for Typical Replacement Installation Items

Installation Items	Specifications/Requirements
Basic trip charge	Plumbers charge for making a trip to the house to recover time for driving.
Removal of old water heater*	Labor to remove and disconnect the existing water heater. Typically, 1.5 hours is the total labor associated with taking out the existing product.
Removal of old vent system	Labor to remove existing vent system to make room for a new through-the-roof vertical venting. Note that if a new venting route is desired, the old vent may be capped.
Capping old vent system	Labor to cap the existing vent system when the existing water heater is commonly vented with an atmospheric vented gas furnace.
Install water heater	Labor for set-up and putting into place new water heater. This includes making gas and water pipe connections, installing vent connector, T&P drain tube, and materials to do so.
Municipal permit	It is common for replacement GSWH installations to require a "municipal permit". The cost of the permit varies by municipality. It can range from $30 to over $100 depending on municipality requirements.
Haul away	The existing water heater needs to be hauled away and disposed of, so the cost of disposal fee or "Haul Away" fee. Most garbage collection companies and municipal garbage collection will not haul away old water heaters. Plumbers are left to find a recycler or land fill that will accept the old products.
Flue vent system	For vertical venting, 20′ length is assumed. For baseline atmospheric direct vent water heaters, horizontal or vertical direct vent kits may be used and the venting assembly must be purchased for the specific direct vent model. For horizontal venting, 10′ length is assumed. Note that vent pipe material, length, and diameter could vary by water heater type and manufacturer. The cost could also include other vent components such as the vent termination. (See tables below for more details)
Wall penetration	For horizontal venting only. Assuming this is a wood frame house. Test drill first, check for any issues and then drill the final hole. It could be more complex for a non-wood frame.
Air intake vent piping (if direct vent model)	For power direct vent and condensing direct vent only. 20′ length assumed for vertical venting and 10′ length assumed for horizontal venting. Vent pipe material, length, and diameter could vary by water heater type. The cost could also include other vent components such as the vent termination. (See tables below for more details)

Installation Items	Specifications/Requirements
Electrical outlet (110V)	Only when electricity is needed to power induced draft, flue damper, power vent, and condensing, 15 A, 120 V, duplex receptacle, can be a branch of an existing circuit (power requirements are typically 5 amps or less).
Power vent assembly	For some power vent water heaters.
Assisted fan assembly	For some induced draft/ fan assisted water heaters.
Condensate drain	Only for condensing and some power vent water heaters. Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Condensate pump	Only for condensing and some power vent water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater. The pump requires more piping.
Condensate neutralizer	Only for condensing water heaters. Specifications vary widely and manufacturers make reference to these products in their installation manual.
Insulation jacket	For some baseline water heaters requiring that are installed onsite with an insulation blanket to be able to meet the Federal water heater efficiency standards.
Water heater stand	Metal "knock down" design with four bolt-on legs. Other designs and materials are available.
Expansion tank	2 gallon, pre-charged, bladder type tank for tee mounting in the cold water line.
Up or down stairs	Plumbing contractors charge extra to move a water heater up or down a stairway. Some use a special motorized lift for this job.
Capacity over 55 gal. - special handling	Large water heaters are difficult to maneuver and lift. There may be extra cost to accommodate these large units.

* Note that this cost could vary for different tank sizes, for example a 50 gallon tank will take longer to drain compared to a 40 gallon tank.

Note that compared to new construction cases, more labor hours for the cost item "install water heater" are usually needed for replacements. The extra labor hours include the additional complexity of doing a replacement installation versus a "more clean" new construction water heater installation. For example, for replacements we need to consider more time for planning for the job, making adjustments to the installation location, potential interruptions of the installation process, homeowner interactions (including providing instructions of how to use the new water heater), dealing with code compliance paperwork or checklist, etc. In addition, gas piping, water piping, and T&P valve installation costs are disaggregated in the new construction cost examples, while in replacement cost examples presented in this section, the assumption is that any simple adjustments required to the existing connections are included in the "install water heater" line item as part of the additional labor and the additional material cost.

The material cost of "install water heater" includes short lengths of water pipe, elbows, couplings, hot and cold fittings at water heater connections, and short black steel pipe and fittings to connect gas to the water heater. Solder, torch gas, flux, pipe dope, plastic pipe prep and glue, leak test liquid, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are also included. Sealant, fasteners, etc. would be covered in the install water heater cost. Tools of any kind needed for the installation are part of the cost of doing business ("basic trip charge").

GSWH Replacement Cost Examples. The following example installation cost tables assume replacing an existing baseline GSWH with a new GSWH. The typical installation costs below assume that the existing equipment to be replaced is a water heater installed in the last 15 years with a Category I flue venting system using single wall or double wall Type B venting materials. They also assume that the existing vent system, water piping, gas piping, metal stand, etc. are up to code, in good working condition, and do not need any modifications and that the combustion air is adequate. If the homeowner is replacing the existing water heater with a higher efficiency model, there is potentially a need for wiring an electrical outlet, new flue venting, condensate drain piping, and/or condensate neutralizer.

Baseline GSWHs. Installation costs for replacing with a baseline non-condensing gas-fired storage water heater are shown in Table 8D.5.19. These water heaters require a Category I flue venting system using Type B vent, which should be the same vent requirement as the existing water heater and typically requires no changes. The cost assumption is that the vent system is in good working condition and meets applicable codes.

Table 8D.5.19 Example of Installation Costs for Baseline GSWHs: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Install water heater	1 Plumber	2.25	Ea.	$135	$40	1	$175
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$420**
Additional Installation Costs (specific to baseline GSWHs)							
Insulation jacket (if provided in water heater box)	1 Plumber	0.50	Ea.	$30	--	1	$30
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

*Cost of doing business charge

Baseline Direct Vent GSWHs. Installation costs for replacing the existing baseline GSWH with a baseline non-condensing direct vent GSWH are shown in Table 8D.5.20. This direct vent design option requires the installation of a new vent kit for horizontal venting (including drilling a hole through the adjacent wall to allow the vent termination outside).

Table 8D.5.20 Example of Installation Costs for Baseline Direct Vent GSWHs: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Removal of old vent system	1 Plumber	1.50	Ea.	$90	--	1	$90
Install water heater	1 Plumber	2.25	Ea.	$135	$40	1	$175
Flue vent system	1 Plumber	2.00	Ea.	$120	--**	1	$120
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$630**
Additional Installation Costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** Vent kit material cost is included in the water heater cost.

GSWHs with Flue Dampers. In Table 8D.5.21, it shows the typical installation costs for a non-condensing gas-fired storage water heater with flue damper. The damper is assumed to be electrical. These water heaters require a Category I flue venting system using Type B vent (which should be the same as the existing water heater and typically requires no changes) and an electrical outlet for the flue vent damper. Since the existing water heater does not require an electrical outlet, an electrical outlet might not be available for the new water heater installation and needs to be installed.

Table 8D.5.21 Example of Installation Costs for GSWHs w/ Flue Damper: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	-	1	$90
Install water heater	1 Plumber	2.25	Ea.	$135	$40	1	$175
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$420**
Additional installation costs (specific to GSWHs w/ Flue Damper)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge

GSWHs with Assisted Fan (Induced Draft). In Table 8D.5.22, it shows the installation costs for GSWH models with an assisted fan. These water heaters require a Category I flue venting system using Type B vent (which should be the same as the existing water heater and typically requires no changes) and an induced draft fan that requires electricity. Since the existing water heater does not require an electrical outlet, an electrical outlet might not be available for the new water heater installation if there isn't an outlet nearby.

Table 8D.5.22 Example of Installation Costs for GSWHs w/ Assisted Fan: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	-	1	$90
Install water heater	1 Plumber	2.25	Ea.	$135	$40	1	$175
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$420**
Additional installation costs (specific to GSWHs w/ assisted fan)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Assisted fan mounting (if required)	1 Plumber	0.25	Ea.	$15	--	1	$15
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge

GSWHs with Power Vent. These power vent water heaters require a Category IV flue venting system using PVC venting materials and an electrical outlet for the power vent blower. Table 2.23 and Table 2.24 show two scenarios of typical replacement installation costs for GSWH with power vent. In Table 8D.5.23, it is assumed that the power vent water heater is vertically vented using the existing vent path after removing the existing metal vent, so the vent length of the new vent is assumed to run the same with the old, 3" PVC in a developed length of 20 feet, with elbows and outside termination fittings. Table 8D.5.24 shows a different case, where the previous water heater was commonly vented with a furnace and the power vent water heater is assumed to vent horizontally through the side wall. There are two main reasons to use this vent path: 1) it is the easiest and most cost effective, and 2) the temperature of the diluted flue products coming out of the power vent water heater is reduced to under 200°F making it unable to be vented through combined venting. For case 2), on average the total vent length is 10 feet total vent length, with the minimum amount of elbows and wall penetrations, assuming that the cost is for a typical wood frame house.

As described in the new construction section, some models require the blower assembly to be mounted to the top of the water heater and the wiring connections to be made and some models also have a condensate drain tube even though the condensate is not as acidic as a condensing water heater. There is also a power direct vent GSWH option that requires additional installation cost associated with the separate pipe for intake air.

Table 8D.5.23 Example of Installation Costs for GSWHs w/ Power Vent (Vertically Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Removal of old vent system**	1 Plumber	1.50	Ea.	$90	--	1	$90
Install water heater	1 Plumber	3.50	Ea.	$210	$40	1	$250
Flue vent system***	1 Plumber	-	Ea.	$7		20	$140
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$725**
Additional installation costs (specific to GSWHs w/ Power Vent)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Air intake vent piping (if direct vent model)****	1 Plumber	-	per ft.	$7		20	$140
Power vent assembly mounting (if required)	1 Plumber	0.50	Ea.	$30	--	1	$30
Condensate drain***** (if required)	1 Plumber	-	per ft.	$4		6	$24
Condensate pump (if no gravity drain available)******	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** This task requires taking out as much as they can of the Type-B vent. This process does not include removing the roof penetration.
*** 3" PVC, suitable for water heater Category IV venting, with a developed length of 20 feet, with elbows and outside termination fittings. This assumes the same run with PVC (so the same vent length) compared to the existing metal vent. The cost assumes the need to create a new roof penetration.
**** 3" PVC, assumed to be the same as the flue vent piping.
***** ½" PVC pipe for condensate drain where necessary.
****** The material cost includes $45 for the pump and $15 for piping.

Table 8D.5.24 Example of Installation Costs for GSWHs w/ Power Vent (Horizontally Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Capping old vent system**	1 Plumber	0.40	Ea.	$24	$15	1	$39
Install water heater	1 Plumber	3.50	Ea.	$210	$40	1	$250
Flue vent system***	1 Plumber	-	Ea.	$7		10	$70
Wall penetration	1 Plumber	0.85	Ea.	$50	$35	1	$85
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$689**
Additional installation costs (specific to GSWHs w/ power vent)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Air intake vent piping (if direct vent model)****	1 Plumber	-	per ft.	$7		10	$70
Power vent assembly mounting (if required)	1 Plumber	0.50	Ea.	$30	--	1	$30
Condensate drain***** (if required)	1 Plumber	-	per ft.	$4		6	$24
Condensate pump (if no gravity drain available)******	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** This task requires taking out as much as they can of the Type-B vent. This process does not include removing the roof penetration.
*** 3" PVC, suitable for water heater Category IV venting, with a developed length of 10 feet, with elbows and outside termination fittings.
**** 3" PVC, assumed to be the same as the flue vent piping.
***** ½" PVC pipe for condensate drain where necessary.
****** The material cost includes $45 for the pump and $15 for piping.

Condensing GSWHs. Installation costs for replacing non-condensing GSWH with a condensing GSWH are shown in Table 8D.5.25 and Table 8D.5.26. These water heaters require a Category IV flue venting system using PVC venting materials, an electrical outlet, condensate drain piping, and possibly a condensate neutralizer filter. In new construction, the electrical work is assumed to already be done as part of the overall building electrical work, while in replacement an electrical outlet will have to be installed if there is no outlet close to the new water heater. For this table, 20 ft flue vent is assumed for vertical through the roof venting and 10 ft flue venting is assumed for horizontal through the wall. There is also a direct vent option for condensing GSWH that requires additional installation cost associated with the separate pipe for intake air.

Table 8D.5.25 Example of Installation Costs for Condensing GSWHs (Vertically Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Removal of old vent system**	1 Plumber	1.50	Ea.	$90	--	1	$90
Install water heater	1 Plumber	3.50	Ea.	$210	$40	1	$250
Flue vent system***	1 Plumber	-	Ea.	$7		20	$140
Condensate drain****	1 Plumber	-	per ft.	$4		6	$24
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$749**
Additional installation costs (specific to condensing GSWHs)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Air intake vent piping (if direct vent model)*****	1 Plumber	-	per ft.	$7		20	$140
Condensate neutralizer (if required)	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)******	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
**This task requires taking out as much as they can of the Type-B vent. This process does not include removing the roof penetration.
*** 3" PVC, suitable for water heater Category IV venting, with a developed length of 20 feet, with elbows and outside termination fittings. This assumes the same run with PVC (so the same vent length) compared to the existing metal vent. The cost assumes the need to create a new roof penetration.
**** ½" PVC pipe for condensate drain.
*****3" PVC, suitable for water heater Category IV vent.
****** The material cost includes $45 for the pump and $15 for piping.

Table 8D.5.26 Example of Installation Costs for Condensing GSWHs (Horizontally Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Capping old vent system**	1 Plumber	0.40	Ea.	$24	$15	1	$39
Install water heater	1 Plumber	3.50	Ea.	$210	$40	1	$250
Flue vent system***	1 Plumber	-	Ea.	$7		10	$70
Wall penetration	1 Plumber	0.85	Ea.	$50	$35	1	$85
Condensate drain****	1 Plumber	-	per ft.	$4		6	$24
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$713**
Additional installation costs (specific to condensing GSWHs)							
Electrical outlet (120V) (if required)	1 Electrician	4.42	Ea.	$265	$45	1	$310
Air intake vent piping (if direct vent model)*****	1 Plumber	-	per ft.	$7		10	$70
Condensate neutralizer (if required)	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)******	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all GSWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** The existing water heater is assumed to be commonly vented with an atmospheric furnace. This task requires taking out the old vent up to the common vent joint and patching up the common vent.
*** 3" PVC, suitable for water heater Category IV venting, with a developed length of 10 feet, with elbows and outside termination fittings.
**** ½" PVC pipe for condensate drain where necessary.
***** 3" PVC, assumed to be the same as the flue vent piping.
****** The material cost includes $45 for the pump and $15 for piping.

Mobile Home GSWHs. GSWHs installed in mobile homes in replacements follow a similar set of installation steps as in that of a stick-built home. For replacements, the laborer is not necessarily a licensed plumber. Building codes are different. For example, Mobile Home Parts Distributors sell and install water heaters in mobile homes but they aren't licensed plumbers. Thus $40/hr labor is assumed in the following tables based on the assumption that the laborer is a non-licensed but knowledgeable service employee.

The mobile home water heaters are certified to specific safety standards outlined in ANSI Z21.10.1 for use in mobile homes. Similar to new construction there are two baseline design options that are installed in mobile homes: atmospheric and direct vent. The fractions of installation for each are the same for new construction and replacements, which are 60% atmospheric and 40% direct vent. Note that the mobile home market is very different from the stick-built home market. Mobile home owners normally will only do like-kind replacements. So the assumption is that the atmospheric model is replaced with a new atmospheric model and the direct vent model is replaced with a new direct vent water heater.

The installation costs for atmospheric mobile home GSWHs are shown in Table 8D.5.27. The water heater is installed in a louvered door outside-access closet, thus access is much better and changeout is simpler. These atmospheric water heaters require a Category I flue venting system with certified roof jack. The roof jack/vent system must be of the design certified for use with the new water heater and be installed with the new water heater. The installer must purchase the new roof jack/vent system separately. The roof jack is available with telescoping tubes and in different lengths, depending on the roof type and height, and the vent connector comes with the installation kit. In the following table, assumption is that the old roof jack needs to be replaced.

Table 8D.5.27 Example of Installation Costs for Mobile Home (Atmospheric) GSWHs: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Removal of old water heater	1 Service Employee	0.75	Ea.	$30	--	1	$30
Install water heater	1 Service Employee	1.50	Ea.	$60	$30	1	$90
Removal of old and Installation of new roof jack/ vent system*	1 Service Employee	2.00	Ea.	$80	$80	1	$160
Haul away	1 Service Employee	Ea.		$35	--	1	$35
						Total	**$315**
Additional installation costs (specific to mobile home atmospheric GSWHs)							
Drain pan and piping	1 Service Employee	0.30	Ea.	$12	$30	1	$42
Gas piping**	1 Service Employee	0.25	per ft.	$10		2	$20
Water piping ***	1 Service Employee	-	per ft.	$6		6	$36
T&P valve drain piping	1 Service Employee	-	per ft.	$2		4	$8

* Applicable if the old roof jack has to be replaced. If not replaced, no added cost. 3" vent/roof jack system specified in water heater certification. Typical 32" roof jack with telescoping 3" connector tube. Note the 32" measurement is the maximum space between the ceiling and roof surface.
** ½" black steel threaded
*** Polybutylene with crimp ring connections

The replacement installation costs for direct vent mobile home GSWHs are shown in Table 8D.5.28. These water heaters require a Category I flue venting system with no draft hood. For the flue vent system, there is no material cost, since the roof jack is included in the purchase of the water heater. In addition, all combustion air is drawn from underneath the floor using a tube through the floor attached to the water heater base. Any leaking water will also go out the air inlet tube and no drain pan is needed in this case.[p] The removal of the existing water heater and installation of the new water heater for direct vent mobile home GSWHs is more labor intensive than for atmospheric mobile home GSWHs, since the water heater is typically installed indoors (usually an indoor closet), compared to an atmospheric mobile home GSWHs which is typically installed in an outdoor closet and does not require indoor access by the installer.

[p] Some mobile home direct vent manuals show a drain pan, but any water leaking into the pan will go out the air inlet tube. The drain pan would have to be cut out for the intake tube to pass through it. Therefore, even though it is shown it will not be used since the water leak will exit through the inlet tube in the floor.

Table 8D.5.28 Typical Installation Costs for Mobile Home (Direct Vent) GSWHs: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Removal of old water heater	1 Service Employee	1.00	Ea.	$40	--	1	$40
Install water heater	1 Service Employee	2.50	Ea.	$100	$35	1	$135
Removal of old and installation of new roof jack/ vent system*	1 Service Employee	2.00	Ea.	$80	--**	1	$80
Haul away	1 Service Employee	Ea.		$35	--	1	$35
						Total	$290
Additional installation costs (specific to mobile home direct vent GSWHs)							
Gas piping	1 Service Employee	-	per ft.	$10		2	$20
Water piping ***	1 Service Employee	-	per ft.	$6		6	$36
T&P valve drain piping	1 Service Employee	-	per ft.	$2		4	$8

* Roof Jack/Vent System must be replaced. 3" Vent/roof jack system specified in water heater certification. Purchased as part of the price of the Direct Vent water heater from the manufacturer.
** The vent/roof jack assembly comes with the water heater.
*** Polybutylene with crimp ring connections

Propane gas is very common in mobile homes, particularly in rural areas. Therefore, mobile homes water heaters are shipped with both natural and propane gas orifices in the installation kits. The water heater also has a convertible gas control for either gas type since they all have to be field convertible. The water heater is shipped already set-up by the water heater manufacturer for the specific gas that is ordered and stocked in the contractor business site. If one client needs a certain gas type of water heater that happens to be out of stock, the contractor will need to do the gas setup conversion at the contractor business site before delivering and installing the water heater.[q] At the contractor business site the conversion can take about 30 minutes, while on the job site it can take 45 minutes to one hour. The main labor effort is due to having to take out burner assembly and reinstall the burner assembly with the correct burner orifices. The orifices are generally located in a bag with instructions tied to the water heater gas control. However, this conversion cost is not paid by the consumer, but is absorbed by the contractor who is performing the installation. So it has no direct impact on the replacement cost itself.

Summary of Installation Cost for GSWH in Replacements. To sum up, Table 8D.5.29 shows the replacement installation costs for each product model. Models with power vents usually need new venting which leads to increased costs compared to baseline water heaters.

[q] One difference between mobile home water heaters and standard water heaters, is that the standard water heater will either be propane or natural gas only (not convertible), while the mobile home water heater will be convertible.

Condensing GSWH requires installation of new venting, electrical outlets, and neutralizer, so it comes out to be the most expensive replacement option.

Table 8D.5.29 Summary Installation Costs for GSWHs: Replacement

Water Heater Technology or Type	Total	Differential
Baseline GSWH (Minimum Efficiency, Atmospheric)	$420	-
with Insulation Jacket Option	$450	$30
Baseline GSWH (Minimum Efficiency, Direct Vent)	$630	$210
GSWH with Flue Damper	$420	$0
+ Electrical Outlet if Required	$730	$310
GSWH with Assisted Fan (Induced Draft)	$420	$0
+ Assisted Fan Mounting Required	$435	$15
+ Electrical Outlet if Required	$730	$310
+ Assisted Fan Mounting Required	$745	$325
GSWH with Power Vent (Vertical Flue Venting)*	$725	$305
+ Power Vent Mounting Required	$755	$335
+ Condensate Drain Piping Required	$749	$329
+ Power Vent Mounting and Condensate Drain Piping Required	$779	$359
+ Electrical Outlet if Required	$1035	$615
with Direct Vent Option	$865	$445
+ Power Vent Mounting Required	$895	$475
+ Condensate Drain Piping Required	$889	$469
+ Power Vent Mounting and Condensate Drain Piping Required	$919	$499
+ Electrical Outlet if Required	$1175	$755
Condensing GSWH (Vertical Flue Venting)*	$749	$329
+ Condensate Neutralizer Required	$844	$424
+ Electrical Outlet if Required	$1059	$639
with Direct Vent Option	$889	$469
+ Condensate Neutralizer Required	$984	$564
+ Electrical Outlet if Required	$1199	$779

*Only shows costs for vertical venting cases.

Table 8D.5.30 shows a summary of the replacement costs in mobile homes. For the atmospheric model, we assume that the contractor has to buy a new vent kit for this replacement. Drain pan, gas, water, and T&P valve piping are assumed to be in good working condition.

Table 8D.5.30 Summary Installation Costs for Mobile Home GSWHs: Replacement

Water Heater Technology or Type	Total
Baseline Mobile Home GSWH (atmospheric)*+	$315
Baseline Mobile Home GSWH (direct vent)**+	$290

*Assume that the roof jack kit has to be replaced. Note that the roof jack kit includes everything from the top of the water heater to the vent cap above the roof.
+The roof jack assembly is an added cost component for atmospheric mobile home water heater. The roof jack assembly comes with the direct vent mobile home water heater and is part of the purchase price.
**No drain pan needed.

8D.5.3 Electric Storage Water Heaters

8D.5.3.1 Electric Storage Water Heater Technology Description

Electric storage water heaters (ESWHs) are separated into four distinct groups based on their rated volumes:

- models with rated volume at or above 20 gallons and at or below 55 gallons,
- models with rated volume above 55 gallons,
- models with rated volume above 75 gallons, and
- models with rated volume below 20 gallons,

where models with rated volume ≥ 20 gallons and ≤ 55 gallons are the most common. ESWHs come with multiple tank designs. There are tall, medium, lowboy, table top, compact, and point of use options available. Compact models are usually below 20 gallons and can only be used for potable water heating. Even smaller than that, point of use models have nominal 2.5 to 6 gallons tanks. Table tops can provide extra counter space. Low boy presents a low profile large diameter design suited for installation with height constraints.

In this chapter, the following electric storage water heater designs are considered:

- **Baseline ESWHs** (between 20 to 55 gallons) - Storage tank with dual heating elements (4,500 watt).
- **Heat pump ESWHs** (between 20 to 55 gallons, higher efficiency option) - Storage tank with back-up heating element and closed loop reverse cycle refrigerant heating system as primary heat source.
- **Baseline mobile home ESWHs** (between 20 to 55 gallons) - Most mobile home manufacturers use tall version electric water heaters with side tapings for water connections, and the electrical connection, since the piping and electrical supply come up through the floor.
- **Baseline heat pump ESWHs** (above 55 gallons) - Storage tank with back-up heating element and closed loop reverse cycle refrigerant heating system as primary heat source.
- **Baseline grid-enabled ESWHs** (above 75 gallons) - Similar to Baseline ESWH (between 20 to 55 gallons) design, but with a control system that is Utility controlled. The Utility can disconnect the electricity to some or all the heat sources. This water heater type needs to be equipped at the point of manufacture with an activation lock to meet the federal standard for the grid-enabled product class criteria.
- **Grid-enabled heat pump ESWHs** (above 75 gallons, higher efficiency option) - Similar to hybrid/ heat pump but with a control system that is utility controlled. The utility can disconnect the electricity to some or all the heat sources. This water heater type needs to be equipped at the point of manufacture with an activation lock to meet the federal standard for the grid-enabled product class criteria.
- **Baseline tabletop[r] (dimension specific - about 30 gallon)** - Usually located in the kitchen or laundry area. Typical dimensions of 36 inches high, 25 inches deep, and 24

[r] In the vast majority of cases, this product replaces one of the same design but possibly less efficient than the new.

inches wide and are designed to be installed as part of a countertop in a kitchen for example.

- **Baseline compact or point of use (below 20 gallon)** - Small storage tank models with side water and electrical connections. Usually installed as a supplemental hot water source. Inside cabinets or on shelves.

All residential electric water heaters are compliant with HUD standards for mobile home/manufactured housing. However, most mobile home manufacturers use electric models with side connections for water and electrical supply.

8D.5.3.2 New Construction

Typical Installation Steps. Typical installation steps for ESWHs that a plumber usually follows are shown in Table 8D.5.31.

For water heaters installed in new construction, the installation costs typically include installing a drain pan with piping, putting in place and setting up the new water heater, connecting water piping and T&P valve drain piping, and making electrical connections. Some garage or utility area installations may also require the installation of a water heater stand. The install could also include the installation of an expansion tank, additional labor to install the unit up or down stairs, and/or additional labor for special handling of ESWH with capacity over 55 gallons. Some heat pump water heaters might also require an addition of a condensate pump and longer water line to the drain if the water heater is installed below an adequate drain.

Table 8D.5.31 Typical Installation Steps for ESWHs in New Construction

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Install water heater stand (if required)	Water heater stand (optional)
2	Install drain pan and any code or builder required accessories	Drain pan and piping
3	Uncarton new water heater and move to install location	Install water heater
4	Lift and place water heater into drain pan at install location and line up fittings to existing stubbed piping	
5	Make hot and cold water connections to water heater fittings (note: install shutoff valves if nonexistent)	Water piping
6	Make electrical connection to home wiring.	Install water heater
7	Install expansion tank (if required)	Expansion tank (optional)
8	Install T&P valve drain line	T&P valve drain piping
9	Install condensate drain (only for heat pump models)	Condensate drain (optional)
10	Install insulation jacket (if supplied with water heater)	Insulation jacket (used only if supplied from the water heater manufacturer in the water heater box)

At this point, the installation is done. When the house utilities are turned "ON", the following check-up steps apply as shown in Table 8D.5.32. Similar to GSWH, this checklist is a list of essential steps to take for ensuring the water heater is operating appropriately and in good condition. Some steps can be done concurrently. The additional labor hours to conduct this checkup could range from 30 minutes to 2 hour and included as part of the installation of the water heater. These steps could occur before occupation as part of commissioning of the new construction.

Table 8D.5.32 Typical Post-Installation (Check-up) Steps for ESWHs in New Construction

No.	Typical Post-Installation Step
1	Turn on water supply to house
2	Open hot water faucet in house and fill water heater until water runs from faucet
3	Shutoff hot water faucet
4	Turn on circuit breaker to water heater and allow heating for at least one hour
5	Once heating of water is confirmed, turn off circuit breaker
6	Check all water connections for leaks
7	Clean install area and recheck for any leaks
8	Turn off water heater breaker and close cold water inlet shutoff valve

Typical Installation Cost Items. Table 8D.5.33 shows the specifications for each of the typical installation line items for installing electric storage water heaters in new construction. It is assumed in new construction that the electrical supply is already provided by the electrician when the house is constructed. This is part of the overall electrical wiring for the home.

Table 8D.5.33 Engineering Specifications for Typical New Construction Installation Items

Installation Items	Specifications/Requirements
Install water heater	Labor for set-up and putting into place new water heater and making electrical connections. For heat pump models it also includes additional labor for operational verification of the heat pump section after installation, proper function of compressor, evaporator fan, circulation pump, and control system.
Drain pan and piping	Sized at least 4" larger in diameter than the diameter of the water heater and no more than 3" in depth. For this study, the drain pan is assumed to be of aluminum material with drain-pipe connector.
Water piping	Copper pipe and fittings, most commonly ¾″inch in diameter (½″ also used sometimes), 3′ length each for hot and cold water, 6′ length in total.
T&P valve drain piping	Plastic pipe and fittings ending 6 inches above the floor, floor drain, or adequate drainage for water, ¾" PVC Schedule 40 water pipe.
Electric connection	Typically, 240V, 30A, service. Some models may use 120V, 20A, service. All must be connected to a dedicated circuit breaker. Models under 6 gallon may be equipped with line cord and plug for 15A wall receptacle.
Condensate drain	Only for heat pump water heaters. Some manufacturers supply a length of vinyl tubing for drainage which may or may not meet code requirements. The assumption is to use PVC for this purpose. Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Condensate pump	Only for heat pump water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater. Generally, the water heating heat pump generates more condensation than a condensing or power vent gas water heater.
Control equipment	Grid enabled models may require connections to utility control equipment.
Wiring harness and connectors	Some hybrid/heat pump and grid enabled models may require connections of a wiring harness to connect utility components of the water heater.
Insulation jacket (if required)	To meet the Federal water heater efficiency standards, some water heaters must be installed with an insulation jacket, which is supplied in the box with the water heater.
Water heater stand (if required)	Metal "knock down" design with four bolt-on legs. Other designs and materials are available.
Expansion tank (if required)	2 gallon, pre-charged, bladder type tank with a tee mounting in the cold water line.
Up or down stairs (if required)	Plumbing contractors charge extra to move a large or heavy water heater up or down a stairway. Some use a special motorized lift for this job.
Capacity over 55 gal. - special handling (if required)	Large water heaters are difficult to maneuver and lift. There may be extra cost to accommodate these large units.

The installation costs for each line item are based on the following assumptions:

- Installation of water heater (setting up and putting in place a new water heater, making electrical connection) - Estimated by assuming that the labor is about 1.5 to 2 hours for installing a 30 to 50 gallon standard size baseline ESWH. Higher efficiency models require more time to install them. See example tables for more details.

- Drain pan and piping - A drain pan is assumed to be sized appropriately for each ESWH group. Assumption is that an adequate drain is provided at the water heater installation location. Code requirements that mandate drain to outside or adequate floor drain may impose added costs not accounted for in this study.
- Water piping - For water piping, the assumption is that there are "stubbed" hot and cold supply pipes in the area of the installation location. To join those stubs to the hot and cold fittings of the water heater would take an average of 3 feet equivalent of pipe each.
- Electrical connection - In new construction, the electrical work is assumed to already be done as part of the overall building electrical work, so the cost of additional electrical outlets is not included in the new construction cost tables.
- T&P valve drain piping - For each ESWH group, the T&P valve drain pipe is sized accordingly to accommodate codes that require the end of the drain pipe to be 6" above the floor drain.
- Condensate drain - Only for heat pump models. The pipe length is assumed based on the manufacturer not providing the pipe and the pipe going from the water heater to a drain. There may be one manufacturer that provides a flexible vinyl tubing. However, it may not meet the code.
- Condensate pump - Only for heat pump models. The condensate pump is required if no gravity drain is available.

ESWH New Construction Installation Costs Examples. Based on the assumptions above, the following tables include an installation cost example for each of the ESWH designs. The labor cost for the "install water heater" line item includes setting up the water heater, making electrical connections, and potential heat pump related check-ups for higher efficiency models which may involve more labor. Plumbing materials such as solder, flux, pipe dope, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are included in the individual cost items such as drain pan and piping, water piping, and T&P valve drain piping.

Baseline ESWH (≥20 and ≤55 gals) Installation Cost Example. Table 8D.5.34 shows an example of an installation cost breakdown for baseline ESWH models in new construction. For the ESWH (≥20 and ≤55 gals) group, standard size is assumed to be 50 gallons.[s] In general, the installation costs for other water heater sizes is the same or very similar. In new construction, assumption is that electrical work has been done and there is 240V, 30A electrical connection near the water heater.

[s] Other standard sizes such as 30 and 40 gallon are also common.

Table 8D.5.34 Example of Installation Costs for Baseline ESWHs (≥20 and ≤55 gals): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	1.67	Ea.	$100	--	1	$100
Water piping	1 Plumber	-	per ft.	$8		6	$48
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping**	1 Plumber	0.67	Ea.	$40	$30	1	$70
						Total	**$234**
Additional installation costs (specific to baseline ESWHs)							
Insulation jacket (if provided in water heater box)	1 Plumber	0.50	per ft.	$30	--	1	$30
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 28" diameter drain pan. Assumed 24" water heater diameter.

Heat Pump ESWH (>20 and <55 gals) Installation Cost Example. Table 8D.5.35 shows an example of an installation cost breakdown for 20-55 gallons HPWH models in new construction. When installed in an indoor closet either a louvered door or ducting could be required for HPWH, as the surrounding supply air in a confined space is not sufficient for the heat pump operation. Heat pump water heaters produce cold air that can increase heating loads when installed in a conditioned space during heating season. For the cost example, the HPWH is assumed to be installed in a space where ambient air cooling and/or supply air is not an issue.

The HPWH is assumed to be the same size (50 gallons) as the baseline ESWH. Condensate drain of 6′ length is assumed. Provision of drainage beyond that is with a condensate pump if no gravity drain is available. The condensate is not corrosive, so a neutralizer is not necessary. In new construction, assumption is that electrical work has been done and there is 240V, 30A electrical junction near the water heater. Heat pump models require higher labor cost to install because it includes additional labor for operational verification of the heat pump section, proper function of compressor, evaporator fan, circulation pump, and control system after installation.

Table 8D.5.35 Example of Installation Costs for Heat Pump ESWHs (>20 and <55 gals): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	2.50	Ea.	$150	--	1	$150
Water piping	1 Plumber	-	per ft.	$8		6	$48
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Condensate drain	1 Plumber	-	per ft	$4		6	$24
Drain pan and piping**	1 Plumber	0.67	Ea.	$40	$30	1	$70
						Total	**$308**
Additional installation costs (specific to HPWH 20 to 55 Gal.)							
Condensate pump (if no gravity drain available)	1 Plumber	1.20	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* This includes making wiring connections to the house electrical system and additional heat pump related labor. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 28” diameter drain pan. Assumed 24” water heater diameter.

Mobile Home ESWH (>20 and <55 gals). Similar to GSWHs, ESWHs installed in new construction mobile homes follow a similar set of installation steps as a stick built new construction home. During the mobile home construction process, often the water heater is connected with the water piping when the floor of the home is without walls. The walls are added around the water heater and roof sections are applied. Most mobile home ESWHs use side plumbing, since plumbing is coming from the floor (to reduce overall plumbing length). Keep in mind that this is an assembly line process starting with a fabricated framework/carriage assembly and progresses to a finished home, so the people who install the water heaters are not necessarily licensed plumbers but line workers. This labor cost ($30/hr) is reflected in the following table.

The electrical storage baseline design is usually installed in a closet in mobile homes.[t] The standard size for mobile home electrical water heater products is assumed to be 30 gallons.[u] The electrical requirements for a small mobile home (800 sq. ft. or less) may be 120V, 15A circuit (1650W single heating element). For a larger mobile home (over 800 sq. ft.) 240V, 30A

[t] Mobile home ESWHs are installed in wall cavities or closets, mostly indoors, but sometimes they are installed in outside access closets.
[u] 40 gallon is also a common standard water heater size for mobile home ESWHs, but 20 gallons was also common in the past with smaller mobile home sizes (they were labeled as “park” models for smaller mobile homes, but they represent a very small fraction of the mobile home market now).

electric service is required (for the larger 3500W or 4500W dual heating element). An example of the installation costs for mobile home ESWHs are shown in Table 8D.5.36.

Table 8D.5.36 Typical Installation Costs for Mobile Home ESWHs (>20 and <50 gals): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Line Worker	0.77	Ea.	$23	--	1	$23
Drain pan and piping	1 Line Worker	0.50	Ea.	$15	$30	1	$45
Water piping*	1 Line Worker	-	per ft.	$4		6	$24
T&P valve drain piping	1 Line Worker	-	per ft.	$2		4	$8
Electrical connection	1 Line Worker	0.27	Ea.	$8	--	1	$8
						Total	**$108**

Note: Labor rates for Mobile Home assembly line workers are on average $30/Hr.
* Polybutylene with crimp ring connections

Baseline Heat Pump ESWH (>55 gals) Installation Cost Example. Among water heaters with rated volume above 55 gallons, HPWHs represent the baseline and all different HPWH efficient options are assumed to have the same installation costs. For the ESWH (>55 gals) group, standard size is assumed to be 80 gallons.[v] Table 8D.5.37 shows the costs breakdown for the baseline HPWHs. In new construction, assumption is that electrical work has been done and there is 240V, 30A electrical outlet near the water heater.

[v] Other standard sizes such as 40, 50 and 65 gallons are also common.

Table 8D.5.37 Example of Installation Costs for Baseline Heat Pump ESWHs (>55 gals): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	2.50	Ea.	$150	--	1	$150
Water piping**	1 Plumber	-	per ft.	$8		8	$64
T&P valve drain piping	1 Plumber	-	per ft.	$4		5	$20
Condensate drain	1 Plumber	-	per ft.	$4		6	$24
Drain pan and piping***	1 Plumber	0.67	Ea.	$40	$40	1	$80
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$413**
Additional installation costs (specific to HPWH over 55 gal.)							
Condensate pump (if no gravity drain available)****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* This includes making wiring connections to the house electrical system and additional heat pump related labor. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 8 ft of water pipe is assumed, since the larger than 55 gallon HPWHs are taller and larger in diameter compared to the below 55 gallon HPWHs, so more pipe length is needed to make the water pipe connections.
*** 30” diameter drain pan. Assumed 26” water heater diameter.
**** The material cost includes $45 for the pump and $15 for piping.

Baseline Grid-enabled ESWH (>75 gals) Installation Cost Example. Table 8D.5.38 shows an example of an installation cost breakdown for grid-enabled ESWH models in new construction. For the grid-enabled ESWH (>75 gals) group, standard size is assumed to be 80 gallons.[w] There are different requirements from utilities that affect the internal wiring of the water heater. This estimate is based upon utility control of heating elements only.

In new construction, assumption is that electrical work has been done and there is 240V, 30A electrical outlet near the water heater.

[w] Other standard sizes such as 40 and 50 gallons are also common.

Table 8D.5.38 Example of Installation Costs for Baseline Grid-enabled ESWHs (>75 gals): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	2.42	Ea.	$145	--	1	$145
Control equipment	1 Plumber	-	Ea.	$75		1	$75
Wiring harness and connectors	1 Plumber	-	Ea.	$55		1	$55
Water piping**	1 Plumber	-	per ft.	$8		8	$64
T&P valve drain piping	1 Plumber	-	per ft.	$4		5	$20
Drain pan and piping***	1 Plumber	0.67	Ea.	$40	$40	1	$80
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$514**
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 8 ft of water pipe is assumed, since the larger than 55 gallon HPWHs are taller and larger in diameter compared to the below 55 gallon HPWHs, so more pipe length is needed to make the water pipe connections.
*** 30” diameter drain pan. Assumed 26” water heater diameter.

Grid-enabled Heat Pump ESWH (>75 gals) Installation Cost Example. Table 8D.5.39 shows an example of an installation cost breakdown for grid-enabled HPWH models in new construction. Assumption is that electrical work has been done and there is 240V, 30A electrical outlet near the water heater. The heat pump section is usually larger on larger tanks. Thus, extra effort to access all the components inside the heat pump to verify proper operation is needed.

Table 8D.5.39 Example of Installation Costs for Grid-enabled Heat Pump (>75 gals) : New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	3.42	Ea.	$205**	--	1	$205
Control equipment	1 Plumber	-	Ea.	$75		1	$75
Wiring harness and connectors	1 Plumber	-	Ea.	$55		1	$55
Water piping***	1 Plumber	-	per ft.	$8		8	$64
T&P valve drain piping	1 Plumber	-	per ft.	$4		5	$20
Condensate drain	1 Plumber	-	Ea.	$4		7	$28
Drain pan and piping****	1 Plumber	0.67	Ea.	$40	$40	1	$80
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$602**
Additional installation costs (specific to HPWH over 55 Gal.)							
Condensate pump (if no gravity drain available)*****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

*This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
**The heat pump section is usually larger on larger tanks. Thus, extra effort to access all the components inside the heat pump to verify proper operation compared to a <55 gallon HPWH.
*** 8 ft of water pipe is assumed, since the larger than 55 gallon HPWHs are taller and larger in diameter compared to the below 55 gallon HPWHs, so more pipe length is needed to make the water pipe connections.
**** 30” diameter drain pan. Assumed 26” water heater diameter.
***** The material cost includes $45 for the pump and $15 for piping.

Summary. The following table shows the summary of costs of installing electrical storage water heaters in new constructions. ESWHs are installed with generally lower costs compared to GSWHs since flue venting is not a problem anymore.

Table 8D.5.40 ESWH Typical Installation Costs Summary: New Construction

Water Heater Technology or Type	Total	Differential
Baseline ESWH (>20 and <55 gals)	$234	--
Heat Pump ESWH (>20 and <55 gals)	$308	$74
Mobile Home Baseline ESWH (>20 and <55 gals)	$108	--
Baseline Heat Pump ESWH (>55 gals)	$413	$79
Baseline Grid-enabled ESWH (>75 gals)	$514	$280
Grid-enabled Heat Pump ESWH (>75 gals)	$602	$368

8D.5.3.3 Replacement

Typical Replacement Steps. Typical steps for installing a new ESWH in replacement application (where the existing water heater is also a ESWH[x]) that a plumber usually follows are shown in Table 8D.5.41. Similar to GSWHs, the installation costs for an electrical water heater typically include basic trip charge, disconnecting and removing the existing water heater, putting in place and setting up the new water heater, municipal permit if required, and haul away charge. Higher efficiency electric water heaters (heat pump design) might also require making different electrical connections and condensate drainage. Some installations may also require the installation of a water heater stand, an expansion tank, additional labor to install in up or down stairs locations, and/or additional labor for special handling of water heaters with capacity over 55 gallons.

Table 8D.5.41 Typical Installation Steps for ESWHs: Replacement

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Check and clean space around old water heater	Install water heater
2	Confirm adequate space and utilities for new water heater	
3	Shutoff water supply to the house	Removal of old water heater
4	Turn off circuit breaker to water heater	
5	Connect drain hose to water heater, open cold water faucet in house and start draining water heater	
6	Disconnect cold and hot water pipe connections at water heater	
7	Shutoff cold water faucet in house	
8	Disconnect T&P valve drain line, if existing	
9	Determine if existing drain pan is reusable	
10	After draining, disconnect drain hose and lift water heater out of drain pan and remove from house	
11	Determine the need for water heater stand, expansion tank, code requested changes, etc.	Installation of water heater
12	Uncarton new water heater and move to install location	Installation of water heater
13	Lift and place water heater into drain pan at install location and line up fittings to existing piping	

[x] Some of the assumptions and cost estimates are related to the replacement of 50 gallon standard size ESWH.

No.	Typical Installation Step	Corresponding Installation Cost Item
14	Make hot and cold water connections to water heater fittings (note: Install shutoff valves if nonexistent)	
15	Make electrical connection to home wiring	
16	Install T&P valve drain line	
17	Install condensate drain and condensate pump (only if below adequate drain)	Condensate drain (optional)
18	Turn on water supply to house	Installation of water heater
19	Open hot water faucet in house and fill water heater until water runs from faucet	
20	Turn on water heater breaker	
21	Shutoff water faucet	Install water heater (startup, post- installation checks and interaction with homeowner)
22	Check all new water connections for leaks, clean install area and recheck for any leaks	
23	Instruct homeowner to wait at least two hours before using hot water	

Typical Replacement Cost Items. Table 8D.5.42 shows the engineering specifications for typical installation items when replacing an old water heater with an electric storage water heater.

Table 8D.5.42 Engineering Specifications for Typical Replacement Installation Items

Installation Items	Specifications/Requirements
Basic trip charge	Plumbers charge for making a trip to the house to recover time for driving.
Removal of old water heater	Labor to remove and disconnect the existing water heater. Typically, 1.2 hours is the total labor associated with taking out the existing product.*
Install water heater	Labor for set-up and putting into place new water heater. This includes making electrical and water pipe connections, T&P drain tube, and materials to do so.
Control equipment	Grid enabled models may require connections to utility control equipment.
Wiring harness and connectors	Some hybrid/heat pump and grid enabled models may require connections of a wiring harness to connect utility components of the water heater.
Condensate drain	Only for heat pump water heaters. Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Municipal permit	It is common for replacement ESWH installations to require a "municipal permit". Permits for water heater replacement can range from $30 to over $100 depending on municipality requirements.
Haul away	The existing water heater needs to be hauled away and disposed of, so the cost of disposal fee or "haul away" fee. Most garbage collection companies and municipal garbage collection will not haul away old water heaters. Plumbers are left to find a recycler or land fill that will accept the old products.
Condensate pump	Only for heat pump water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater. Generally, the water heating heat pump generates more condensation than a condensing or power vent gas water heater.

Installation Items	Specifications/Requirements
Insulation jacket	Some baseline water heaters have a fiberglass insulation blanket included in the water heater box which must be installed to meet the Federal water heater efficiency standards.
Water heater stand	Metal "knock down" design with four bolt-on legs. Other designs and materials are available.
Expansion tank	2 gallon, pre-charged, bladder type tank for tee mounting in the cold water line.
Up or down stairs	Plumbing contractors charge extra to move a water heater up or down a stairway. Some use a special motorized lift for this job.
Capacity over 55 gal. - special handling	Large water heaters are difficult to maneuver and lift. There may be extra cost to accommodate these large units.

* Note that this cost could vary for different tank sizes, for example a 50 gallon tank will take longer to drain compared to a 40 gallon tank.

ESWH Replacement Costs Examples. The following installation costs tables assume that the existing 50 gallon[y] baseline ESWH was installed in the last 15 years, with water piping, metal stand, drain pan, etc. up to code, in good working condition without needing any modifications. The material cost for the "install water heater" cost item includes short lengths of water pipe, elbows, couplings, hot and cold fittings at water heater connections, making electrical connections to the water heater, and miscellaneous supplies including solder, torch gas, flux, pipe dope, plastic pipe prep and glue, rags, sandpaper for pipe prep, screws, and so on.

Baseline ESWH (≥20 and <55 gals) Replacement Cost Example. The costs of installing a baseline ESWH in replacements are broken down in Table 8D.5.43.

[y] The 50 gallon model is the most prevalent existing model. For the removal of a larger sized water heater the cost could be more.

Table 8D.5.43 Example of Installation Costs for Baseline ESWHs (≥20 and <55 gals): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.23	Ea.	$74	--	1	$74
Install water heater	1 Plumber	1.85	Ea.	$111	$40	1	$151
Municipal permit (if required)	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$380**
Additional installation costs (specific to baseline ESWHs)							
Insulation jacket (if provided with the water heater)	1 Plumber	0.50	per ft.	$30	--	1	$30
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge

Heat Pump ESWH (≥20 and ≤55 gals) Replacement Cost Example. Table 8D.5.44 shows an example of replacing an existing baseline ESWH with heat pump ESWHs. The installation requires additional labor for its larger size, condensate removal, and the operational verification of the heat pump section after installation, including checking the proper function of compressor, evaporator fan, circulation pump, and control system. As there is no provision for the condensate piping in the replacement and the plumbing connections are not the same as the old water heater, more pipe and fittings are needed pushing material cost higher compared to the baseline.

Table 8D.5.44 Example of Installation Costs for Heat Pump ESWHs (>20 and ≤55 gals): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.23	Ea.	$74	--	1	$74
Install water heater**	1 Plumber	2.97	Ea.	$178	$64	1	$242
Condensate drain	1 Plumber	-	per ft.	$4		6	$24
Municipal permit (if required)	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$495**
Additional installation costs (specific to heat pump ESWH 20 to 55 gal.)							
Condensate pump (if no gravity drain available)***	1 Plumber	1.20	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** The additional cost takes into account that the HPWH is a larger water heater so it is harder to handle and lift into place, drain pan is larger, condensate piping needs to be provided, and the heat pump component operational needs to be checked.
*** The material cost includes $45 for the pump and $15 for piping.

Mobile Home ESWH (>20 and <55 gals) Cost Example. Similar to GSWHs, in the mobile home market the laborer is not necessarily a licensed plumber. $40/hr labor is assumed in the following table based on the assumption that the laborer is a non-licensed but knowledgeable service employee.

The installation costs for baseline mobile home ESWHs are shown in Table 8D.5.45.

Table 8D.5.45 Example of Installation Costs for Mobile Home ESWHs: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Removal of old water heater	1 Service Employee	0.75	Ea.	$30	--	1	$30
Install water heater	1 Service Employee	1.20	Ea.	$48	$25	1	$73
Haul away	1 Service Employee	Ea.		$35	--	1	$35
						Total	**$138**
Additional installation costs (specific to baseline mobile home ESWHs)							
Insulation jacket (if provided with water heater)	1 Service Employee	0.50	Ea.	$20	--	1	$20
Additional installation costs (specific to all mobile home ESWHs)							
Drain pan and piping	1 Service Employee	0.30	Ea.	$12	$30	1	$42
Water piping *	1 Service Employee	-	per ft.	$6		6	$36
T&P valve drain piping	1 Service Employee	-	per ft.	$2		4	$8

* Polybutylene with crimp ring connections

Baseline Heat Pump ESWH (>55 gals) Replacement Cost Example. Among water heaters with rated volume above 55 gallons, HPWHs are the baseline and all different HPWH efficient options are assumed to have the same installation costs. For this cost table the existing ESWH is assumed to be 50 gallons. For the ESWH (>55 gals) group, standard size is assumed to be 80 gallons.[z] Table 8D.5.46 shows the costs breakdown for the baseline HPWHs.

z Other standard sizes such as 40, 50, and 65 gallon are also common.

Table 8D.5.46 Example of Installation Costs for Baseline Heat Pump ESWHs (> 55 gals): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.23	Ea.	$74	--	1	$74
Install water heater**c**	1 Plumber	3.22	Ea.	$193	$74	1	$267
Condensate drain	1 Plumber	-	Ea.	$4		6	$24
Municipal permit (if required)	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$595**
Additional Installation Costs (specific to heat pump ESWH over 55 gal.)							
Condensate pump (if no gravity drain available)**	1 Plumber	1.20	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** The material cost includes $45 for the pump and $15 for piping.

Baseline Grid-enabled ESWH (> 75 gals) Replacement Cost Example. Costs of installing a grid-enabled ESWH in replacement are shown in Table 8D.5.47. For this cost table, the existing ESWH is assumed to be 50 gallons. Note that there are different requirements from utilities that affect the internal wiring of the water heater. This estimate is based upon utility control of heating elements only. Water heaters above 75 gallons are more difficult to un-carton. The drain pan is larger, and sitting inside the drain pan and longer supply wiring from the wall are generally more difficult to install because of its size. The $75 handling is just to get the water heater from the truck to the installation location.

Table 8D.5.47 Example of Installation Costs for Baseline Grid-enabled ESWHs (>75 gals): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.23	Ea.	$74	--	1	$74
Install water heater	1 Plumber	2.70	Ea.	$162	$40	1	$202
Control equipment	1 Plumber	-	Ea.	$75		1	$75
Wiring harness and connectors	1 Plumber	-	Ea.	$55		1	$55
Municipal permit (if required)	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$636**
Additional Installation Costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge

Grid-enabled Heat Pump ESWH (>75 gals) Installation Cost Example. Table 8D.5.48 shows an example of replacing an existing water heater with grid-enabled heat pump ESWH that is over 75 gallons.

Table 8D.5.48 Example of Installation Costs for Grid-enabled Heat Pump ESWHs (> 75 gals): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.23	Ea.	$74	--	1	$74
Install water heater	1 Plumber	4.02	Ea.	$241	$74	1	$315
Control equipment	1 Plumber	-	Ea.	$75		1	$75
Wiring harness and connectors	1 Plumber	-	Ea.	$55		1	$55
Condensate drain	1 Plumber	-	Ea.	$4		7	$28
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
Capacity over 55 gal. - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75
						Total	**$777**
Additional Installation Costs (specific to Heat Pump ESWH over 55 Gal.)							
Condensate pump (if no gravity drain available)**	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional Installation Costs (applicable to all ESWH designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs - special handling	1 Plumber	upcharge	Ea.	$75	--	1	$75

* Cost of doing business charge
** The material cost includes $45 for the pump and $15 for piping.

Summary. Replacement costs for all types of ESWHs are summarized in the table below.

Table 8D.5.49 Replacement Costs Summary for ESWH

Water Heater Technology or Type	Total	Differential
Baseline ESWH (>20 and <55 gals)	$380	--
Heat Pump ESWH (>20 and <55 gals)	$495	$115
Mobile Home Baseline ESWH (>20 and <55 gals)	$138	--
Baseline Heat Pump ESWH (>55 gals)	$595	$215
Baseline Grid-enabled ESWH (>70 gals)	$636	$256
Grid-enabled Heat Pump ESWH (>70 gals)	$777	$397

8D.5.4 Oil-Fired Storage Water Heater

8D.5.4.1 Oil-fired Storage Water Heater Technology Description

Oil-fired storage water heaters (OSWHs) are much less common than gas and electric water heaters. In this study, we will discuss the baseline OSWHs. OSWHs currently do not have a direct vent option.[aa] OSWHs are mostly seen in 30/32 gallons and 50 gallons sizes. Note that there is a cost difference in the amount of oil and water piping between 30 and 50 gallon models. Also oil fired tanks are VERY heavy and the larger the water heater the more difficult it is to move.

8D.5.4.2 New Construction

Typical Installation Steps. Typical installation steps for OSWHs that a plumber usually follows are similar to a gas storage water heater shown in Table 8D.5.50.

For OSWHs installed in new construction, the installation costs typically include installing a drain pan with piping, putting in place and setting up the new water heater, mounting the burner, connecting oil and water piping, and T&P valve drain piping and making electrical connections. Some garage or utility area installations may also require the installation of a water heater stand or non-combustible floor platform. An important install function unique to oil-fired water heaters is the combustion CO2 measurement and adjustment, smoke reading and adjustment, and draft check of the vent system. The install could also include the installation of an expansion tank, additional labor to install in up or down stairs location and movement of the heavy tank.

[aa] John Wood's direct vent model is simply a through-the-wall vent kit. The combustion air still comes from inside the room.

Table 8D.5.50 Typical Installation Steps for OSWHs in New Construction

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Install drain pan and any Code or builder required accessories	Drain pan and piping
2	Uncarton new water heater and move to install location	Install water heater
3	Install location made non-combustible floor platform ,or put on non-combustible water heater stand	Non-combustible water heater stand or floor platform
4	Lift and place water heater into drain pan at install location and line up fittings to existing stubbed piping	Install water heater
5	Install vent system (may be done in advance)	Flue vent system
6	Install the burner assembly* into the water heater and make control wiring connections.	Install water heater
7	Make electrical connections from burner to electrical supply	
8	Make oil pipe connection to water heater oil burner (note: install shutoff valve if nonexistent)	Oil piping
9	Make hot and cold water connections to water heater fittings (note: install shutoff valves if nonexistent)	Water piping
10	Install expansion tank (if required)	Expansion tank (optional)
11	Install T&P valve drain line	T&P valve drain piping

* Note that the burner is commonly sold separately from the water heater.

At this point, the installation is done. When the house utilities are turned "ON", the following check-up steps apply as shown in Table 8D.5.51. This checklist is a list of essential steps to take for ensuring the water heater is operating appropriately and in good condition. Some steps can be done concurrently. The additional labor hours to conduct this checkup could range from 30 minutes to 1 hour and included as part of the installation of the water heater. The checkup may have to be performed by the oil suppliers technician. These steps could occur before occupation as part of commissioning of the new construction. Once this check-up is complete, the next startup will be by either a plumber or oil company when the house is sold or fully operable and this cost is not included as part of the water heater installation costs.

Table 8D.5.51 Typical Post-Installation (Check-up) Steps for OSWHs in New Construction

No.	Typical Post-Installation Step
1	Remove any access covers to burner area for burner start up process
2	Turn on water supply to house
3	Open hot water faucet in house and fill water heater until water runs from faucet
4	Shutoff hot water faucet
5	Check all water connections for leaks
6	Turn on oil supply to water heater and leak test all fittings
7	Turn on electricity to water heater
8	Initiate oil burner startup and check for proper burner operation, perform combustion CO2, smoke and overfire draft analysis and adjust air shutter
9	After proper combustion is confirmed, shut off burner
10	Clean install area and recheck for any leaks
11	Replace any removed covers
12	Turn off oil supply valve to burner and close cold water inlet shutoff valve

Typical Installation Cost Items. In most cases, when plumbers quote plumbing for a new home, they include all water supply, waste and vent piping, oil piping, toilets, sinks, appliance connections, tubs, showers and all other plumbing related items. Table 8D.5.52 shows the specifications for each of the typical installation line items for installing oil-fired storage water heaters in new construction.

Table 8D.5.52 Engineering Specifications for Typical New Construction Installation Items

Installation Items	Specifications/Requirements
Install water heater	Labor for set-up and putting into place new water heater, including un-carton water heater and burner, move both to install location, lift water heater onto pad or stand inside drain pan, install correct nozzle in burner and install burner, install thermostat in tank and wire to burner, open combustion chamber inspection port, connect control/burner system to electrical supply switch box, install "blocked vent" safety switch on vent and run wire to burner, check overall installation and test fire burner, set proper smoke, CO_2 and draft, close combustion chamber inspection port, check all water and oil connections for leaks, clean area, and haul away all discarded materials.
Drain pan and piping	30″ assumed, min. 2" deep (typical 26" water heater diameter + 2" additional on each side), aluminum with drain opening and drain connector.
Flue vent system	20′ length assumed, 6" stainless steel. Vent length and diameter of pipe will be different if a through-the-wall vent kit is used.
Oil piping	Threaded pipe and fittings, ½″ diameter, Schedule 40, 3′ length assumed off branch. Or minimum 3/8" diameter copper flexible tubing with flared fittings can be used for connection of the house oil supply to the water heater burner pump. If not already provided, install an inline oil filter.
Water piping	Copper pipe and fittings, most commonly ¾″inch in diameters, 4'length each for hot and cold water because of the large diameter of the water heater and the clearance to wall surfaces, longer length of pipe needed for connections, 8′ length in total.
T&P valve drain piping	Plastic pipe and fittings, 6" above floor drain or adequate drainage from water heater, ¾" PVC Schedule 40 water pipe.
Dedicated electrical outlet (110V)	The 110V, 15A dedicated junction box with disconnect switch will be supplied as part of building electrical work
Non-combustible floor or platform	Needed if there is no non-combustible water heater stand. Site built concrete pad with metal cap. Installation must comply with National Fire Protection Association (NFPA 31) Code.
Water heater stand	Metal "knock down" design with four bolt-on legs. Other designs and materials are available.
Up or down stairs	Plumbing contractors charge extra to move a water heater up or down a stairway. Some use a special motorized lift for this job.

The installation costs for each line item are based on the following assumptions:

- Install water heater (setting up and putting in place a new water heater) - Estimated on installation of a new 50 gallon model.[bb]
- Drain pan and piping - 30″ drain pan is assumed for a standard size 50 gallon water heater. Assumption is that an adequate drain is provided at the water heater installation location. Code requirements that mandate drain to outside or adequate floor drain may impose added costs not accounted for in the report.

[bb] For oil-fired storage tank water heaters there are two standard sizes that are commonly installed in residential applications: 30/32 gallon and 50 gallon.

- Flue vent system - Stainless steel vent. In all cost tables below, the average developed vent length (including vertical and horizontal components) is assumed to be 20 ft. The vent length varies significantly between different household types, water heater design options, and water heater installation locations. Plumbers are guided by manufacturer installation manual vent instructions, National Fire Protection Association (NFPA) 31: Standard for the Installation of Oil-Burning Equipment, and other building and safety codes to determine the exact flue vent length, diameter, and type of material needed.
- Flue vent connector - Oil-fired water heaters are installed with Type L vent connectors. Type L vent connectors are double-walled and generally have a stainless steel inner wall (while Type B vents which are used for natural gas do not). Type L vent connectors are for high temperature flue gases that do not exceed a temperature of 570º F as in oil-fired water heaters.
- Oil piping - For oil piping, 3 feet length is assumed. The length is developed considering all elbows, tees, valves, etc or an option (not assumed here) is to use flexible copper, minimum 3/8" diameter with flared fittings, between the oil shutoff valve and the burner pump.
- Water piping - For water piping, the assumption is that there are "stubbed" hot and cold supply pipes in the area of the installation location. To join those stubs to the hot and cold fittings of the water heater would take an average of 4 feet equivalent for pipe each.
- Dedicated electrical outlet with switch (110V, 15A) - In new construction, the electrical work is assumed to already be done as part of the overall building electrical work, so the cost of additional electrical outlets is not included in the new construction cost tables.
- T&P valve drain piping - For a 50 gallon oil-fired water heater, the T&P valve is approximately 50" from the floor. Codes require the end of the T&P drain pipe to be 6" above the floor drain. Thus 44" is assumed in Table 4.3.
- Expansion tank - Expansion tanks are needed in some cases to address water heater thermal expansion and water hammer issues.

OSWH New Construction Installation Cost Examples. Based on the assumptions above, the following table includes the installation costs of the OSWH design. Plumbing materials such as solder, torch gas, flux, pipe dope, plastic pipe prep and glue, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are also included in the individual cost items such as drain pan and piping, water piping, flue vent system, and T&P valve drain piping.

Baseline OSWH Installation Cost Example. Installation costs for the baseline OSWHs in new construction are summarized in the table below.

Table 8D.5.53 Example of Installation Costs for Baseline OSWH: New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater	1 Plumber	4.33	Ea.	$260	--	1	$260
Flue vent system	1 Plumber	-	per ft.	$17		20	$340
Water piping*	1 Plumber	-	per ft.	$8		8	$64
Oil piping	1 Plumber	-	Ea.	$41		1	$41
T&P valve drain piping	1 Plumber	-	per ft.	$4		4	$16
Drain pan and piping	1 Plumber	0.67	Ea.	$40	$40	1	$80
Electrical outlet	1 Electrician	Included as part of overall building electrical work					$0
						Total	**$801****
Additional Installation Costs (applicable to all oil-fired storage designs)							
Water heater stand	1 Plumber	0.25	Ea.	$15	$48	1	$63
Non-combustible floor platform (if not on metal Stand)	1 Plumber	1.25	Ea.	$75	$85	1	$160
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs	1 Plumber	upcharge	Ea.	$75	--	1	$75

* 8 ft of water pipe is assumed, since oil fired water heaters have larger clearances to wall surfaces thus require longer pipe lengths from stubbed supply.
** Note that there will be an extra charge if the oil supplier mandates that their tech does the smoke, draft and CO2 check and burners settings.

8D.5.4.3 Replacement

In the OSWH market, more than 90% of the sales are for replacement. Markets in Alaska, possibly Canada and far northern locales do have some new installs where propane isn't available and electric water heaters are too power consuming.

Typical Replacement Steps. Typical replacement steps for OSWHs in replacement applications that a plumber usually follows are shown in Table 8D.5.53. The assumption is that the old water heater is an oil fired product. For water heaters installed in replacements, the installation costs typically include basic trip charge, disconnecting and removing the existing water heater, putting in place and setting up the new water heater, municipal permit if required, and haul away charge. It might also require an electrical outlet and water heater stand or non-combustible platform if needed. Some installations may also require the installation of an expansion tank, and additional labor to install in up or down stairs locations.

Table 8D.5.54 Typical Installation Steps for OSWHs: Replacement

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Check and clean space around old water heater	Install water heater
2	Confirm adequate space and utilities for new water heater	
3	Shutoff oil supply valve to the water heater and water supply to the house	Removal of old water heater
4	Connect drain hose to water heater, open cold water faucet in house and start draining water heater	
5	Disconnect vent connector pipe from water heater flue	
6	Disconnect oil supply pipe from water heater burner pump	
7	Disconnect cold and hot water pipe connections at water heater	
8	Disconnect T&P valve drain line, if existing	
9	Determine if existing drain pan is reusable	
10	After draining, disconnect drain hose, close cold water faucet in house, and lift water heater out of drain pan and remove from house	
11	Determine the need for water heater stand or new concrete platform, new vent connector, expansion tank, code requested changes, etc.	Install water heater
12	Insure that a 110V, 15A, dedicated electric supply with disconnect switch is available for the new water heater	Electrical outlet (optional)
13	Uncarton new water heater and burner and move to install location	Install water heater
14	Lift and place water heater into drain pan at install location and line up fittings to existing piping	
15	Remove any access covers to burner area to prepare for burner mounting	
16	Install correct nozzle in burner for input rate, mount burner to water heater and make wiring connections to electrical supply	
17	Make oil pipe connection to water heater burner with new pipe connector (either ½" threaded pipe or flexible copper minimum 3/8"diameter. Ensure that a filter is in the supply line and it is clean. (note: install shutoff valve if nonexistent)	
18	Make hot and cold water connections to water heater fittings (note: install shutoff valves if nonexistent)	
19	Install T&P valve drain line	
20	Turn on water supply to house	Install water heater
21	Open hot water faucet in house and fill water heater until water runs from faucet	
22	Shutoff hot water faucet	
23	Check all new water connections for leaks	
24	Install a new flue vent connector and ensure the vent system or chimney is in good condition and will handle the input rate and draft of the new burner. Refer to NFPA 31 for a proper vent system. (if current vent/chimney is not adequate a new vent system may be required)	Flue vent connector (recommended)
25	Install new vent blockage safety switch on vent (if not equipped) and wire to burner.	
26	Smoke, CO2 and draft must be set for proper burner operation. Special analysis equipment is used for this process. And, the oil supplier may require their own tech to do this operation.	Install water heater (Startup, post- installation checks and interaction with homeowner)

No.	Typical Installation Step	Corresponding Installation Cost Item
27	Clean install area and recheck for any leaks	
28	Observe burner operation again and replace any removed covers	
29	Instruct homeowner on shutdown and restarting instructions for the water heater	
30	Instruct homeowner to wait at least two hours before using hot water	

Typical Replacement Cost Items. Table 8D.5.55 shows the engineering specifications for typical installation items in replacement.

Table 8D.5.55 Engineering Specifications for Typical Replacement Installation Items

Installation Items	Specifications/Requirements
Basic trip charge	Plumbers charge for making a trip to the house to recover time for driving.
Removal of old water heater	Labor to remove and disconnect the existing water heater. Typically, for various types of water heaters, 3 labor hours is required for taking out the existing product.
Install water heater	Labor for set-up and putting into place new water heater. This includes making oil and water pipe connections, setup and mounting of burner, component wiring, installing vent connector, T&P drain tube, analyzing and adjusting burner for clean combustion and smokeless exhaust and materials to do so.
Municipal permit	It is common for replacement OSWH installations to require a "municipal permit". Permits for water heater replacement can range from $30 to over $100 depending on municipality requirements.
Haul away	The existing water heater needs to be hauled away and disposed of, so the cost of disposal fee or "haul away" fee. Most garbage collection companies and municipal garbage collection will not haul away old water heaters. Plumbers are left to find a recycler or land fill that will accept the old products.
Flue vent connector	The oil-fired water heaters use Type L vent connectors. The current vent/chimney has to be examined to determine whether it will properly handle the new water heater venting requirements. NFPA 31 is the guide for this determination. If the current venting isn't adequate, it must be replaced. 20′ length assumed, but vent pipe material type, length, and diameter vary by water heater firing rate. The cost could also include other vent components such as the vent termination. (See tables below for more details)
Dedicated electrical outlet (110V)	15 A, 110 V, dedicated receptacle with shutoff switch
Non-combustible floor or platform	Needed if there is no non-combustible water heater stand. Site built concrete pad with metal cap. Installation must comply with National Fire Protection Association (NFPA 31) Code.
Water heater stand	Metal "knock down" design with four bolt-on legs. Other designs and materials are available. but have to be non-combustible
Expansion tank	2 gallon, pre-charged, bladder type tank for tee mounting in the cold water line.

Installation Items	Specifications/Requirements
Up or down stairs	Plumbing contractors charge extra to move a water heater up or down a stairway. Some use a special motorized lift for this job.

The material cost of "install water heater" includes short lengths of water pipe, elbows, couplings, hot and cold fittings at water heater connections, short threaded pipe and fittings or flexible copper minimum 3/8" diameter with flared fittings to connect oil to the water heater, and miscellaneous supplies including solder, torch gas, flux, pipe dope, plastic pipe prep and glue, rags, sandpaper for pipe prep, screws, sealant, fasteners and so on. Tools of any kind needed for the installation are part of the cost of doing business.

OSWH Replacement Cost Examples. The following example installation cost table assumes replacing an existing baseline OSWH that was installed in the last 15 years with a stainless steel vent system complying with manufacturer and NFPA 31 guidelines. It is also assumed that the new water heater will be installed with a new burner, since the motor, fan, pump, and other components have all worn out over time. It is assumed that the existing electrical supply with switch, water piping, oil piping, metal stand, etc. are up to code and do not need any modifications. Combustion air is assumed to be adequate. An oil-fired water heater must be installed on a non-combustible floor. A concrete floor, concrete pad with a metal cap, or a suitable metal stand are acceptable.

Baseline OSWHs. Table 8D.5.56 shows the costs breakdown for baseline OSWH in replacement.

Table 8D.5.56 Example of Installation Costs for Baseline OSWH: Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	3.17	Ea.	$190	--	1	$190
Install water heater**	1 Plumber	6.42	Ea.	$385	$285	1	$670
Flue vent connector***	1 Plumber	-	per ft.	$17		6	$102
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$1,117**
Additional Installation Costs (applicable to all oil-fired storage designs)							
Non-combustible floor platform (if not on metal stand)	1 Plumber	1.25	Ea.	$75	$85	1	$160
Dedicated electrical outlet (110V)	1 Plumber	4.42	Ea.	$265	$115	1	$380
Expansion tank	1 Plumber	0.75	Ea.	$45	$68	1	$113
Up or down stairs	1 Plumber	1.25	Ea.	$75	--	1	$75

* Cost of doing business charge
** Includes all water piping, main wiring of burner to electric supply switch, burner setup with aquastat and wiring, blocked vent sensor and wiring, oil filter, oil shutoff valve and piping, adjusting combustion CO2 and smoke, proper draft, verification of proper operation of entire system.
*** The old connector will have screw holes, test probe holes, and absorb the hottest flue gases. Best practice is to replace it with a new vent.

8D.5.5 Gas-Fired Instantaneous Water Heater

8D.5.5.1 Water Heater Technology Descriptions

There are two types of gas-fired instantaneous water heaters (GIWHs) we are going to discuss in this study:

- **Non-condensing GIWHs** - Mid efficiency heat exchanger with average thermal efficiency at 80% to 83%. Electronic ignition and controls. Fan assisted exhaust. Flue temperatures average 300°F and must be vented with stainless steel vent pipe.
- **Condensing GIWHs** - High efficiency heat exchanger, sometimes with a secondary heat exchanger. Efficiency ranges average from 90% to 96%. Electronic ignition and controls. Power burner or fan assisted combustion system. Flue temperatures average 170°F and are installed with an approved polymer vent pipe. Due to the absorption of

combustion heat, this product generates corrosive condensation, as a by-product, which must be disposed of properly.

All currently available GIWHs are whole home units that have a input capacity of at least 100 kBtu/Hr input (the upper capacity limit for the residential size GWHs is 199 kBtu/h) and no more than 2 gallons water capacity. In the past, there have been smaller input capacity models and manufacturers have discussed introducing instantaneous “hybrid” models with larger capacity storage tanks.

8D.5.5.2 New Construction

Typical Installation Steps. Typical installation steps for tankless GIWHs that a plumber usually follows are shown in Table 8D.5.57. Assumption is that all gas and water lines in house have been leak tested and utilities are "OFF" in house. Leak test is done with an air charge in all piping with a pressure gage to determine any leaks that occur over an appropriate period of time.

For gas instantaneous water heaters installed in new construction, the installation costs typically include putting in place and setting up the new water heater, adding flue venting, connecting to a gas line branch, adding water piping, and adding T&P or pressure only valve drain piping. GIWHs also require an electrical outlet and condensate disposal. A condensate neutralizer filter may be required.

Table 8D.5.57 Typical Installation Steps for GIWHs in New Construction

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Uncarton new water heater and wall mounting bracket. Move to install location.	Install water heater
2	Install the mounting bracket on the wall close to the existing water and electrical supply	
3	Lift and place water heater onto install bracket and line up fittings to existing stubbed piping	
4	Install vent system (may be done in advance)*	Flue vent system
5	Install air intake vent piping (if direct vent, may be done in advance)*	Air intake vent piping
6	Make gas pipe connection to water heater gas inlet fitting (note: Install shutoff valve if nonexistent)	Gas piping
7	Make hot and cold water connections to water heater fittings (note: Install shutoff valves if nonexistent)	Water piping
8	Install T&P or pressure only relief valve drain line	T&P or pressure only relief valve drain piping
9	Make electrical connections to existing electric receptacle (hardwired) and, if equipped, mount and wire remote control device	Electrical connection
10	Install condensate pump (only if there is no gravity drain)	Condensate pump (optional)
11	Install condensate drain (if required)	Condensate drain (optional)
12	Put in condensate neutralizer (if required and if water heater is not factory equipped)	Condensate neutralizer (optional, only for condensing models)

* There are some GIWHs that are installed outdoors (less than 15%) that don't need flue vent piping or air intake piping.
Note: GIWHs do not typically include an expansion tank, since if there is no water flow, there is no heat for expansion. Heating occurs only when there is flow and expansion does not occur.

At this point, the installation is done. When the house utilities are turned "ON", the following check-up steps apply as shown in Table 8D.5.58. This checklist is a list of essential steps to take for ensuring the water heater is operating appropriately and in good condition. Some steps can be done concurrently. The additional labor hours to conduct this checkup could range from 30 minutes to 1 hour and included as part of the installation of the water heater. These steps could occur before occupation as part of commissioning of the new construction. Once this check-up is complete, the next startup will be by either a plumber or gas company when the house is sold or fully operable and this cost is not included as part of the water heater installation costs.

Table 8D.5.58 Typical Post-Installation (Check-up) Steps for GIWHs in New Construction

No.	Typical Post-Installation Step
1	Remove front panel to burner area for burner start up process
2	Turn on gas supply to water heater and leak test all fittings
3	Turn on water supply to house
4	Open hot water faucet in house and fill water heater until water runs from faucet
5	Shutoff hot water faucet
6	Check all water connections for leaks
7	Initiate gas burner startup and check for proper burner operation
8	Clean install area and recheck for any leaks
9	Observe burner operation again and replace the removed front panel
10	Turn off water heater gas control and close cold water inlet shutoff valve

Typical Installation Cost Items. In most cases, when plumbers quote plumbing for a new home, they include all water supply, waste and vent piping, gas piping, toilets, sinks, appliance connections, tubs, showers and all other plumbing related items. Table 8D.5.59 shows the specifications for each of the typical installation line items for installing gas instantaneous water heaters in new construction.

Table 8D.5.59 Engineering Specifications for Typical New Construction Installation Items

Installation Items	Specifications/Requirements
Install water heater	Labor for putting into place and set-up the new water heater.
Wall mounting bracket	Labor for securing brackets and mounting the water heater (if wall mounted).
Flue vent system	20′ length assumed, but vent pipe material type, length, and diameter vary by water heater type. The cost could also include other vent components such as the vent termination. (See tables below for more details)
Air intake vent piping (if direct vent model)	20' length assumed for vertical venting and 10, but vent pipe material type, length, and diameter vary by water heater installation instructions. The cost could also include other vent components such as the vent termination. (See tables below for more details)
Gas piping	Threaded black gas pipe* and fittings, ¾" diameter, Schedule 40, 7′ length assumed off branch. (Sediment trap has been required in building codes for many years, so the assumption is that it is included as part of gas supply pipe installation).
Water piping	Copper pipe and fittings, most commonly ¾″inch in diameters, 4′ length each for hot and cold water, 8′ length in total.
Relief valve drain piping	T&P or pressure only valve drain piping. Plastic pipe and fittings, 3′ to floor drain or adequate drainage from water heater, ¾" PVC Schedule 40 water pipe.
Electrical outlet (110V)	110V, 15A, electrical supply.
Altitude adjustment	For altitude adjustment, some models require circuit board DIP switch settings before installation is complete.
Condensate drain	Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Condensate pump	Only for condensing models. A condensate pump may be necessary if the drain location is above the level of the water heater.
Condensate neutralizer	Only for condensing water heaters. Specifications vary widely and manufacturers make reference to these products in their installation manual. Some models are factory equipped.

* Flexible gas tubing (flexible copper tubing with outer plastic) is also used especially as part of an installation kit or building code requirement for earthquake areas.

The installation costs for each line item are based on the following assumptions:

- Install water heater (setting up and putting in place a new water heater) - Estimated based upon labor hours for taking out the new water heater and making all water and electrical connections.
- Wall mounting brackets - Brackets for wall mounting the water heater are included from the manufacturer, so there is only labor cost for this line item. Location might require reinforced materials for better mounting. Applicable for both wall mount models (non-condensing and condensing).
- Flue vent system - In all cost tables below the average developed vent length (including vertical and horizontal components) is assumed to be 20 ft. The vent length varies significantly between different household types, water heater design options, and water heater installation locations. Plumbers are guided by water heater manufacturer installation manual vent tables, National Fuel Gas Code, and other building and safety codes to determine the exact flue vent length, diameter, and type of material needed.

- Gas piping - For gas piping, 7 feet length is assumed but it could vary significantly based on the installation circumstances.[cc] The length is developed considering all elbows, tees, valves, etc.
- Water piping - For water piping, the assumption is that there are "stubbed" hot and cold supply pipes in the area of the installation location. To join those stubs to the hot and cold fittings of the water heater would take an average of 4 feet equivalent of pipe each.
- Electrical outlet (110V) - In new construction, the electrical work is assumed to already be done as part of the overall building electrical work, so the cost of additional electrical outlets is not included in the new construction cost tables. Water heater must be connected to an electrical outlet.
- Relief valve drain piping - T&P or pressure only valve. Some models have a high water temp sensor to shut off heat, thus using a pressure only relief valve. This is the most common, and it is in the bottom of the unit so the piping is shorter – The assumed length for drain pipe is 3' to within 6" of floor drain.
- Air intake vent piping (if direct vent model) - Can be PVC. If direct vent, the assumed vent length is 20 feet, 3" in diameter. As with the exhaust. Air intake may be different diameter and material than exhaust but run parallel.
- Condensate drain - For condensing models, 6′ PVC pipe length is assumed going from the condensate outlet of the water heater to a drain close to the water heater. Condensate removal piping is not often supplied with a water heater. One manufacturer provides flexible vinyl tubing and yet the tubing may not meet code.
- Condensate pump - Only for condensing water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater.
- Condensate neutralizer - Currently there is a wide spectrum of neutralizer filter products available on the market. The water heater manufacturer may make reference to specified products, criteria, or recommendations. The costs for the neutralizer filter assumes ½" PVC piping, fittings, and typical neutralizer unit from different sources. Note that some models may have factory installed neutralizers.

GIWH New Construction Installation Cost Examples. In this study, an indoor wall-mount whole-home unit is considered. The size is assumed to be 100 to199 kBtu/h (similar capacity to a 40 gallon GSWH).

Based on the assumptions above, the following tables include an installation costs example for each of the GIWH designs. Plumbing materials such as solder, torch gas, flux, pipe dope, plastic pipe prep and glue, leak test liquid, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are also included in the individual cost items such as water piping, flue vent system, and relief valve drain piping. The labor cost of "install water heater" is higher than the other models because some models have DIP (dual in-line package) switch settings for vent length, direct vent, preset water temp, and other features, also the plumber needs to complete error code determination, check out of the control system once installed, and provide longer customer instructions.

[cc] Note that natural gas and propane gas piping is the same for standard water heaters used in single and multi family, since they are factory built either for natural gas or propane installations.

Baseline Gas-Fired Instantaneous Non-Condensing Wall Mount Water Heater. Table 8D.5.60 and Table 8D.5.61. show the cost breakdowns for non-condensing GIWHs[dd] installed with vertical and horizontal venting respectively.

Table 8D.5.60 Example of Installation Costs for Baseline Non-Condensing GIWH (Vertically Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	3.75	Ea.	$225	--	1	$225
Wall mounting bracket (materials included with water heater)**	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system	1 Plumber	-	per ft..	$17		20	$340
Water piping	1 Plumber	-	per ft.	$8		8	$64
Gas piping	1 Plumber	-	per ft.	$16		7	$112
Relief valve drain piping	1 Plumber	-	per ft.	$4		3	$12
						Total	**$798**
Additional installation costs (applicable to the gas instantaneous non-condensing designs)							
Air intake vent piping (if direct vent model)***	1 Plumber	-	per ft.	$7		20	$140
Additional installation costs (applicable to all gas instantaneous designs)							
Condensate neutralizer	1 Plumber	0.50	Ea.	$30	$65	1	$95

*This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** Includes boring holes in the wall.
*** 3" PVC, assumed to be the same as the flue vent piping.
Note: Drain pans are available for wall mount GIWH. Some may be fabricated by the installer.

[dd] Some GIWH manufacturers make conversion kits available to change from one gas to the other.

Table 8D.5.61 Example of Installation Costs for Baseline Non-Condensing GIWH (Horizontally Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	3.75	Ea.	$225	--	1	$225
Wall mounting bracket (materials included with water heater)**	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system	1 Plumber	-	per ft..	$17		10	$170
Water piping	1 Plumber	-	per ft.	$8		8	$64
Gas piping	1 Plumber	-	per ft.	$16		7	$112
Relief valve drain piping	1 Plumber	-	per ft.	$4		3	$12
						Total	**$628**
Additional installation costs (applicable to the gas instantaneous non-condensing designs)							
Air intake vent piping (if direct vent model)***	1 Plumber	-	per ft.	$7		10	$70
Additional installation costs (applicable to all gas instantaneous designs)							
Condensate neutralizer	1 Plumber	0.50	Ea.	$30	$65	1	$95

*This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** Includes boring holes in the wall.
*** 3" PVC, assumed to be the same as the flue vent piping.
Note: Drain pans are available for wall mount GIWH. Some may be fabricated by the installer.

Gas-Fired Instantaneous Condensing Wall Mount Water Heater. Table 8D.5.62 and Table 8D.5.63 shows the cost breakdowns for condensing GISWHs in new construction installed with vertical and horizontal venting respectively.

Table 8D.5.62 Example of Installation Costs for Condensing GIWH (Vertically Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	4.25	Ea.	$255	--	1	$255
Wall mounting bracket (materials included with water heater)	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system**	1 Plumber	-	per ft.	$7		20	$140
Water piping	1 Plumber	-	per ft.	$8		8	$64
Gas piping	1 Plumber	-	Ea.	$16		7	$112
Relief valve drain piping	1 Plumber	-	per ft.	$4		3	$12
Condensate drain	1 Plumber	-	Ea.	$4		6	$24
						Total	**$652**
Additional installation costs (applicable to gas instantaneous condensing design only)							
Air intake vent piping (if installed as direct vent)***	1 Plumber	-	Ea.	$7		20	$140
Condensate neutralizer (if not factory installed)****	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)*****	1 Plumber	1.17	Ea.	$70	$60	1	$130

*This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 3" PVC, suitable for GIWH Category IV venting, with a developed length of 20 feet, with elbows and outside termination fittings. The vent length depends on many factors including wall location, buildings codes, etc. For example, a thru the wall vent system could be shorter.
*** 3" PVC, assumed to be the same as the flue vent piping. Assumption is that direct vent always requires two pipes. There are some concentric models, but more common is two-pipe system.
**** Some condensing GIWH models come with the neutralizer already installed as part of the unit.
***** The material cost includes $45 for the pump and $15 for piping.

Table 8D.5.63 Example of Installation Costs for Condensing GIWH (Horizontally Vented): New Construction

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Install water heater*	1 Plumber	4.25	Ea.	$255	--	1	$255
Wall mounting bracket (materials included with water heater)	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system**	1 Plumber	-	per ft.	$7		10	$70
Water piping	1 Plumber	-	per ft.	$8		8	$64
Gas piping	1 Plumber	-	Ea.	$16		7	$112
Relief valve drain piping	1 Plumber	-	per ft.	$4		3	$12
Condensate drain	1 Plumber	-	Ea.	$4		6	$24
						Total	**$582**
Additional installation costs (applicable to gas instantaneous condensing design only)							
Air intake vent piping (if installed as direct vent)***	1 Plumber	-	Ea.	$7		10	$70
Condensate neutralizer (if not factory installed)****	1 Plumber	0.50	Ea.	$30	$65	1	$95
Condensate pump (if no gravity drain available)*****	1 Plumber	1.17	Ea.	$70	$60	1	$130

* This includes making wiring connections to the house electrical system. The electrical junction box associated with the water heater is assumed to be part of overall house electrical work.
** 3" PVC, suitable for GIWH Category IV venting, with a developed length of 10 feet, with elbows and outside termination fittings. The vent length depends on many factors including wall location, buildings codes, etc.
*** 3" PVC, assumed to be the same as the flue vent piping. Assumption is that direct vent always requires two pipes. There are some concentric models, but more common is two pipe system.
**** Some condensing GIWH models come with the neutralizer already installed as part of the unit.
***** The material cost includes $45 for the pump and $15 for piping.

8D.5.5.3 Replacement

Typical Replacement Steps. Typical steps for installing a new GIWH in replacement application (where the existing water heater is also a baseline GSWH[ee]) that a plumber usually follows are shown. For water heaters installed in replacements, the installation costs typically include basic trip charge, disconnecting and removing the existing water heater, putting in place and setting up the new water heater, municipal permit if required, and haul away charge. Condensing water heaters might also require condensate treatment and/or drainage.

[ee] Some of the assumptions and cost estimates are related to the replacement of 40 gallon standard size GSWH.

Table 8D.5.64 Typical Installation Steps for GIWHs: Replacement

No.	Typical Installation Step	Corresponding Installation Cost Item
1	Check and clean space around old water heater	Install water heater
2	Confirm adequate space and utilities for new water heater	
3	Shutoff gas to the water heater and water supply to the house	Removal of old water heater, removal of old vent system/ capping old vent system
4	Connect drain hose to water heater, open cold water faucet in house and start draining water heater	
5	Disconnect vent connector pipe from draft hood	
6	Disconnect gas supply pipe from water heater gas control	
7	Disconnect cold and hot water pipe connections at water heater	
8	Disconnect T&P valve drain line, if existing	
9	After draining, disconnect drain hose and lift water heater out of drain pan and remove from house	
10	Determine the mounting position for the new wall mount bracket, routing of new vent system, water and gas pipe routing, electrical supply outlet, code required changes and any other considerations before moving in the new water heater.	Install water heater
11	Install 110V, 15A electrical outlet (if needed)	Electrical outlet (optional)
12	Uncarton new water heater and mounting bracket and move to install location	Install water heater
13	Install the mounting bracket on the wall close to the water and gas supply pipes and electrical outlet	Wall mounting bracket
14	Lift and place water heater onto install wall bracket and line up fittings to existing piping	
15	Remove the front access panel for access to internal components	Install water heater
16	Determine if the existing gas line is of adequate size to supply the input rating of the new water heater. If not, a new larger supply pipe will be necessary from the main gas trunk.	
17	Make gas pipe connection to water heater gas inlet fitting (note: Install shutoff valve if nonexistent)	
18	Make hot and cold water connections to water heater fittings (note: Install shutoff valves if nonexistent)	
19	Install T&P or pressure only relief valve drain line	
20	Install condensate drain (if replacing with condensing models)	Condensate drain (optional)
21	Put in condensate neutralizer, if not factory equipped (if replacing with condensing models)	Condensate neutralizer (optional)
22	Install a drain pan	Install water heater
23	Connect electrical supply in water heater junction box	
24	Shutoff cold water faucet in house	
25	Turn on water supply to house	
26	Open hot water faucet in house and fill water heater until water runs from faucet	
27	Shutoff hot water faucet	

No.	Typical Installation Step	Corresponding Installation Cost Item
28	Check all new water and gas connections for leaks	
29	Install a new vent system and connect to water heater exhaust outlet (If direct vent, attach the intake vent to water heater inlet)	Flue vent system, wall penetration
30	Turn on gas supply valve to water heater	Startup, post- installation checks and interaction with homeowner
31	Initiate gas burner startup and check for proper burner operation and venting	
32	Clean install area and recheck for any leaks	
33	Observe burner operation again and replace the removed front panel	
34	Instruct homeowner on shutdown and startup instructions, temperature settings and operation of the digital controls for the water heater	
35	Instruct homeowner to wait at least two hours before using hot water	

Typical Replacement Cost Items. Table 8D.5.65 shows the engineering specifications for typical installation items when replacing a water heater.

Table 8D.5.65 Engineering Specifications for Typical Replacement Installation Items

Installation Items	Specifications/Requirements
Basic trip charge	Plumbers charge for making a trip to the house to recover time for driving.
Removal of old water heater	Labor to remove and disconnect the existing water heater. Typically, 1.5 hours is required for taking out the existing product.
Removal of old vent system/ capping old vent system	Remove the old vent system when using the existing vent path for vertical venting; capping the old vent system when the old water heater is commonly vented with an atmospheric furnace and will be horizontally vented through the side wall.
Install water heater	Labor for set-up and putting into place new water heater. This includes making gas and water pipe connections, making electrical connections, installing vent system, relief valve drain tube, and materials to do so, and added wiring if any.
Wall mounting bracket	Labor for securing brackets and mounting the water heater if wall mounted.
Wall penetration	For horizontal venting only. Assuming this is a wood frame house. Test drill first, check for any issues and then drill the final hole. It could be more complex for a non-wood frame.
Municipal permit	It is common for replacement installations to require a "municipal permit". Permits for water heater replacement can range from $30 to over $100 depending on municipality requirements.
Haul away	The existing water heater needs to be hauled away and disposed of, so the cost of disposal fee or "Haul Away" fee. Most garbage collection companies and municipal garbage collection will not haul away old water heaters. Plumbers are left to find a recycler or land fill that will accept the old products.
Flue vent system	20′ length is assumed for vertical venting and 10′ for horizontal venting. Vent pipe material type, length, and diameter vary by water heater type. The cost could also include other vent components such as the vent termination. (See tables below for more details).
Air intake vent piping (if direct vent model)	For non condensing direct vent and condensing direct vent only. 20′ length assumed for vertical venting scenario and 10′ for horizontal venting. Vent pipe material type, length, and

Installation Items	Specifications/Requirements
	diameter vary by water heater type. The cost could also include other vent components such as the vent termination. (See tables below for more details)
Electrical outlet (110V)	110V, 15A, electrical supply if one doesn't exist in the area of the water heater.
Condensate drain	Only for condensing water heaters. Plastic pipe and fittings, 6′ length assumed, ½" PVC schedule 40 water pipes.
Condensate pump	Only for condensing water heaters. A condensate pump may be necessary if the drain location is above the level of the water heater.
Condensate neutralizer	Only for condensing water heaters. Some models have these installed at the factory. Specifications vary widely and manufacturers make reference to these products in their installation manual.

The material cost of "install water heater" includes extending water and gas piping as well as adding more elbows, couplings, hot and cold fittings at water heater connections, and black pipe and fittings to connect gas to the water heater. Solder, torch gas, flux, pipe dope, plastic pipe prep and glue, leak test liquid, rags, sandpaper for pipe prep, screws, and miscellaneous supplies are also included. Sealant, fasteners, etc. would also be covered in the installation of water heater cost. Tools of any kind needed for the installation are part of the cost of doing business ("basic trip charge").

GIWH Replacement Cost Examples. The following example installation cost tables assume replacing an existing baseline GSWH (40 gallon) with a 160 kBtu/h new GIWH. The assumption is that the existing water heater was installed in the last 15 years, that the water piping, etc. are up to code in good working condition and do not need any modifications, and that the combustion air is adequate. There is potentially a need for wiring an electrical outlet (if there is not one nearby), new flue venting, condensate drain piping, and/or condensate neutralizer.

Note that depending on the new model input rate, the gas supply line may have to be replaced with a larger pipe (from the existing ½" to ¾" piping diameter). Changes in gas supply pipe diameter are not considered in this study.

Baseline Gas-Fired Instantaneous Non-Condensing Wall Mount Water Heater. Table 8D.5.66 and Table 8D.5.67 shows the cost breakdowns for non-condensing GISWHs in replacement with vertical and horizontal venting respectively.

Table 8D.5.66 Example of Installation Costs for Baseline GIWH (Vertically Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Removal of old vent system	1 Plumber	1.50	Ea.	$90	--		$90
Install water heater	1 Plumber	5.62	Ea.	$337	$40	1	$377
Wall mounting bracket	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system	1 Plumber	-	per ft.	$17		20	$340
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$1,097**
Additional installation costs (applicable to all gas instantaneous designs)							
Air intake vent piping (if direct vent model) (can be PVC)	1 Plumber	-	per ft.	$7		20	$140
Electrical outlet (110V) (if required)	1 Plumber	4.42	Ea.	$265	$45	1	$310

*Cost of doing business charge

Table 8D.5.67 Example of Installation Costs for Baseline GIWH (Horizontally Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75		1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Capping old vent system	1 Plumber	0.40	Ea.	$24	$15		$39
Install water heater	1 Plumber	5.62	Ea.	$337	$40	1	$377
Wall mounting bracket	1 Plumber	0.75	Ea.	$45	--	1	$45
Wall penetration	1 Plumber	0.85	Ea.	$50	$35	1	$85
Flue vent system	1 Plumber	-	per ft.	$17		10	$170
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$961**
Additional installation costs (applicable to all gas instantaneous designs)							
Air intake vent piping (if direct vent model) (can be PVC)	1 Plumber	-	per ft.	$7		10	$70
Electrical outlet (110V) (if required)	1 Plumber	4.42	Ea.	$265	$45	1	$310

*Cost of doing business charge

Gas-Fired Instantaneous Condensing Wall Mount Water Heater. Table 8D.5.68 and Table 8D.5.69 show the cost breakdowns for condensing GISWHs in replacement with vertical and horizontal venting respectively. The labor cost of installation is higher because of larger size and more elaborate electronics and burner system.

Table 8D.5.68 Example of Installation Costs for Condensing GIWH (Vertically Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75	--	1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Removal of old vent system	1 Plumber	1.50	Ea.	$90	--		$90
Install water heater	1 Plumber	6.40	Ea.	$384	$40	1	$424
Wall mounting bracket	1 Plumber	0.75	Ea.	$45	--	1	$45
Flue vent system**	1 Plumber	-	per ft.	$7		20	$140
Condensate drain	1 Plumber	-	per ft	$4		6	$24
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$968**
Additional installation costs (applicable to condensing gas instantaneous designs)							
Condensate neutralizer (if not factory installed)***	1 Plumber	0.50	Ea..	$30	$65	1	$95
Condensate pump (if no gravity drain available)****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all gas instantaneous designs)							
Air intake vent piping (if direct vent model) (can be PVC)*****	1 Plumber	-	per ft.	$7		20	$140
Electrical outlet (110V) (if required)	1 Plumber	4.42	Ea.	$265	$45	1	$310

* Cost of doing business charge
** 3" PVC, suitable for GIWH Category IV venting, with a developed length of 20 feet, with elbows and outside termination fittings. The existing flue vent opening can be used. The vent length depends on many factors including wall location, buildings codes, etc. For example, a thru the wall vent system could be a shorter pipe.
*** Some condensing GIWH models come with the neutralizer already installed as part of the unit.
**** The material cost includes $45 for the pump and $15 for piping.
***** 3" PVC, assumed to be the same as the flue vent piping. Assumption is that direct vent always requires two pipes. There are some concentric models, but more common is two-pipe system.

Table 8D.5.69 Example of Installation Costs for Condensing GIWH (Horizontally Vented): Replacement

Description	Crew	Labor Hours	Unit	Per Unit Costs		Quantity	Total
				Labor	Material		
Basic trip charge	1 Plumber	--*	Ea.	$75	--	1	$75
Removal of old water heater	1 Plumber	1.50	Ea.	$90	--	1	$90
Capping old vent system	1 Plumber	0.40	Ea.	$24	$15		$39
Install water heater	1 Plumber	6.40	Ea.	$384	$40	1	$424
Wall mounting bracket	1 Plumber	0.75	Ea.	$45	--	1	$45
Wall penetration	1 Plumber	0.85	Ea.	$50	$35	1	$85
Flue vent system**	1 Plumber	-	per ft.	$7		10	$70
Condensate drain	1 Plumber	-	per ft	$4		6	$24
Municipal permit	Ea.			$45		1	$45
Haul away	Ea.			$35		1	$35
						Total	**$932**
Additional installation costs (applicable to condensing gas instantaneous design)							
Condensate neutralizer (if not factory installed)***	1 Plumber	0.50	Ea..	$30	$65	1	$95
Condensate pump (if no gravity drain available)****	1 Plumber	1.17	Ea.	$70	$60	1	$130
Additional installation costs (applicable to all gas instantaneous designs)							
Air intake vent piping (if direct vent model) (can be PVC)*****	1 Plumber	-	per ft.	$7		10	$70
Electrical outlet (110V) (if required)	1 Plumber	4.42	Ea.	$265	$45	1	$310

* Cost of doing business charge
** 3" PVC, suitable for GIWH Category IV venting, with a developed length of 10 feet, with elbows and outside termination fittings. The existing flue vent opening can be used. The vent length depends on many factors including wall location, buildings codes, etc.
*** Some condensing GIWH models come with the neutralizer already installed as part of the unit.
**** The material cost includes $45 for the pump and $15 for piping.
***** 3" PVC, assumed to be the same as the flue vent piping. Assumption is that direct vent always requires two pipes. There are some concentric models, but more common is two-pipe system.

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APPENDIX 8E. ENERGY PRICE CALCULATIONS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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APPENDIX 8E. ENERGY PRICE CALCULATIONS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

8E.1 INTRODUCTION

Figure 8E.1.1 depicts the energy price calculation process, which also encompasses average energy price, seasonal marginal price factor, and monthly price factor calculations.

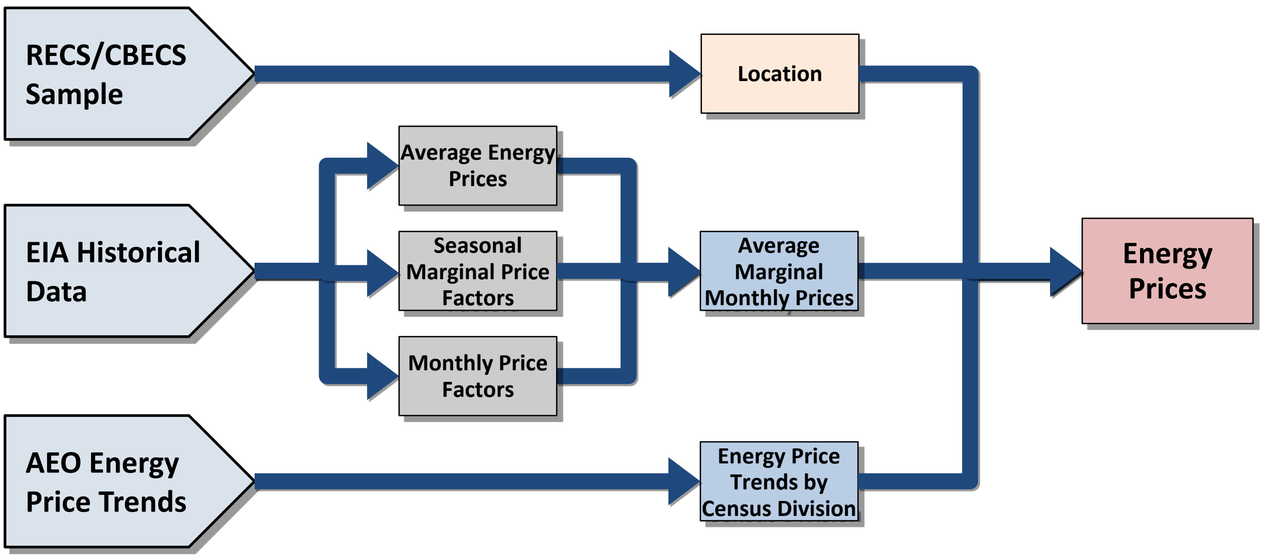

Figure 8E.1.1 Energy Price Calculation Process

DOE used Energy Information Administration (EIA) data by state to determine average annual prices for the 2022 base year (section 8E.2), monthly price factors (section 8E.3), and seasonal marginal price factors (section 8E.4). To match the state energy price data to the building sample developed using EIA's *2020 Residential Energy Consumption Survey* (RECS 2020)[1] and *2018 Commercial Building Energy Consumption Survey* (CBECS 2018),[2] the Department of Energy (DOE) used weather data to assign a state to each sampled housing unit or building. In DOE's LCC analysis energy prices were further adjusted to 2023$ using the consumer price index (CPI).[a]

Energy prices in 2030 were then projected by the EIA's *2023 Annual Energy Outlook* (AEO 2023)[3] forecasts to estimate future energy prices at the census division level (see section 8E.7).

[a] https://www.bls.gov/cpi/

8E.2 AVERAGE ANNUAL ENERGY PRICE DETERMINATION

8E.2.1 Annual Electricity and Natural Gas Prices

DOE derived 2022 annual electricity prices from EIA's Form 861M.[4] The EIA Form 861M data include residential and commercial energy prices by state. Table 8E.2.1 and Table 8E.2.2 show the monthly residential and commercial electricity prices for each state. DOE calculated annual electricity prices by averaging monthly electricity prices by state.

DOE obtained the data for natural gas prices from EIA's Natural Gas Navigator,[5] which includes monthly natural gas prices by state for residential, commercial, and industrial customers. Table 8E.2.3 shows the monthly residential natural gas prices for each state. Table 8E.2.4 shows the monthly commercial natural gas prices for each state. DOE calculated both residential and commercial annual natural gas prices by averaging monthly natural gas prices by state. DOE used a conversion factor (1.037) to convert cubic feet of natural gas to MMBtu.[b]

[b] www.eia.gov/tools/faqs/faq.cfm?id=45&t=7

Table 8E.2.1 2022 Monthly Residential Electricity Prices by State, 2023¢/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	13.9	14.3	14.8	15.3	15.1	15.4	15.3	15.5	15.5	15.4	15.0	14.1	15.0
Alaska	22.9	23.0	23.5	23.7	24.5	24.7	25.2	24.9	24.4	24.4	24.1	23.8	24.1
Arizona	12.3	12.6	12.8	13.5	14.5	14.3	14.3	14.2	14.1	13.9	12.9	12.7	13.5
Arkansas	11.1	11.5	11.8	12.4	12.6	13.0	12.9	12.9	13.0	12.5	12.5	11.8	12.3
California	27.2	27.0	26.6	24.7	27.2	28.3	28.5	28.6	28.0	24.6	27.8	27.6	27.2
Colorado	14.0	14.3	14.4	14.7	14.8	15.4	15.4	15.4	15.5	15.0	14.9	14.5	14.9
Connecticut	24.9	25.8	25.8	26.6	26.8	26.4	25.5	25.9	26.4	26.4	25.7	25.0	25.9
Delaware	13.3	13.4	13.7	14.3	15.2	15.0	14.5	14.6	14.9	15.5	15.1	14.2	14.5
District of Columbia	14.0	14.2	14.4	14.6	15.0	15.4	15.3	15.4	15.3	15.4	14.8	14.6	14.9
Florida	14.1	14.3	14.3	14.5	14.2	14.5	14.5	14.5	14.7	14.6	14.8	14.5	14.5
Georgia	13.2	13.5	14.0	14.2	14.7	15.6	15.8	15.9	15.3	14.4	13.9	13.1	14.5
Hawaii	43.2	43.5	43.7	44.2	44.5	45.0	45.2	45.3	45.4	45.5	45.5	45.4	44.7
Idaho	10.4	10.3	10.5	10.5	10.9	11.5	11.6	11.5	10.9	11.2	10.7	10.6	10.9
Illinois	15.0	15.6	16.3	17.0	17.5	16.9	16.5	16.7	16.8	17.4	16.9	15.6	16.5
Indiana	14.3	14.6	15.2	16.3	16.4	15.8	15.6	15.7	16.1	16.8	16.3	15.2	15.7
Iowa	12.0	12.3	12.8	13.5	14.2	14.8	15.2	15.3	14.5	13.7	13.1	12.4	13.7
Kansas	13.1	13.8	14.3	15.0	15.2	15.3	15.4	15.4	15.2	14.9	14.6	13.7	14.7
Kentucky	12.5	12.7	12.9	13.7	13.7	13.6	13.5	13.6	13.6	14.1	13.9	13.4	13.4
Louisiana	12.0	12.4	12.8	13.1	13.4	13.3	13.5	13.7	13.7	13.8	13.1	12.7	13.1
Maine	23.2	23.6	23.5	23.7	24.0	24.0	23.7	23.6	24.0	23.9	23.9	23.4	23.7
Maryland	14.3	14.4	14.6	14.8	15.2	15.9	15.6	15.6	15.7	15.8	15.0	15.0	15.2
Massachusetts	27.1	27.4	27.4	27.3	27.1	26.9	26.3	26.9	27.6	26.9	27.1	28.1	27.2
Michigan	17.7	17.8	17.9	18.2	18.6	19.1	19.2	19.3	18.9	18.7	18.3	18.3	18.5
Minnesota	13.8	13.9	14.1	14.5	15.0	15.7	15.8	15.7	15.5	15.1	14.5	14.1	14.8
Mississippi	12.3	12.6	13.2	13.7	13.8	13.5	13.3	13.3	13.2	13.4	13.6	13.0	13.2
Missouri	10.7	10.9	11.6	12.3	13.9	14.7	14.7	14.6	13.4	12.6	12.1	11.3	12.7
Montana	11.1	11.2	11.4	11.6	12.0	12.4	12.5	12.4	12.5	12.3	11.9	11.6	11.9
Nebraska	9.6	10.1	10.4	11.1	11.6	12.7	12.9	12.9	13.1	11.6	11.1	10.2	11.4
Nevada	14.1	14.5	14.7	14.8	14.5	14.1	13.9	14.0	14.2	14.9	15.1	14.5	14.4
New Hampshire	25.9	26.4	26.6	26.9	27.2	26.8	26.1	26.5	27.3	27.6	27.3	27.1	26.8
New Jersey	16.7	16.9	16.9	17.0	17.2	18.0	18.5	18.5	18.1	17.0	17.0	17.1	17.4
New Mexico	13.7	14.0	14.1	14.2	14.3	15.2	15.5	15.7	15.3	15.2	14.2	14.0	14.6
New York	21.9	22.4	22.0	22.3	23.0	23.8	23.9	23.7	24.0	23.7	23.0	22.4	23.0
North Carolina	11.7	12.2	12.5	13.0	12.8	12.6	12.7	12.9	13.2	13.5	12.7	12.1	12.7
North Dakota	9.8	10.1	10.5	11.2	12.2	13.3	13.0	13.1	13.3	12.2	11.2	10.4	11.7
Ohio	13.4	13.6	14.0	14.7	15.1	15.4	15.3	15.3	15.0	14.9	14.7	14.0	14.6
Oklahoma	11.0	12.2	12.5	13.7	13.3	13.5	13.4	13.7	14.4	14.2	12.8	11.4	13.0
Oregon	11.5	11.6	11.6	11.7	11.9	12.0	12.1	12.1	12.1	12.1	11.9	11.7	11.9
Pennsylvania	15.8	16.1	16.2	16.6	17.1	17.3	17.2	17.2	17.2	17.2	16.9	16.5	16.8
Rhode Island	24.4	25.1	24.7	24.2	23.9	23.7	23.0	24.2	25.4	24.5	25.1	25.8	24.5
South Carolina	13.9	14.2	14.4	15.0	14.9	14.9	14.8	14.8	15.0	15.1	15.0	14.4	14.7
South Dakota	11.4	11.7	11.9	12.5	13.2	13.7	13.6	13.5	13.8	13.5	12.7	12.0	12.8
Tennessee	12.3	12.2	12.6	13.0	13.1	13.0	12.9	12.9	12.8	13.3	13.3	13.0	12.9
Texas	13.4	13.6	13.9	14.2	14.3	14.4	14.3	14.4	14.4	14.3	14.2	13.9	14.1
Utah	10.7	10.8	10.9	11.0	11.4	11.9	12.1	12.1	11.8	11.2	11.0	11.0	11.3
Vermont	20.3	20.5	20.6	21.2	21.3	21.4	21.0	21.0	21.3	21.8	21.6	21.0	21.1
Virginia	13.0	13.2	13.6	14.1	14.5	14.7	14.8	14.8	14.7	14.4	14.1	13.4	14.1
Washington	10.3	10.4	10.5	10.6	10.7	10.8	10.9	10.9	11.0	10.9	10.8	10.7	10.7
West Virginia	13.0	13.2	13.6	14.1	14.4	14.2	14.0	14.1	14.3	14.7	14.3	13.5	14.0
Wisconsin	15.4	15.6	15.8	16.2	16.6	16.7	16.4	16.4	16.7	16.5	16.1	15.7	16.2
Wyoming	10.7	10.9	11.1	11.4	11.9	12.3	12.3	12.2	12.4	12.3	11.6	11.1	11.7
United States	14.7	15.0	15.3	15.7	16.0	16.2	16.2	16.3	16.3	16.0	15.8	15.3	15.7

Table 8E.2.2 2022 Monthly Commercial Electricity Prices by State, 2023¢/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	13.6	13.7	13.7	13.8	13.8	14.2	14.1	14.2	14.0	14.0	14.1	13.7	13.9
Alaska	19.9	20.1	20.3	20.6	21.1	21.1	21.2	20.9	20.7	20.9	20.8	20.6	20.7
Arizona	10.2	10.5	10.4	10.8	11.7	11.9	12.1	11.9	11.7	11.5	10.6	10.5	11.1
Arkansas	10.1	10.5	10.4	10.4	10.6	11.0	10.9	10.9	10.8	10.6	10.5	10.4	10.6
California	19.7	20.4	20.0	20.4	21.5	24.8	25.8	25.6	25.2	23.4	21.5	20.1	22.4
Colorado	11.1	11.6	11.6	12.0	12.1	12.8	12.7	12.7	12.7	12.3	12.3	11.8	12.1
Connecticut	19.2	19.9	19.2	19.5	19.4	19.5	19.2	19.5	19.4	19.3	19.1	19.2	19.4
Delaware	11.0	11.4	11.4	11.2	11.6	11.8	11.6	11.6	11.6	11.6	11.7	11.5	11.5
District of Columbia	15.5	15.9	15.8	15.9	16.2	16.5	16.2	16.3	16.8	16.4	16.2	16.1	16.2
Florida	11.5	11.9	11.7	11.6	11.5	11.5	11.5	11.5	11.7	11.8	11.9	11.8	11.6
Georgia	12.8	12.9	12.9	12.9	12.9	13.4	13.5	13.5	13.2	13.0	13.0	12.7	13.1
Hawaii	41.2	40.9	41.0	41.2	41.6	41.9	42.4	42.8	42.9	43.1	43.2	43.2	42.1
Idaho	8.3	8.4	8.5	8.6	8.6	9.1	8.9	8.9	8.5	8.7	8.6	8.3	8.6
Illinois	11.5	11.8	12.0	12.1	12.3	12.4	12.5	12.5	12.3	12.4	12.0	11.7	12.1
Indiana	13.0	13.4	13.5	13.7	13.6	13.6	13.6	13.7	13.7	13.9	14.0	13.7	13.6
Iowa	9.9	10.1	10.3	10.4	10.9	11.8	12.5	12.6	11.6	10.4	10.2	10.0	10.9
Kansas	11.2	11.7	12.0	12.1	12.3	12.7	12.8	12.7	12.4	12.2	11.8	11.5	12.1
Kentucky	11.8	12.3	12.2	12.5	12.5	12.5	12.4	12.5	12.6	12.5	12.7	12.5	12.4
Louisiana	11.9	12.2	12.4	12.3	12.2	12.1	12.3	12.4	12.4	12.6	12.4	12.4	12.3
Maine	16.6	17.3	16.9	15.7	15.8	15.7	15.7	15.6	15.9	15.9	16.5	16.9	16.2
Maryland	12.8	13.0	12.8	12.7	12.9	13.4	13.5	13.5	13.8	13.4	13.0	13.3	13.2
Massachusetts	19.3	19.8	19.5	18.9	18.6	19.8	20.0	20.1	20.4	19.4	18.9	19.7	19.5
Michigan	12.4	12.9	12.8	12.8	13.2	13.3	13.2	13.2	13.0	13.0	13.0	13.0	13.0
Minnesota	11.8	12.1	12.1	12.4	12.7	13.8	13.7	13.5	13.3	12.5	12.3	12.0	12.7
Mississippi	12.4	12.6	12.7	12.7	12.7	12.6	12.4	12.5	12.4	12.5	12.8	12.8	12.6
Missouri	8.8	9.0	9.2	9.3	10.8	11.9	12.0	11.9	10.5	9.5	9.3	9.2	10.1
Montana	10.7	10.8	11.0	11.0	11.2	11.3	11.3	11.2	11.4	11.4	11.3	11.1	11.1
Nebraska	8.5	8.7	8.9	8.9	9.2	9.9	10.0	9.9	9.9	9.1	8.9	8.8	9.2
Nevada	9.9	10.2	10.0	10.0	9.8	9.8	9.9	10.0	10.3	10.2	10.1	10.0	10.0
New Hampshire	19.3	19.9	19.6	19.5	19.5	19.4	19.2	19.2	19.5	19.6	19.5	19.8	19.5
New Jersey	13.7	13.8	13.8	13.8	14.4	15.7	15.7	15.9	15.2	13.9	13.7	13.8	14.4
New Mexico	11.0	11.3	11.2	11.1	11.3	12.1	12.3	12.4	12.0	11.8	11.4	11.3	11.6
New York	17.8	18.1	17.8	17.7	18.3	20.0	20.7	20.5	20.5	19.4	18.2	18.0	18.9
North Carolina	9.1	9.5	9.5	9.3	9.3	9.4	9.7	9.7	9.7	9.7	9.4	9.5	9.5
North Dakota	8.7	8.9	9.0	9.2	9.4	10.0	9.8	10.0	10.1	9.6	9.3	9.0	9.4
Ohio	10.6	10.9	11.0	11.1	11.1	11.0	11.0	11.0	11.1	11.1	11.1	10.7	11.0
Oklahoma	9.9	10.2	9.9	10.1	10.3	11.5	11.6	11.8	11.7	11.1	10.0	9.9	10.7
Oregon	9.5	9.7	9.7	9.8	9.8	9.7	9.6	9.5	9.5	9.8	9.8	9.6	9.7
Pennsylvania	11.0	11.2	11.2	11.2	11.3	11.4	11.3	11.3	11.3	11.2	11.3	11.1	11.2
Rhode Island	17.4	18.0	17.3	16.4	16.5	16.6	16.5	16.8	16.8	16.6	17.0	17.8	17.0
South Carolina	11.9	12.2	12.0	12.0	12.0	12.5	12.4	12.4	12.5	12.1	12.5	12.5	12.3
South Dakota	10.0	10.4	10.3	10.5	10.7	11.0	11.1	11.1	11.0	10.8	10.6	10.4	10.6
Tennessee	12.3	12.3	12.5	12.5	12.5	12.7	12.7	12.7	12.6	12.7	12.8	12.8	12.6
Texas	9.3	9.8	9.7	9.6	9.5	9.7	9.6	9.7	9.6	9.5	9.5	9.4	9.6
Utah	8.1	8.3	8.4	8.5	9.2	9.6	9.1	9.0	9.4	9.1	8.4	8.0	8.8
Vermont	17.7	17.8	18.0	18.2	18.4	18.3	18.1	17.9	18.2	18.4	18.3	18.2	18.1
Virginia	9.7	9.7	9.8	9.7	9.9	9.9	10.0	10.1	10.0	10.0	10.0	10.0	9.9
Washington	9.9	9.9	10.0	9.8	9.8	9.8	9.8	9.8	9.9	10.1	10.1	10.1	9.9
West Virginia	10.4	10.9	11.0	11.1	11.0	10.7	10.6	10.7	10.9	11.2	11.4	10.7	10.9
Wisconsin	11.7	12.0	11.8	12.1	12.3	12.6	12.5	12.5	12.6	12.1	12.1	11.8	12.2
Wyoming	9.4	9.7	9.8	10.0	10.2	10.3	10.1	10.0	10.2	10.3	10.0	9.4	9.9
United States	12.4	12.7	12.7	12.7	12.9	13.5	13.6	13.6	13.5	13.2	12.9	12.7	13.0

Table 8E.2.3 2022 Monthly Residential Natural Gas Prices by State, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	16.10	15.94	16.56	18.58	21.12	23.43	24.48	24.73	24.64	23.71	19.87	17.29	20.54
Alaska	10.85	10.99	10.83	11.16	11.91	13.07	13.71	13.44	12.22	11.33	10.90	11.29	11.81
Arizona	15.15	16.08	17.18	19.00	21.24	23.61	25.70	26.32	25.59	22.70	18.79	16.20	20.63
Arkansas	14.38	14.29	15.00	16.77	19.81	23.48	25.68	26.79	26.00	23.39	17.64	15.43	19.89
California	20.38	20.03	19.34	19.47	20.53	20.97	21.26	21.25	20.98	20.92	19.99	20.61	20.48
Colorado	11.78	11.91	12.50	12.96	15.04	18.95	21.28	21.46	19.05	14.52	12.99	12.30	15.39
Connecticut	17.46	17.65	18.05	19.29	21.69	25.04	27.31	28.60	27.72	23.58	19.54	18.35	22.02
Delaware	13.91	14.22	14.94	16.29	18.92	22.95	25.63	27.03	26.06	22.76	16.54	14.79	19.50
District of Columbia	17.02	16.89	17.50	18.62	21.47	23.97	26.25	25.96	25.25	22.35	19.26	17.56	21.01
Florida	22.60	22.61	24.16	25.54	27.81	30.21	32.01	32.92	32.18	31.55	28.37	24.87	27.90
Georgia	16.45	17.36	18.49	21.77	27.00	32.26	34.22	34.49	34.54	27.78	20.07	17.80	25.19
Hawaii	53.52	55.52	57.02	57.29	58.87	59.25	59.64	59.58	59.62	60.33	58.11	56.92	57.97
Idaho	7.93	7.96	8.19	8.33	8.71	9.39	9.97	10.16	9.58	8.66	8.09	8.03	8.75
Illinois	13.35	13.39	14.44	15.83	19.51	23.94	27.89	28.29	26.10	18.56	15.17	13.90	19.20
Indiana	10.31	10.51	11.78	13.39	15.57	20.28	21.39	21.13	18.99	12.68	10.58	10.34	14.75
Iowa	11.35	11.64	12.88	13.08	15.59	20.01	22.86	23.88	22.74	16.67	13.12	11.59	16.28
Kansas	13.56	13.91	14.76	17.67	21.28	26.76	28.83	30.67	28.51	21.74	15.48	14.16	20.61
Kentucky	14.03	14.07	14.98	17.17	22.79	27.87	30.02	31.04	29.47	21.38	16.15	15.04	21.17
Louisiana	14.59	14.69	15.73	17.74	20.40	22.62	23.48	24.01	23.19	22.40	18.64	15.99	19.46
Maine	23.07	23.78	23.57	24.23	24.40	27.94	31.35	32.52	31.34	25.51	23.34	23.76	26.23
Maryland	15.96	15.92	16.48	18.29	21.79	25.72	27.51	28.11	27.11	21.67	17.79	17.00	21.11
Massachusetts	21.35	21.32	21.36	22.01	22.25	21.97	24.07	24.98	24.17	20.84	21.51	22.23	22.34
Michigan	10.76	10.87	11.19	11.90	13.77	16.20	17.55	18.14	16.53	13.08	11.68	11.28	13.58
Minnesota	12.73	12.82	13.12	13.02	15.16	18.13	19.37	19.17	17.95	14.02	13.36	13.00	15.15
Mississippi	14.34	14.50	15.63	17.43	20.14	22.65	22.49	23.16	23.13	21.63	17.26	15.36	18.98
Missouri	11.73	11.70	12.42	14.61	17.90	23.85	27.84	29.16	27.29	22.35	15.51	12.94	18.94
Montana	10.34	10.47	10.58	10.93	11.55	13.10	15.16	16.26	14.77	12.06	11.03	10.64	12.24
Nebraska	12.04	12.27	12.55	13.77	15.78	20.11	23.31	24.54	23.81	19.69	14.74	13.08	17.14
Nevada	11.41	11.78	12.37	13.74	14.97	16.10	17.62	18.37	17.63	16.00	13.67	12.02	14.64
New Hampshire	20.92	20.63	20.75	21.81	22.75	24.56	29.20	31.02	30.37	25.88	22.56	22.63	24.42
New Jersey	12.23	12.17	12.22	12.37	13.66	15.05	15.90	16.36	15.92	14.53	13.38	12.69	13.87
New Mexico	12.02	12.01	12.41	13.37	15.26	18.95	21.10	21.55	21.46	19.05	14.49	12.73	16.20
New York	15.75	15.54	15.97	16.78	19.12	22.99	24.92	25.34	24.81	21.70	18.17	16.55	19.80
North Carolina	15.42	15.59	16.43	19.14	23.73	27.66	29.51	28.80	28.58	23.64	17.67	16.85	21.92
North Dakota	11.46	11.58	12.09	12.82	15.57	22.27	27.45	27.57	23.35	14.69	12.49	11.81	16.93
Ohio	13.28	13.47	13.91	15.65	19.91	28.06	31.82	33.21	30.92	21.11	15.61	14.18	20.93
Oklahoma	12.87	13.12	13.91	17.45	22.31	28.32	33.02	36.05	34.49	30.54	19.77	13.91	22.98
Oregon	12.55	12.48	12.84	13.29	14.32	15.36	16.74	17.81	16.52	14.23	13.23	12.69	14.34
Pennsylvania	13.70	13.80	14.15	15.02	17.19	21.10	23.65	24.59	23.19	18.33	15.21	14.26	17.85
Rhode Island	16.67	16.81	17.16	18.28	19.80	21.79	23.78	24.73	24.31	22.00	18.92	17.68	20.16
South Carolina	13.83	14.27	15.14	18.05	23.20	26.36	28.11	27.90	27.45	21.99	15.82	14.86	20.58
South Dakota	10.23	10.43	11.11	11.09	12.02	15.16	17.93	18.62	17.47	12.72	11.13	10.26	13.18
Tennessee	11.75	11.68	12.06	13.62	16.32	19.64	21.64	22.68	21.36	18.88	14.14	12.41	16.35
Texas	14.63	14.56	15.89	19.55	23.48	26.54	28.55	30.52	29.70	26.63	20.19	16.67	22.24
Utah	10.32	10.53	10.61	10.32	10.12	11.16	12.23	12.79	12.50	11.29	10.66	10.82	11.11
Vermont	15.09	14.80	15.13	15.67	17.32	20.84	23.91	25.23	24.32	20.53	17.25	16.02	18.84
Virginia	14.99	15.10	15.33	17.21	20.84	24.69	27.11	27.21	26.47	21.67	17.07	16.04	20.31
Washington	12.28	12.33	12.48	12.95	14.07	15.41	16.76	17.36	16.04	13.70	12.89	12.58	14.07
West Virginia	11.69	11.77	11.94	12.84	15.12	19.04	21.03	21.36	18.95	14.51	12.59	12.17	15.25
Wisconsin	11.61	11.63	12.17	12.18	13.70	16.85	18.09	18.59	16.87	12.11	12.24	11.92	14.00
Wyoming	12.93	13.11	13.40	13.92	15.03	18.34	24.23	25.82	23.47	17.68	14.62	13.62	17.18
United States	14.07	14.16	14.70	15.80	18.15	21.29	23.15	23.78	22.65	18.39	15.63	14.76	18.04

Table 8E.2.4 2022 Monthly Commercial Natural Gas Prices by State, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg.
Alabama	13.23	13.21	13.33	13.90	14.05	14.25	14.30	14.41	14.66	14.62	14.32	13.77	14.00
Alaska	10.52	10.50	10.27	10.12	10.05	10.36	10.45	10.52	10.40	10.59	10.56	10.74	10.42
Arizona	10.57	10.74	10.93	11.01	11.26	11.21	11.28	11.30	11.33	11.30	11.02	10.78	11.06
Arkansas	12.37	12.22	12.42	12.84	13.55	14.15	14.28	14.33	13.89	13.30	13.39	12.94	13.31
California	17.24	16.66	16.42	15.64	15.25	15.78	16.12	16.06	15.70	15.64	16.41	17.64	16.21
Colorado	11.26	11.21	11.41	11.59	12.46	13.53	14.60	14.53	14.16	12.60	12.10	11.65	12.59
Connecticut	12.77	12.82	12.93	13.64	14.41	15.34	15.08	15.06	14.96	14.74	13.44	12.93	14.01
Delaware	11.60	11.90	12.37	12.98	13.82	14.57	15.19	15.36	15.03	14.41	12.65	12.09	13.50
District of Columbia	16.06	16.24	16.42	16.82	16.72	17.01	17.27	16.85	16.62	16.40	16.99	16.29	16.64
Florida	14.25	14.26	14.26	14.20	14.22	14.31	14.40	14.28	14.34	14.20	14.20	14.30	14.27
Georgia	10.67	10.80	11.13	11.74	12.47	13.00	13.19	13.23	13.06	12.41	11.55	10.62	11.99
Hawaii	40.65	42.44	43.83	43.87	44.95	45.94	45.97	45.31	45.30	45.75	44.25	43.09	44.28
Idaho	7.00	6.99	7.10	7.29	7.34	7.39	7.51	7.52	7.47	7.27	7.18	7.12	7.27
Illinois	12.35	12.38	13.11	14.29	17.31	19.90	21.37	21.67	19.81	15.31	13.57	12.85	16.16
Indiana	8.77	8.82	9.76	10.40	11.34	12.42	12.53	12.29	10.73	8.78	8.62	8.64	10.26
Iowa	10.86	11.07	11.75	11.13	12.25	13.39	13.86	13.91	13.40	10.88	11.29	11.26	12.09
Kansas	11.82	12.05	12.57	14.28	15.96	17.51	18.36	18.38	18.40	15.50	12.81	12.13	14.98
Kentucky	12.51	12.43	12.90	14.03	15.89	17.19	17.47	17.80	17.23	15.27	13.81	13.27	14.98
Louisiana	14.07	13.51	13.61	13.15	13.45	13.65	13.79	13.53	13.38	13.72	14.03	14.33	13.68
Maine	18.48	18.81	18.36	18.38	17.09	16.65	17.63	18.01	17.29	16.04	17.09	18.28	17.67
Maryland	14.71	14.79	14.84	15.17	16.10	16.65	16.76	16.77	16.76	16.02	15.42	15.45	15.79
Massachusetts	16.93	17.00	17.08	17.23	16.30	14.94	15.39	15.42	15.46	14.39	16.10	17.42	16.14
Michigan	10.19	10.25	10.46	10.62	11.48	12.54	13.01	13.09	12.67	11.30	10.79	10.59	11.42
Minnesota	12.03	11.97	12.12	11.54	12.14	13.08	13.26	13.07	12.65	11.36	11.90	11.98	12.26
Mississippi	13.17	13.06	13.35	13.11	12.94	12.53	12.56	12.35	12.49	13.38	13.52	13.29	12.98
Missouri	10.80	10.64	10.87	11.58	12.23	13.60	14.47	14.58	14.01	13.40	12.42	11.48	12.51
Montana	10.28	10.41	10.50	10.74	11.32	12.52	13.37	13.58	13.17	11.45	10.83	10.55	11.56
Nebraska	11.54	11.50	11.48	11.18	10.80	11.27	11.96	12.04	12.03	11.36	11.39	11.87	11.54
Nevada	9.16	9.26	9.33	9.60	9.83	9.91	10.25	10.43	10.28	10.07	9.76	9.40	9.77
New Hampshire	17.54	17.35	17.51	18.07	18.22	18.53	20.96	21.49	21.20	18.84	18.23	18.71	18.89
New Jersey	14.40	14.16	14.32	12.72	13.40	14.22	14.55	14.05	13.54	13.96	14.93	14.81	14.09
New Mexico	10.68	10.62	10.56	10.47	10.96	11.75	12.48	12.63	12.43	12.40	11.93	11.26	11.51
New York	11.29	11.26	11.32	10.82	10.56	10.29	9.84	9.58	9.82	10.36	10.83	11.38	10.61
North Carolina	11.90	11.77	11.81	12.37	12.76	13.23	13.44	12.92	12.93	12.83	12.96	13.09	12.67
North Dakota	10.00	10.02	10.09	9.69	10.47	11.74	12.39	12.27	11.55	9.85	10.22	10.20	10.71
Ohio	8.51	8.50	8.48	8.84	9.55	10.27	10.45	10.52	10.24	9.48	8.77	8.73	9.36
Oklahoma	10.61	10.70	11.14	13.39	15.85	18.55	20.22	21.49	20.54	19.45	15.04	11.33	15.69
Oregon	10.15	10.05	10.24	10.39	10.55	10.81	10.98	11.29	10.99	10.63	10.49	10.43	10.58
Pennsylvania	12.10	12.30	12.59	12.75	13.85	14.64	15.01	14.78	14.37	13.12	12.40	12.45	13.36
Rhode Island	14.20	14.39	14.61	15.32	16.50	18.63	20.13	20.73	20.28	18.64	16.05	15.22	17.06
South Carolina	12.86	12.10	12.41	12.46	12.11	12.53	12.72	12.39	12.44	12.54	13.17	13.70	12.62
South Dakota	9.27	9.36	9.76	9.12	9.44	10.43	11.11	11.27	10.64	9.18	9.30	9.28	9.84
Tennessee	11.79	11.64	11.60	11.91	12.29	12.86	13.34	13.63	13.25	13.32	12.71	12.34	12.56
Texas	11.39	11.48	11.49	11.87	12.39	12.86	13.09	13.20	13.30	13.19	12.74	12.26	12.44
Utah	9.01	9.13	9.14	8.68	8.17	8.51	9.04	9.31	9.19	8.85	8.98	9.45	8.96
Vermont	9.26	9.35	9.11	8.97	8.89	8.53	8.53	8.58	8.79	8.56	8.95	9.35	8.91
Virginia	11.78	11.77	11.46	11.70	12.21	12.86	12.83	12.74	12.83	12.12	11.84	12.14	12.19
Washington	10.20	10.21	10.19	10.34	10.61	10.97	11.37	11.53	11.17	10.62	10.51	10.46	10.68
West Virginia	9.06	9.11	9.21	9.69	10.57	11.51	11.63	11.74	11.25	10.28	9.49	9.41	10.25
Wisconsin	10.70	10.73	10.88	10.40	10.20	10.96	10.92	10.86	10.66	9.29	10.74	10.92	10.61
Wyoming	11.63	11.60	11.69	11.56	11.72	12.46	13.54	13.76	13.61	12.90	12.43	12.09	12.42
United States	11.56	11.57	11.78	11.84	12.23	12.70	12.89	12.83	12.69	12.11	11.93	11.92	12.17

8E.2.2 Annual LPG Prices

DOE collected 2021 average liquid petroleum gas (LPG) prices from EIA's 2021 State Energy Consumption, Price, and Expenditures Estimates (SEDS).[6] SEDS includes annual LPG prices for residential, commercial, industrial, and transportation consumers by state. All prices in 2021 were converted to 2022$ using the CPI (1.0799 factor) to be consistent with the prices used in the rest of the analysis.[c] DOE also adjusted the prices to 2022 prices using EIA's 2023 Annual Energy Outlook (AEO 2023), see Table 8E.2.5.

Table 8E.2.6 shows the resulting annual residential and commercial LPG prices for each state. Prices in 2022 were converted to 2023$ using the CPI with a factor of 1.041.[d]

Table 8E.2.5 LPG Excalation Factors from 2021 to 2022 based on AEO 2023, 2022$/MMBtu

State	LPG, Residential			LPG, Commercial		
	2021	2022	Factor	2021	2022	Factor
New England	37.7	34.1	0.90	21.1	28.5	1.35
Middle Atlantic	32.8	33.7	1.03	22.3	30.0	1.35
East North Central	24.8	26.1	1.05	19.7	25.7	1.30
West North Central	22.7	23.7	1.05	19.6	24.6	1.25
South Atlantic	36.6	32.3	0.88	22.4	29.0	1.30
East South Central	29.7	30.8	1.04	20.3	27.5	1.35
West South Central	28.4	30.2	1.06	20.8	27.4	1.31
Mountain	27.7	27.9	1.01	21.5	27.7	1.29
Pacific	32.0	33.3	1.04	23.4	29.9	1.28
United States	29.0	29.1	1.01	21.3	27.8	1.30

Table 8E.2.6 2022 Average Annual LPG by State, 2022$/MMBtu

State	LPG	
	Residential	Commercial
Alabama	30.31	27.81
Alaska	36.73	28.33
Arizona	33.74	30.17
Arkansas	29.53	27.63
California	34.38	30.39
Colorado	26.08	26.39
Connecticut	37.51	28.94
Delaware	27.95	27.56
District of Columbia	32.16	29.21
Florida	38.70	29.19
Georgia	29.10	28.63
Hawaii	55.66	29.46

[c] www.bls.gov/cpi/
[d] www.bls.gov/cpi/

State	LPG	
	Residential	Commercial
Idaho	28.57	27.18
Illinois	24.09	25.79
Indiana	27.67	25.97
Iowa	21.62	24.69
Kansas	23.83	24.79
Kentucky	29.86	26.73
Louisiana	34.72	27.11
Maine	31.71	28.70
Maryland	32.07	29.21
Massachusetts	38.42	28.91
Michigan	25.92	25.73
Minnesota	25.15	24.89
Mississippi	32.65	28.62
Missouri	25.52	24.27
Montana	24.05	25.65
Nebraska	22.52	24.56
Nevada	34.00	30.52
New Hampshire	31.10	27.22
New Jersey	39.10	30.51
New Mexico	29.53	26.71
New York	35.24	29.76
North Carolina	31.95	28.84
North Dakota	21.72	24.46
Ohio	30.99	25.66
Oklahoma	25.47	25.57
Oregon	31.98	28.33
Pennsylvania	30.55	30.32
Rhode Island	36.03	29.11
South Carolina	33.09	29.19
South Dakota	24.16	24.33
Tennessee	30.45	26.98
Texas	32.60	27.57
Utah	27.36	27.21
Vermont	30.70	28.85
Virginia	32.02	29.00
Washington	29.29	30.17
West Virginia	32.59	29.19
Wisconsin	24.39	25.49
Wyoming	26.62	26.66
United States	29.13	27.83

8E.3 MONTHLY ENERGY PRICE FACTORS DETERMINATION

For gas-fired instantaneous water heaters, DOE developed monthly energy price factors and used monthly energy consumption data for the life-cycle cost and payback period calculation. DOE developed monthly energy price factors to capture robust seasonal trends in monthly energy prices. To convert available annual energy prices into monthly energy prices, DOE determined monthly energy price factors.

8E.3.1 Monthly Electricity Price Factor Calculations

DOE collected historical electricity prices from 2003 to 2022 from EIA's Form 861M. These data are published annually and include monthly electricity sales, revenues from electricity sales, and average price for the residential, commercial, industrial, and transportation sectors by year and by state. As an example, to illustrate the methodology for producing monthly price factors, the following tables and charts show the calculation of monthly average residential electricity price factors, based on New York historic residential electricity price data. Table 8E.3.1 shows the average residential electricity prices for New York.

Table 8E.3.1 2003-2022 Average Residential Electricity Prices for New York from EIA Data (nominal cents/kWh)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2003	12.77	13.30	13.91	14.55	14.77	14.98	15.14	14.94	14.92	14.75	14.23	13.63	14.32
2004	13.32	14.02	13.98	14.03	14.20	14.99	15.36	15.32	15.10	14.93	14.88	14.29	14.53
2005	14.05	14.53	14.40	14.64	15.36	15.58	15.63	16.16	16.69	17.36	17.57	16.53	15.71
2006	16.61	16.66	15.89	16.36	16.56	17.33	17.56	17.74	17.92	17.22	16.33	15.88	16.84
2007	16.09	15.89	16.83	17.14	17.50	18.17	17.27	17.96	17.15	17.48	16.94	16.66	17.09
2008	16.87	17.32	16.93	18.05	18.74	19.41	19.75	20.93	19.50	17.58	16.97	16.63	18.22
2009	16.86	16.75	16.39	16.50	16.87	18.21	18.65	18.19	18.78	18.17	16.82	17.51	17.47
2010	17.30	18.05	17.55	18.92	19.21	19.41	20.11	19.35	20.09	18.36	18.25	17.72	18.69
2011	17.25	17.45	17.58	17.63	18.30	19.07	19.22	19.25	18.84	18.78	17.93	17.26	18.21
2012	16.79	16.51	16.64	16.70	17.33	18.31	18.38	18.12	18.52	18.44	17.44	17.47	17.55
2013	17.93	19.10	18.16	17.67	18.35	19.32	20.03	19.14	19.56	18.88	18.49	18.18	18.74
2014	19.57	21.69	20.90	19.54	20.59	20.88	20.48	19.51	19.41	19.43	19.45	19.26	20.06
2015	19.28	19.75	18.92	17.72	18.06	18.76	18.71	18.38	18.38	18.30	18.23	17.50	18.50
2016	16.56	16.76	16.79	17.38	17.71	17.87	17.93	17.99	18.36	18.26	17.73	17.17	17.54
2017	17.30	17.48	17.02	17.30	18.53	18.74	18.79	18.56	18.80	18.74	17.80	16.99	18.01
2018	17.75	18.19	17.52	17.98	18.51	19.28	19.37	19.02	19.28	19.29	18.17	17.33	18.47
2019	17.30	17.65	16.85	17.54	17.35	18.53	18.64	18.38	18.72	18.58	18.01	17.33	17.91
2020	17.58	17.46	17.20	17.35	18.55	19.13	18.75	18.43	19.01	19.29	18.95	18.26	18.33
2021	18.31	18.83	18.04	18.55	19.93	19.60	19.64	19.97	20.50	20.66	20.09	19.56	19.47
2022	21.02	21.60	20.33	21.07	21.87	22.37	21.88	21.19	23.95	23.27	23.66	22.79	22.08

DOE then calculated monthly energy price factors by dividing the monthly prices by the annual average for each year. Table 8E.3.2 and Figure 8E.3.1 show the calculated results for New York. DOE then averaged the monthly energy price factors for 2003 to 2022 to develop an average energy price factor for each month.

Table 8E.3.2 Monthly Residential Electricity Price Factors for New York (2003-2022)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	0.89	0.93	0.97	1.02	1.03	1.05	1.06	1.04	1.04	1.03	0.99	0.95
2004	0.92	0.96	0.96	0.97	0.98	1.03	1.06	1.05	1.04	1.03	1.02	0.98
2005	0.89	0.93	0.92	0.93	0.98	0.99	0.99	1.03	1.06	1.11	1.12	1.05
2006	0.99	0.99	0.94	0.97	0.98	1.03	1.04	1.05	1.06	1.02	0.97	0.94
2007	0.94	0.93	0.98	1.00	1.02	1.06	1.01	1.05	1.00	1.02	0.99	0.97
2008	0.93	0.95	0.93	0.99	1.03	1.07	1.08	1.15	1.07	0.96	0.93	0.91
2009	0.97	0.96	0.94	0.94	0.97	1.04	1.07	1.04	1.07	1.04	0.96	1.00
2010	0.93	0.97	0.94	1.01	1.03	1.04	1.08	1.04	1.07	0.98	0.98	0.95
2011	0.95	0.96	0.97	0.97	1.00	1.05	1.06	1.06	1.03	1.03	0.98	0.95
2012	0.96	0.94	0.95	0.95	0.99	1.04	1.05	1.03	1.05	1.05	0.99	0.99
2013	0.96	1.02	0.97	0.94	0.98	1.03	1.07	1.02	1.04	1.01	0.99	0.97
2014	0.98	1.08	1.04	0.97	1.03	1.04	1.02	0.97	0.97	0.97	0.97	0.96
2015	1.04	1.07	1.02	0.96	0.98	1.01	1.01	0.99	0.99	0.99	0.99	0.95
2016	0.94	0.96	0.96	0.99	1.01	1.02	1.02	1.03	1.05	1.04	1.01	0.98
2017	0.96	0.97	0.95	0.96	1.03	1.04	1.04	1.03	1.04	1.04	0.99	0.94
2018	0.96	0.98	0.95	0.97	1.00	1.04	1.05	1.03	1.04	1.04	0.98	0.94
2019	0.97	0.99	0.94	0.98	0.97	1.03	1.04	1.03	1.05	1.04	1.01	0.97
2020	0.96	0.95	0.94	0.95	1.01	1.04	1.02	1.01	1.04	1.05	1.03	1.00
2021	0.94	0.97	0.93	0.95	1.02	1.01	1.01	1.03	1.05	1.06	1.03	1.00
2022	0.95	0.98	0.92	0.95	0.99	1.01	0.99	0.96	1.08	1.05	1.07	1.03
20-Year Avg.	0.95	0.97	0.96	0.97	1.00	1.03	1.04	1.03	1.04	1.03	1.00	0.97

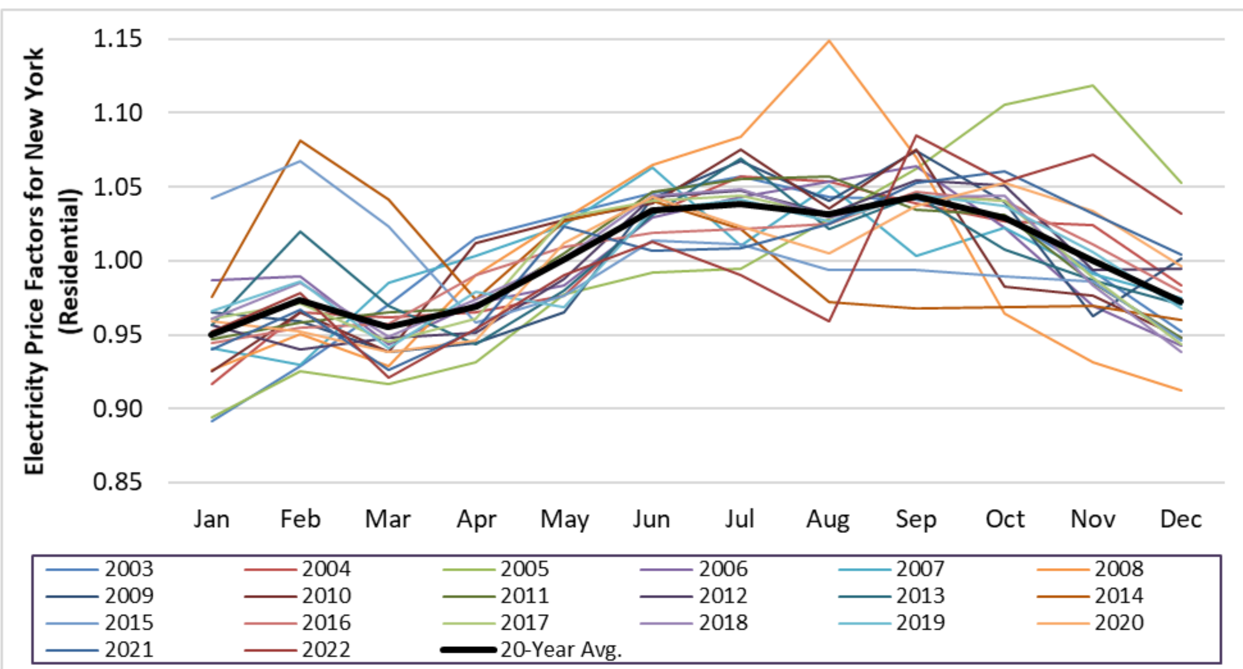

Figure 8E.3.1 Monthly Electricity Price Factors for New York (2003-2022)

DOE performed the same calculations for each state to develop the average monthly residential and commercial energy price factors as shown in Table 8E.3.3 and Table 8E.3.4, respectively.

Table 8E.3.3 Average Monthly Residential Electricity Price Factors (2003-2022)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.93	0.96	0.99	1.02	1.01	1.03	1.02	1.03	1.04	1.03	1.00	0.94
Alaska	0.95	0.95	0.97	0.98	1.02	1.03	1.05	1.03	1.01	1.01	1.00	0.99
Arizona	0.91	0.93	0.95	1.00	1.07	1.06	1.06	1.05	1.05	1.03	0.95	0.94
Arkansas	0.90	0.93	0.96	1.01	1.02	1.05	1.05	1.05	1.05	1.01	1.01	0.95
California	1.00	0.99	0.98	0.91	1.00	1.04	1.05	1.05	1.03	0.91	1.02	1.01
Colorado	0.94	0.96	0.97	0.99	1.00	1.03	1.04	1.04	1.05	1.01	1.00	0.97
Connecticut	0.96	1.00	1.00	1.03	1.03	1.02	0.98	1.00	1.02	1.02	0.99	0.97
Delaware	0.92	0.93	0.95	0.99	1.05	1.04	1.00	1.01	1.03	1.07	1.04	0.98
District of Columbia	0.94	0.96	0.97	0.98	1.01	1.04	1.03	1.04	1.03	1.03	1.00	0.98
Florida	0.98	0.99	0.99	1.00	0.98	1.00	1.00	1.01	1.02	1.01	1.02	1.00
Georgia	0.91	0.93	0.96	0.98	1.02	1.08	1.09	1.10	1.06	1.00	0.96	0.91
Hawaii	0.97	0.97	0.98	0.99	0.99	1.01	1.01	1.01	1.02	1.02	1.02	1.02
Idaho	0.95	0.95	0.96	0.97	1.00	1.05	1.07	1.06	1.00	1.03	0.98	0.98
Illinois	0.91	0.95	0.98	1.03	1.06	1.02	1.00	1.01	1.02	1.05	1.02	0.94
Indiana	0.91	0.93	0.97	1.04	1.05	1.01	0.99	1.00	1.03	1.07	1.04	0.97
Iowa	0.88	0.90	0.93	0.99	1.04	1.08	1.11	1.12	1.06	1.01	0.96	0.91
Kansas	0.90	0.94	0.98	1.02	1.04	1.04	1.05	1.05	1.04	1.02	0.99	0.93
Kentucky	0.93	0.94	0.96	1.02	1.02	1.01	1.01	1.01	1.02	1.05	1.03	1.00
Louisiana	0.92	0.94	0.97	1.00	1.02	1.02	1.03	1.04	1.04	1.05	1.00	0.97
Maine	0.98	0.99	0.99	1.00	1.01	1.01	1.00	1.00	1.01	1.01	1.01	0.99
Maryland	0.94	0.95	0.96	0.98	1.00	1.05	1.03	1.03	1.04	1.04	0.99	0.99
Massachusetts	1.00	1.01	1.01	1.01	1.00	0.99	0.97	0.99	1.02	0.99	1.00	1.03
Michigan	0.96	0.96	0.97	0.98	1.00	1.03	1.04	1.04	1.02	1.01	0.99	0.99
Minnesota	0.93	0.94	0.95	0.98	1.01	1.06	1.07	1.06	1.05	1.02	0.98	0.96
Mississippi	0.93	0.95	0.99	1.03	1.04	1.02	1.00	1.00	1.00	1.01	1.03	0.98
Missouri	0.84	0.86	0.91	0.97	1.09	1.16	1.15	1.15	1.05	0.99	0.95	0.89
Montana	0.94	0.94	0.96	0.97	1.01	1.04	1.05	1.04	1.05	1.03	1.00	0.97
Nebraska	0.84	0.88	0.91	0.97	1.01	1.11	1.13	1.13	1.14	1.02	0.97	0.90
Nevada	0.97	1.00	1.02	1.03	1.01	0.98	0.97	0.97	0.99	1.03	1.05	1.00
New Hampshire	0.96	0.99	0.99	1.00	1.01	1.00	0.97	0.99	1.02	1.03	1.02	1.01
New Jersey	0.96	0.97	0.97	0.98	0.99	1.03	1.06	1.06	1.04	0.98	0.97	0.98
New Mexico	0.94	0.96	0.96	0.97	0.98	1.04	1.06	1.07	1.04	1.04	0.97	0.96
New York	0.95	0.97	0.96	0.97	1.00	1.03	1.04	1.03	1.04	1.03	1.00	0.97
North Carolina	0.93	0.97	0.98	1.03	1.01	0.99	1.01	1.02	1.04	1.06	1.01	0.95
North Dakota	0.84	0.87	0.90	0.96	1.05	1.14	1.11	1.12	1.14	1.04	0.95	0.89
Ohio	0.92	0.93	0.96	1.00	1.03	1.05	1.05	1.05	1.02	1.02	1.01	0.96
Oklahoma	0.85	0.94	0.96	1.05	1.02	1.04	1.03	1.05	1.10	1.09	0.99	0.88
Oregon	0.96	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.02	1.02	1.00	0.99
Pennsylvania	0.94	0.96	0.96	0.99	1.02	1.03	1.03	1.03	1.02	1.03	1.01	0.98
Rhode Island	1.00	1.03	1.01	0.99	0.98	0.97	0.94	0.99	1.04	1.00	1.02	1.05
South Carolina	0.94	0.97	0.98	1.02	1.01	1.01	1.01	1.01	1.02	1.03	1.02	0.98
South Dakota	0.89	0.91	0.93	0.97	1.04	1.07	1.07	1.06	1.08	1.06	0.99	0.94
Tennessee	0.96	0.95	0.98	1.01	1.02	1.01	1.01	1.00	1.00	1.03	1.04	1.01
Texas	0.95	0.96	0.99	1.01	1.01	1.02	1.02	1.02	1.02	1.02	1.01	0.98
Utah	0.95	0.96	0.96	0.97	1.01	1.05	1.07	1.07	1.04	0.99	0.97	0.97
Vermont	0.96	0.97	0.98	1.00	1.01	1.01	1.00	1.00	1.01	1.03	1.03	0.99
Virginia	0.92	0.94	0.96	1.00	1.03	1.04	1.05	1.05	1.04	1.02	1.00	0.95
Washington	0.96	0.98	0.98	0.99	1.00	1.01	1.02	1.02	1.03	1.02	1.01	1.00
West Virginia	0.93	0.94	0.98	1.01	1.03	1.02	1.00	1.01	1.03	1.05	1.02	0.97
Wisconsin	0.95	0.97	0.97	1.00	1.03	1.03	1.01	1.02	1.03	1.02	1.00	0.97
Wyoming	0.92	0.93	0.95	0.98	1.02	1.05	1.06	1.04	1.06	1.05	0.99	0.95
United States	0.94	0.95	0.97	1.00	1.02	1.03	1.03	1.04	1.04	1.02	1.01	0.97

Table 8E.3.4 Average Monthly Commercial Electricity Price Factors (2003-2022)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.97	0.99	0.99	0.99	0.99	1.02	1.01	1.02	1.01	1.01	1.01	0.98
Alaska	0.96	0.97	0.98	1.00	1.02	1.02	1.02	1.01	1.00	1.01	1.00	1.00
Arizona	0.92	0.94	0.94	0.97	1.05	1.07	1.08	1.07	1.05	1.03	0.95	0.94
Arkansas	0.95	0.99	0.98	0.98	1.00	1.03	1.03	1.03	1.02	1.00	0.99	0.98
California	0.88	0.91	0.89	0.91	0.96	1.11	1.15	1.15	1.13	1.05	0.96	0.90
Colorado	0.92	0.95	0.96	0.99	0.99	1.06	1.05	1.05	1.05	1.02	1.01	0.97
Connecticut	0.99	1.03	0.99	1.01	1.00	1.01	0.99	1.01	1.00	1.00	0.99	0.99
Delaware	0.96	0.99	0.99	0.97	1.01	1.03	1.00	1.01	1.01	1.01	1.02	1.00
District of Columbia	0.96	0.99	0.98	0.99	1.00	1.02	1.00	1.01	1.04	1.02	1.00	0.99
Florida	0.98	1.02	1.00	1.00	0.98	0.99	0.98	0.99	1.00	1.01	1.02	1.01
Georgia	0.98	0.99	0.99	0.99	0.99	1.02	1.03	1.04	1.01	1.00	1.00	0.98
Hawaii	0.98	0.97	0.97	0.98	0.99	1.00	1.01	1.01	1.02	1.02	1.03	1.03
Idaho	0.96	0.98	0.98	1.00	1.00	1.06	1.03	1.03	0.99	1.01	0.99	0.97
Illinois	0.95	0.97	0.99	1.00	1.01	1.02	1.03	1.03	1.02	1.02	0.99	0.96
Indiana	0.96	0.99	0.99	1.01	1.00	1.00	1.00	1.01	1.01	1.02	1.03	1.01
Iowa	0.91	0.93	0.94	0.96	1.00	1.08	1.15	1.15	1.06	0.96	0.94	0.92
Kansas	0.93	0.96	0.99	1.00	1.02	1.05	1.05	1.05	1.03	1.01	0.98	0.95
Kentucky	0.95	0.99	0.98	1.00	1.01	1.01	1.00	1.01	1.02	1.00	1.02	1.01
Louisiana	0.97	1.00	1.01	1.00	0.99	0.98	1.00	1.01	1.01	1.02	1.01	1.01
Maine	1.02	1.07	1.04	0.97	0.98	0.97	0.97	0.96	0.98	0.98	1.02	1.04
Maryland	0.97	0.99	0.97	0.97	0.98	1.02	1.02	1.02	1.05	1.01	0.99	1.01
Massachusetts	0.99	1.02	1.00	0.97	0.95	1.01	1.02	1.03	1.05	0.99	0.97	1.01
Michigan	0.96	0.99	0.99	0.99	1.01	1.02	1.02	1.02	1.00	1.00	1.00	1.00
Minnesota	0.93	0.96	0.95	0.97	1.00	1.08	1.08	1.07	1.05	0.99	0.97	0.95
Mississippi	0.99	1.00	1.01	1.01	1.01	1.00	0.99	0.99	0.99	1.00	1.02	1.02
Missouri	0.87	0.89	0.91	0.92	1.06	1.18	1.18	1.18	1.04	0.94	0.92	0.91
Montana	0.96	0.97	0.98	0.99	1.01	1.01	1.01	1.00	1.02	1.03	1.02	0.99
Nebraska	0.92	0.95	0.97	0.97	1.00	1.07	1.08	1.07	1.08	0.99	0.96	0.95
Nevada	0.99	1.01	0.99	1.00	0.98	0.98	0.99	0.99	1.03	1.02	1.01	1.00
New Hampshire	0.99	1.02	1.00	1.00	1.00	1.00	0.98	0.99	1.00	1.01	1.00	1.01
New Jersey	0.95	0.95	0.95	0.95	0.99	1.09	1.09	1.10	1.05	0.96	0.95	0.95
New Mexico	0.95	0.97	0.97	0.96	0.97	1.04	1.06	1.07	1.03	1.02	0.98	0.97
New York	0.94	0.96	0.94	0.94	0.97	1.06	1.09	1.08	1.08	1.03	0.96	0.95
North Carolina	0.96	1.00	1.00	0.98	0.98	0.99	1.03	1.02	1.03	1.03	0.99	1.00
North Dakota	0.92	0.95	0.96	0.98	1.00	1.06	1.05	1.06	1.07	1.01	0.98	0.95
Ohio	0.96	0.99	1.00	1.01	1.01	1.01	1.00	1.00	1.01	1.02	1.01	0.98
Oklahoma	0.93	0.95	0.93	0.94	0.96	1.08	1.09	1.11	1.10	1.04	0.94	0.93
Oregon	0.98	1.00	1.01	1.01	1.01	1.00	1.00	0.99	0.98	1.02	1.01	0.99
Pennsylvania	0.98	1.00	0.99	1.00	1.01	1.01	1.00	1.00	1.00	1.00	1.01	0.99
Rhode Island	1.02	1.06	1.02	0.97	0.97	0.98	0.97	0.99	0.99	0.98	1.00	1.05
South Carolina	0.97	1.00	0.98	0.98	0.98	1.02	1.01	1.01	1.02	0.99	1.02	1.02
South Dakota	0.94	0.98	0.97	0.98	1.00	1.04	1.04	1.04	1.04	1.02	0.99	0.97
Tennessee	0.98	0.98	0.99	0.99	0.99	1.01	1.01	1.01	1.00	1.01	1.02	1.02
Texas	0.97	1.02	1.01	1.00	0.99	1.01	1.01	1.01	1.00	0.99	0.99	0.98
Utah	0.92	0.95	0.96	0.97	1.05	1.10	1.04	1.03	1.07	1.04	0.96	0.91
Vermont	0.98	0.98	0.99	1.00	1.02	1.01	1.00	0.99	1.00	1.02	1.01	1.00
Virginia	0.98	0.98	0.99	0.98	1.00	1.00	1.01	1.02	1.01	1.01	1.01	1.01
Washington	1.00	1.00	1.01	0.99	0.99	0.99	0.99	0.99	1.00	1.01	1.02	1.02
West Virginia	0.96	1.00	1.01	1.02	1.01	0.98	0.97	0.99	1.00	1.03	1.04	0.99
Wisconsin	0.96	0.98	0.97	0.99	1.01	1.03	1.03	1.03	1.03	1.00	1.00	0.97
Wyoming	0.95	0.97	0.98	1.01	1.02	1.04	1.01	1.00	1.02	1.03	1.01	0.95
United States	0.95	0.98	0.97	0.97	0.99	1.03	1.04	1.05	1.04	1.01	0.99	0.97

8E.3.2 Monthly Natural Gas Price Factor Calculations

DOE collected historical natural gas prices from 2003 to 2022 from the EIA's Natural Gas Navigator. The Natural Gas Navigator includes annual and monthly natural gas prices for residential, commercial, and industrial consumers by year and by state. As an example for how DOE determined monthly natural gas price factors, the methodology used to determine monthly average price factors can be seen below. Table 8E.3.5 shows the historic average residential gas prices for New York.

Table 8E.3.5 2003-2022 Average Residential Natural Gas Prices for New York, $/tcf

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
2003	9.63	9.88	11.69	12.22	12.93	14.71	16.01	16.17	15.58	13.01	12.02	11.36	12.93
2004	11.41	11.33	11.48	11.51	13.07	15.34	16.29	16.89	16.22	14.41	13.44	13.19	13.72
2005	12.80	12.65	12.42	13.45	14.49	16.16	17.62	18.48	20.78	22.24	20.21	17.44	16.56
2006	16.61	15.11	13.99	14.58	16.09	16.69	18.04	18.91	18.43	13.37	14.75	14.97	15.96
2007	15.24	14.43	15.08	15.47	17.33	19.59	19.95	18.94	18.53	18.64	16.04	14.83	17.01
2008	14.99	14.91	15.21	16.76	19.95	22.88	24.96	24.20	21.66	18.42	16.48	16.26	18.89
2009	15.46	14.84	14.63	14.19	15.13	16.82	18.24	17.81	17.74	14.71	14.97	14.02	15.71
2010	12.97	13.01	13.60	15.08	15.82	18.42	20.00	20.17	18.54	16.47	13.88	12.09	15.84
2011	12.05	12.27	12.73	13.60	15.88	19.74	19.77	19.78	19.75	16.56	13.93	12.65	15.73
2012	11.67	11.69	12.99	13.06	15.13	18.00	17.40	18.78	18.16	15.26	11.35	11.97	14.62
2013	11.27	10.80	11.41	12.65	15.73	18.16	19.25	18.99	18.42	16.12	12.27	10.50	14.63
2014	11.18	11.32	11.78	12.49	14.55	17.99	18.99	18.88	17.86	15.99	12.27	10.66	14.50
2015	10.51	9.79	9.34	10.19	12.68	16.26	17.09	17.30	17.50	14.24	12.26	11.43	13.22
2016	10.30	9.45	9.64	9.88	10.99	14.69	16.64	17.86	17.34	14.87	10.95	9.60	12.68
2017	9.86	11.04	10.81	11.09	14.45	16.28	19.14	19.06	18.12	17.17	13.07	10.52	14.22
2018	9.51	11.23	12.09	11.29	14.19	19.32	20.10	20.83	20.14	17.15	12.18	11.64	14.97
2019	12.28	11.44	10.86	12.09	13.99	17.06	19.86	20.14	19.97	16.89	12.45	10.75	14.82
2020	11.37	11.62	11.93	12.07	11.56	16.03	19.34	19.82	19.24	16.08	13.67	12.15	14.57
2021	11.15	10.81	11.47	13.77	14.93	17.64	21.13	22.98	22.17	23.01	17.19	14.57	16.74
2022	13.84	13.09	14.15	14.84	17.61	24.59	26.20	26.17	28.22	21.93	19.28	16.75	19.72

DOE then calculated monthly energy price factors for each year by dividing the residential natural gas prices for each month by the natural gas annual average price for each year. Table 8E.3.6 and Figure 8E.3.2 show the calculated results for New York. DOE then averaged the monthly energy price factors for 2003 to 2022 to develop an average energy price factor for each month.

Table 8E.3.6 Monthly Natural Gas Price Factors for New York (2003-2022)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	0.74	0.76	0.90	0.94	1.00	1.14	1.24	1.25	1.20	1.01	0.93	0.88
2004	0.83	0.83	0.84	0.84	0.95	1.12	1.19	1.23	1.18	1.05	0.98	0.96
2005	0.77	0.76	0.75	0.81	0.87	0.98	1.06	1.12	1.25	1.34	1.22	1.05
2006	1.04	0.95	0.88	0.91	1.01	1.05	1.13	1.18	1.15	0.84	0.92	0.94
2007	0.90	0.85	0.89	0.91	1.02	1.15	1.17	1.11	1.09	1.10	0.94	0.87
2008	0.79	0.79	0.81	0.89	1.06	1.21	1.32	1.28	1.15	0.98	0.87	0.86
2009	0.98	0.94	0.93	0.90	0.96	1.07	1.16	1.13	1.13	0.94	0.95	0.89
2010	0.82	0.82	0.86	0.95	1.00	1.16	1.26	1.27	1.17	1.04	0.88	0.76
2011	0.77	0.78	0.81	0.86	1.01	1.26	1.26	1.26	1.26	1.05	0.89	0.80
2012	0.80	0.80	0.89	0.89	1.03	1.23	1.19	1.28	1.24	1.04	0.78	0.82
2013	0.77	0.74	0.78	0.86	1.08	1.24	1.32	1.30	1.26	1.10	0.84	0.72
2014	0.77	0.78	0.81	0.86	1.00	1.24	1.31	1.30	1.23	1.10	0.85	0.74
2015	0.80	0.74	0.71	0.77	0.96	1.23	1.29	1.31	1.32	1.08	0.93	0.86
2016	0.81	0.75	0.76	0.78	0.87	1.16	1.31	1.41	1.37	1.17	0.86	0.76
2017	0.69	0.78	0.76	0.78	1.02	1.15	1.35	1.34	1.27	1.21	0.92	0.74
2018	0.64	0.75	0.81	0.75	0.95	1.29	1.34	1.39	1.35	1.15	0.81	0.78
2019	0.83	0.77	0.73	0.82	0.94	1.15	1.34	1.36	1.35	1.14	0.84	0.73
2020	0.78	0.80	0.82	0.83	0.79	1.10	1.33	1.36	1.32	1.10	0.94	0.83
2021	0.67	0.65	0.69	0.82	0.89	1.05	1.26	1.37	1.32	1.37	1.03	0.87
2022	0.70	0.66	0.72	0.75	0.89	1.25	1.33	1.33	1.43	1.11	0.98	0.85
20-Year Avg.	0.80	0.78	0.81	0.85	0.97	1.16	1.26	1.28	1.25	1.10	0.92	0.84

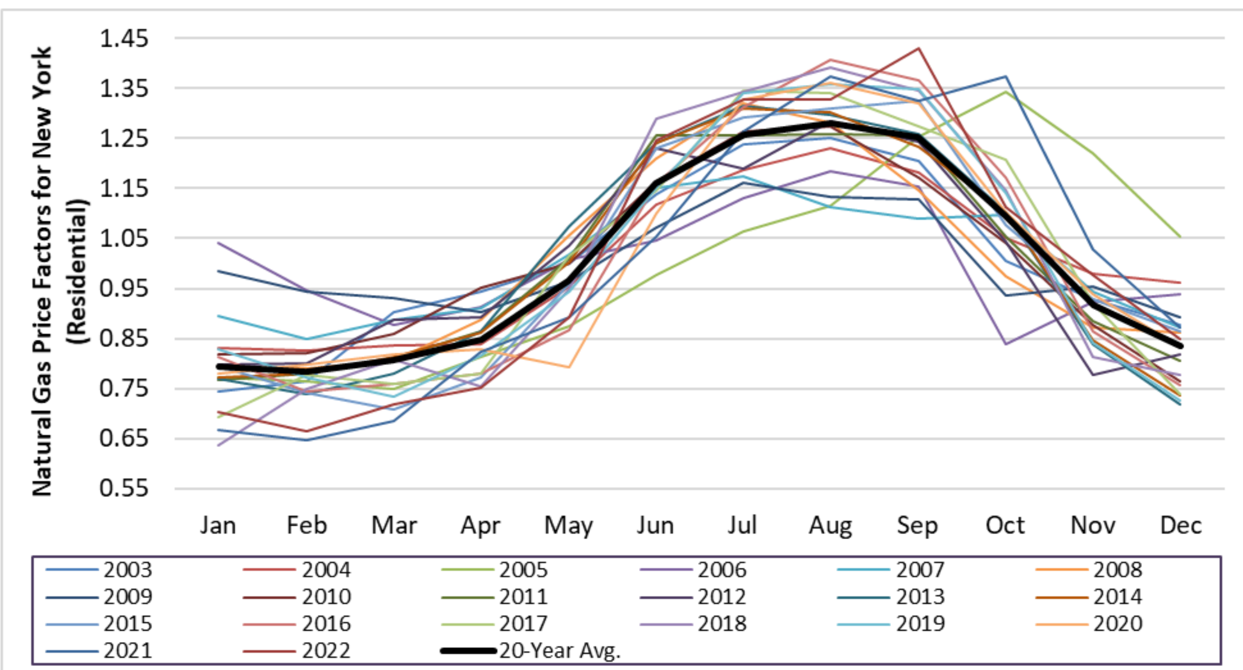

Figure 8E.3.2 Monthly Natural Gas Price Factors for New York (2003-2022)

DOE performed the same calculations for each state to develop the average monthly residential and commercial energy price factors shown in Table 8E.3.7 and Table 8E.3.8, respectively.

Table 8E.3.7 Average Monthly Residential Natural Gas Price Factors (2003-2022)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.78	0.78	0.81	0.90	1.03	1.14	1.19	1.20	1.20	1.15	0.97	0.84
Alaska	0.92	0.93	0.92	0.95	1.01	1.11	1.16	1.14	1.03	0.96	0.92	0.96
Arizona	0.73	0.78	0.83	0.92	1.03	1.14	1.25	1.28	1.24	1.10	0.91	0.79
Arkansas	0.72	0.72	0.75	0.84	1.00	1.18	1.29	1.35	1.31	1.18	0.89	0.78
California	1.00	0.98	0.94	0.95	1.00	1.02	1.04	1.04	1.02	1.02	0.98	1.01
Colorado	0.77	0.77	0.81	0.84	0.98	1.23	1.38	1.39	1.24	0.94	0.84	0.80
Connecticut	0.79	0.80	0.82	0.88	0.98	1.14	1.24	1.30	1.26	1.07	0.89	0.83
Delaware	0.71	0.73	0.77	0.84	0.97	1.18	1.31	1.39	1.34	1.17	0.85	0.76
District of Columbia	0.81	0.80	0.83	0.89	1.02	1.14	1.25	1.24	1.20	1.06	0.92	0.84
Florida	0.81	0.81	0.87	0.92	1.00	1.08	1.15	1.18	1.15	1.13	1.02	0.89
Georgia	0.65	0.69	0.73	0.86	1.07	1.28	1.36	1.37	1.37	1.10	0.80	0.71
Hawaii	0.92	0.96	0.98	0.99	1.02	1.02	1.03	1.03	1.03	1.04	1.00	0.98
Idaho	0.91	0.91	0.94	0.95	1.00	1.07	1.14	1.16	1.09	0.99	0.92	0.92
Illinois	0.70	0.70	0.75	0.82	1.02	1.25	1.45	1.47	1.36	0.97	0.79	0.72
Indiana	0.70	0.71	0.80	0.91	1.06	1.38	1.45	1.43	1.29	0.86	0.72	0.70
Iowa	0.70	0.71	0.79	0.80	0.96	1.23	1.40	1.47	1.40	1.02	0.81	0.71
Kansas	0.66	0.67	0.72	0.86	1.03	1.30	1.40	1.49	1.38	1.05	0.75	0.69
Kentucky	0.66	0.66	0.71	0.81	1.08	1.32	1.42	1.47	1.39	1.01	0.76	0.71
Louisiana	0.75	0.76	0.81	0.91	1.05	1.16	1.21	1.23	1.19	1.15	0.96	0.82
Maine	0.88	0.91	0.90	0.92	0.93	1.07	1.19	1.24	1.19	0.97	0.89	0.91
Maryland	0.76	0.75	0.78	0.87	1.03	1.22	1.30	1.33	1.28	1.03	0.84	0.81
Massachusetts	0.96	0.95	0.96	0.99	1.00	0.98	1.08	1.12	1.08	0.93	0.96	1.00
Michigan	0.79	0.80	0.82	0.88	1.01	1.19	1.29	1.34	1.22	0.96	0.86	0.83
Minnesota	0.84	0.85	0.87	0.86	1.00	1.20	1.28	1.27	1.18	0.92	0.88	0.86
Mississippi	0.76	0.76	0.82	0.92	1.06	1.19	1.19	1.22	1.22	1.14	0.91	0.81
Missouri	0.62	0.62	0.66	0.77	0.94	1.26	1.47	1.54	1.44	1.18	0.82	0.68
Montana	0.84	0.86	0.86	0.89	0.94	1.07	1.24	1.33	1.21	0.99	0.90	0.87
Nebraska	0.70	0.72	0.73	0.80	0.92	1.17	1.36	1.43	1.39	1.15	0.86	0.76
Nevada	0.78	0.80	0.84	0.94	1.02	1.10	1.20	1.25	1.20	1.09	0.93	0.82
New Hampshire	0.86	0.84	0.85	0.89	0.93	1.01	1.20	1.27	1.24	1.06	0.92	0.93
New Jersey	0.88	0.88	0.88	0.89	0.98	1.08	1.15	1.18	1.15	1.05	0.96	0.91
New Mexico	0.74	0.74	0.77	0.83	0.94	1.17	1.30	1.33	1.32	1.18	0.89	0.79
New York	0.80	0.78	0.81	0.85	0.97	1.16	1.26	1.28	1.25	1.10	0.92	0.84
North Carolina	0.70	0.71	0.75	0.87	1.08	1.26	1.35	1.31	1.30	1.08	0.81	0.77
North Dakota	0.68	0.68	0.71	0.76	0.92	1.32	1.62	1.63	1.38	0.87	0.74	0.70
Ohio	0.63	0.64	0.66	0.75	0.95	1.34	1.52	1.59	1.48	1.01	0.75	0.68
Oklahoma	0.56	0.57	0.61	0.76	0.97	1.23	1.44	1.57	1.50	1.33	0.86	0.61
Oregon	0.88	0.87	0.90	0.93	1.00	1.07	1.17	1.24	1.15	0.99	0.92	0.89
Pennsylvania	0.77	0.77	0.79	0.84	0.96	1.18	1.32	1.38	1.30	1.03	0.85	0.80
Rhode Island	0.83	0.83	0.85	0.91	0.98	1.08	1.18	1.23	1.21	1.09	0.94	0.88
South Carolina	0.67	0.69	0.74	0.88	1.13	1.28	1.37	1.36	1.33	1.07	0.77	0.72
South Dakota	0.78	0.79	0.84	0.84	0.91	1.15	1.36	1.41	1.33	0.97	0.84	0.78
Tennessee	0.72	0.71	0.74	0.83	1.00	1.20	1.32	1.39	1.31	1.16	0.87	0.76
Texas	0.66	0.65	0.71	0.88	1.06	1.19	1.28	1.37	1.34	1.20	0.91	0.75
Utah	0.93	0.95	0.95	0.93	0.91	1.00	1.10	1.15	1.12	1.02	0.96	0.97
Vermont	0.80	0.79	0.80	0.83	0.92	1.11	1.27	1.34	1.29	1.09	0.92	0.85
Virginia	0.74	0.74	0.75	0.85	1.03	1.22	1.33	1.34	1.30	1.07	0.84	0.79
Washington	0.87	0.88	0.89	0.92	1.00	1.10	1.19	1.23	1.14	0.97	0.92	0.89
West Virginia	0.77	0.77	0.78	0.84	0.99	1.25	1.38	1.40	1.24	0.95	0.83	0.80
Wisconsin	0.83	0.83	0.87	0.87	0.98	1.20	1.29	1.33	1.21	0.86	0.87	0.85
Wyoming	0.75	0.76	0.78	0.81	0.88	1.07	1.41	1.50	1.37	1.03	0.85	0.79
United States	0.78	0.78	0.81	0.88	1.01	1.18	1.28	1.32	1.26	1.02	0.87	0.82

Table 8E.3.8 Monthly Commercial Natural Gas Price Factors (2003-2022)

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.94	0.94	0.95	0.99	1.00	1.02	1.02	1.03	1.05	1.04	1.02	0.98
Alaska	1.01	1.01	0.99	0.97	0.96	0.99	1.00	1.01	1.00	1.02	1.01	1.03
Arizona	0.96	0.97	0.99	1.00	1.02	1.01	1.02	1.02	1.02	1.02	1.00	0.97
Arkansas	0.93	0.92	0.93	0.96	1.02	1.06	1.07	1.08	1.04	1.00	1.01	0.97
California	1.06	1.03	1.01	0.96	0.94	0.97	0.99	0.99	0.97	0.96	1.01	1.09
Colorado	0.89	0.89	0.91	0.92	0.99	1.07	1.16	1.15	1.12	1.00	0.96	0.93
Connecticut	0.91	0.92	0.92	0.97	1.03	1.09	1.08	1.07	1.07	1.05	0.96	0.92
Delaware	0.86	0.88	0.92	0.96	1.02	1.08	1.13	1.14	1.11	1.07	0.94	0.90
District of Columbia	0.96	0.98	0.99	1.01	1.00	1.02	1.04	1.01	1.00	0.99	1.02	0.98
Florida	1.00	1.00	1.00	1.00	1.00	1.00	1.01	1.00	1.01	1.00	1.00	1.00
Georgia	0.89	0.90	0.93	0.98	1.04	1.08	1.10	1.10	1.09	1.04	0.96	0.89
Hawaii	0.92	0.96	0.99	0.99	1.02	1.04	1.04	1.02	1.02	1.03	1.00	0.97
Idaho	0.96	0.96	0.98	1.00	1.01	1.02	1.03	1.03	1.03	1.00	0.99	0.98
Illinois	0.76	0.77	0.81	0.88	1.07	1.23	1.32	1.34	1.23	0.95	0.84	0.80
Indiana	0.86	0.86	0.95	1.01	1.11	1.21	1.22	1.20	1.05	0.86	0.84	0.84
Iowa	0.90	0.92	0.97	0.92	1.01	1.11	1.15	1.15	1.11	0.90	0.93	0.93
Kansas	0.79	0.80	0.84	0.95	1.07	1.17	1.23	1.23	1.23	1.03	0.86	0.81
Kentucky	0.83	0.83	0.86	0.94	1.06	1.15	1.17	1.19	1.15	1.02	0.92	0.89
Louisiana	1.03	0.99	0.99	0.96	0.98	1.00	1.01	0.99	0.98	1.00	1.02	1.05
Maine	1.05	1.06	1.04	1.04	0.97	0.94	1.00	1.02	0.98	0.91	0.97	1.03
Maryland	0.93	0.94	0.94	0.96	1.02	1.05	1.06	1.06	1.06	1.01	0.98	0.98
Massachusetts	1.05	1.05	1.06	1.07	1.01	0.93	0.95	0.96	0.96	0.89	1.00	1.08
Michigan	0.89	0.90	0.92	0.93	1.01	1.10	1.14	1.15	1.11	0.99	0.95	0.93
Minnesota	0.98	0.98	0.99	0.94	0.99	1.07	1.08	1.07	1.03	0.93	0.97	0.98
Mississippi	1.01	1.01	1.03	1.01	1.00	0.97	0.97	0.95	0.96	1.03	1.04	1.02
Missouri	0.86	0.85	0.87	0.93	0.98	1.09	1.16	1.17	1.12	1.07	0.99	0.92
Montana	0.89	0.90	0.91	0.93	0.98	1.08	1.16	1.17	1.14	0.99	0.94	0.91
Nebraska	1.00	1.00	1.00	0.97	0.94	0.98	1.04	1.04	1.04	0.99	0.99	1.03
Nevada	0.94	0.95	0.96	0.98	1.01	1.01	1.05	1.07	1.05	1.03	1.00	0.96
New Hampshire	0.93	0.92	0.93	0.96	0.96	0.98	1.11	1.14	1.12	1.00	0.97	0.99
New Jersey	1.02	1.00	1.02	0.90	0.95	1.01	1.03	1.00	0.96	0.99	1.06	1.05
New Mexico	0.93	0.92	0.92	0.91	0.95	1.02	1.08	1.10	1.08	1.08	1.04	0.98
New York	1.06	1.06	1.07	1.02	0.99	0.97	0.93	0.90	0.93	0.98	1.02	1.07
North Carolina	0.94	0.93	0.93	0.98	1.01	1.04	1.06	1.02	1.02	1.01	1.02	1.03
North Dakota	0.93	0.94	0.94	0.90	0.98	1.10	1.16	1.15	1.08	0.92	0.95	0.95
Ohio	0.91	0.91	0.91	0.94	1.02	1.10	1.12	1.12	1.09	1.01	0.94	0.93
Oklahoma	0.68	0.68	0.71	0.85	1.01	1.18	1.29	1.37	1.31	1.24	0.96	0.72
Oregon	0.96	0.95	0.97	0.98	1.00	1.02	1.04	1.07	1.04	1.00	0.99	0.99
Pennsylvania	0.91	0.92	0.94	0.95	1.04	1.10	1.12	1.11	1.08	0.98	0.93	0.93
Rhode Island	0.83	0.84	0.86	0.90	0.97	1.09	1.18	1.21	1.19	1.09	0.94	0.89
South Carolina	1.01	0.95	0.98	0.98	0.96	0.99	1.00	0.98	0.98	0.99	1.04	1.08
South Dakota	0.94	0.95	0.99	0.93	0.96	1.06	1.13	1.14	1.08	0.93	0.94	0.94
Tennessee	0.94	0.93	0.92	0.95	0.98	1.02	1.06	1.09	1.05	1.06	1.01	0.98
Texas	0.92	0.92	0.92	0.95	1.00	1.03	1.05	1.06	1.07	1.06	1.02	0.99
Utah	1.01	1.02	1.02	0.97	0.91	0.95	1.01	1.04	1.03	0.99	1.00	1.05
Vermont	1.04	1.05	1.02	1.01	1.00	0.96	0.96	0.96	0.99	0.96	1.00	1.05
Virginia	0.97	0.97	0.94	0.96	1.00	1.05	1.05	1.05	1.05	0.99	0.97	1.00
Washington	0.95	0.96	0.95	0.97	0.99	1.03	1.06	1.08	1.05	0.99	0.98	0.98
West Virginia	0.88	0.89	0.90	0.95	1.03	1.12	1.14	1.15	1.10	1.00	0.93	0.92
Wisconsin	1.01	1.01	1.03	0.98	0.96	1.03	1.03	1.02	1.01	0.88	1.01	1.03
Wyoming	0.94	0.93	0.94	0.93	0.94	1.00	1.09	1.11	1.10	1.04	1.00	0.97
United States	0.95	0.95	0.97	0.97	1.01	1.04	1.06	1.05	1.04	0.99	0.98	0.98

8E.3.3 Monthly LPG Price Factor Calculations

DOE collected historical LPG prices from 1995 to 2009 from EIA's Short-Term Energy Outlook. The Short-Term Energy Outlook includes monthly LPG prices by Census Region (Northeast, South, Midwest, and West).[e]

The same process as used for electricity and natural gas price factors was used for calculating the monthly LPG price factors. These monthly price factors were calculated below, using data from the Northeast region. Table 8E.3.9 shows the Northeast residential LPG prices from 1995 to 2009.

Table 8E.3.9 Average Residential LPG Prices for the Northeast (nominal cents/gallon)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg
1995	119.1	118.3	120.1	121.4	124.4	125.7	126.2	124.8	121.9	121.0	117.9	117.0	121.5
1996	122.6	125.4	128.0	124.7	129.9	130.6	128.9	127.2	127.3	132.8	135.3	144.8	129.8
1997	142.9	136.8	131.2	130.6	130.3	129.5	129.8	127.0	125.7	126.7	122.8	122.2	129.6
1998	121.4	120.2	119.6	122.6	124.0	124.2	122.4	121.0	119.3	117.6	115.1	114.1	120.1
1999	112.1	113.0	113.5	118.1	122.0	124.4	125.6	128.6	127.1	129.3	128.3	127.6	122.5
2000	131.9	147.8	147.8	144.8	148.4	151.4	155.4	154.3	156.7	158.7	156.1	159.9	151.1
2001	175.7	169.8	161.8	160.2	162.3	160.1	155.7	152.4	149.8	149.9	144.1	138.8	156.7
2002	138.9	137.7	138.5	143.3	142.0	144.4	143.0	141.0	141.3	142.1	141.5	141.5	141.3
2003	149.8	166.0	181.6	164.4	161.3	160.5	159.4	155.8	154.6	155.2	154.5	158.0	160.1
2004	168.5	173.4	170.5	167.5	170.2	173.3	173.0	176.4	181.0	187.3	192.6	187.1	176.7
2005	185.9	186.1	189.6	196.8	199.3	199.8	202.2	204.6	217.1	224.1	219.5	217.3	203.5
2006	220.6	220.2	220.0	225.2	231.3	237.4	242.0	243.5	239.7	232.0	228.5	227.9	230.7
2007	227.2	228.6	234.5	238.7	247.1	251.5	253.2	252.4	253.7	259.8	273.9	275.4	249.7
2008	281.9	280.0	284.4	291.9	306.1	319.5	333.0	328.9	323.9	304.7	280.2	266.9	300.1
2009	267.9	267.1	266.7	263.4	257.8	255.4	255.0	250.6	249.3	249.6	251.7	254.7	257.4

DOE then calculated monthly energy price factors for each year by dividing the prices for each month by the average price for each year. Table 8E.3.10 and Figure 8E.3.3 show the calculated results for the Northeast.

[e] Refer to cwww2.census.gov/geo/pdfs/maps-data/maps/reference/us_regdiv.pdf.

Table 8E.3.10 Monthly Residential LPG Price Factors for the Northeast (1995-2009)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1995	0.98	0.97	0.99	1.00	1.02	1.03	1.04	1.03	1.00	1.00	0.97	0.96
1996	0.94	0.97	0.99	0.96	1.00	1.01	0.99	0.98	0.98	1.02	1.04	1.12
1997	1.10	1.06	1.01	1.01	1.01	1.00	1.00	0.98	0.97	0.98	0.95	0.94
1998	1.01	1.00	1.00	1.02	1.03	1.03	1.02	1.01	0.99	0.98	0.96	0.95
1999	0.92	0.92	0.93	0.96	1.00	1.02	1.03	1.05	1.04	1.06	1.05	1.04
2000	0.87	0.98	0.98	0.96	0.98	1.00	1.03	1.02	1.04	1.05	1.03	1.06
2001	1.12	1.08	1.03	1.02	1.04	1.02	0.99	0.97	0.96	0.96	0.92	0.89
2002	0.98	0.97	0.98	1.01	1.01	1.02	1.01	1.00	1.00	1.01	1.00	1.00
2003	0.94	1.04	1.13	1.03	1.01	1.00	1.00	0.97	0.97	0.97	0.97	0.99
2004	0.95	0.98	0.96	0.95	0.96	0.98	0.98	1.00	1.02	1.06	1.09	1.06
2005	0.91	0.91	0.93	0.97	0.98	0.98	0.99	1.01	1.07	1.10	1.08	1.07
2006	0.96	0.95	0.95	0.98	1.00	1.03	1.05	1.06	1.04	1.01	0.99	0.99
2007	0.91	0.92	0.94	0.96	0.99	1.01	1.01	1.01	1.02	1.04	1.10	1.10
2008	0.94	0.93	0.95	0.97	1.02	1.06	1.11	1.10	1.08	1.02	0.93	0.89
2009	1.04	1.04	1.04	1.02	1.00	0.99	0.99	0.97	0.97	0.97	0.98	0.99
Avg	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00

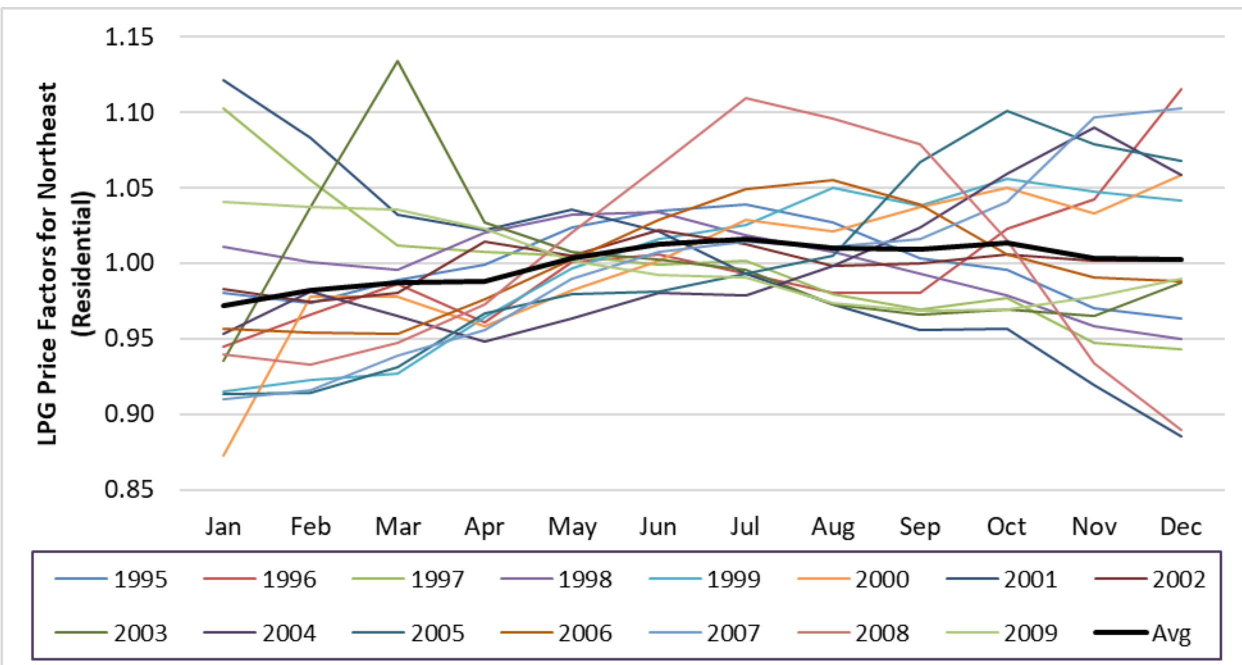

Figure 8E.3.3 Monthly Residential LPG Factors for the Northeast (1995-2009)

DOE then averaged the monthly energy price factors for 1995 to 2009 to develop an average energy price factor for each month. DOE performed the same calculations for each Census region to develop the average monthly residential and commerial energy price factors shown in Table 8E.3.11 and Table 8E.3.12 , respectively.

Table 8E.3.11 Average Monthly Residential LPG Energy Price Factors (1995-2009)

Census Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northeast	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00
Midwest	1.04	1.04	1.03	1.01	1.00	0.97	0.94	0.93	0.96	0.98	1.03	1.07
South	1.04	1.04	1.03	1.01	0.99	0.97	0.95	0.93	0.96	1.00	1.03	1.06
West	1.05	1.05	1.03	1.01	0.99	0.96	0.92	0.91	0.95	1.01	1.04	1.08
U.S.	1.02	1.03	1.02	1.02	1.02	1.00	0.95	0.93	0.96	0.99	1.02	1.05

Table 8E.3.12 Average Monthly Commercial LPG Energy Price Factors (1995-2009)

Census Regions	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Northeast	0.97	0.98	0.99	0.99	1.00	1.01	1.02	1.01	1.01	1.01	1.00	1.00
Midwest	1.04	1.04	1.03	1.01	1.00	0.97	0.94	0.93	0.96	0.98	1.03	1.07
South	1.04	1.04	1.03	1.01	0.99	0.97	0.95	0.93	0.96	1.00	1.03	1.06
West	1.05	1.05	1.03	1.01	0.99	0.96	0.92	0.91	0.95	1.01	1.04	1.08
U.S.	1.02	1.03	1.02	1.02	1.02	1.00	0.95	0.93	0.96	0.99	1.02	1.05

8E.4 SEASONAL MARGINAL PRICE FACTORS DETERMINATION

Marginal energy prices are the prices consumers pay for the last unit of energy used. DOE used the marginal energy prices for each building to determine the cost of saved energy associated with the use of higher-efficiency products. Because marginal prices reflect a change in a consumer’s bill associated with a change in energy consumed, such prices are appropriate for determining energy cost savings associated with possible changes to efficiency standards.

EIA provides historical monthly electricity and natural gas consumption and expenditures by state. This data was used to determine 10-year average marginal prices by state, which are then used to convert average monthly energy prices into marginal monthly energy prices. Because a water heater operates during both the heating and cooling seasons, DOE determined summer and winter marginal price factors.

For LPG, DOE used average energy prices only, as the data necessary for estimating marginal prices were not available.

8E.4.1 Marginal Price Factor Calculation Methodolgy

The methodology used for estimating marginal energy prices follows previous research found in Lawrence Berkeley National Laboratory (LBNL) reports.[7,8,9,10] Calculating marginal energy prices for an individual customer requires a detailed knowledge of the consumer's bill including utility tariff values and structure and energy use as well as items not normally available on utility tariffs such as taxes, special fees, and one-time surcharges or rebates included in the energy bill. Instead DOE relies on aggregate EIA historical monthly electricity and natural gas consumption and expenditures by state. The use of billing data avoids having to estimate the effect of non-tariff items on consumer marginal energy prices.

Seasonal marginal energy prices by state were calculated using a linear regression of monthly expenditures to monthly customer energy consumption. DOE interpreted the slope of the regression line for each state as the average seasonal marginal energy price for that state, as follows:

$$Expenditures = MarginalPrice \times EnergyUse + FixedCost$$

Eq. 8E.1

Where:

Expenditures = total monthly expenditures for electricity or natural gas by state,
FixedCost = total monthly fixed cost for electricity or natural gas by state, and
EnergyUse = total monthly electricity or natural gas usage

For each state, DOE performed this calculation over a 10-year period (2011-2020) to reduce annual fluctuations and improve accuracy. DOE then normalized each annual seasonal marginal price by the corresponding annual seasonal price, as follows:

$$MarginalPriceFactor_{Season} = \frac{MarginalPrice_{Season}}{AveragePrice_{Season}}$$

Eq. 8E.2

Where:

Season = summer or winter.

Based on consumption data, DOE defined winter as the 5 months from November through March and summer or non-winter as the rest of the year (the remaining 7 months). DOE kept the marginal energy prices only for regression values with r-squared greater or equal to 75%. 75% limit gets a close correlation in the cost and consumption data, without excluding too many state records from the analysis or losing the linearity of the relationship between the seasonal costs and consumption.

As an example, Figure 8E.4.1 and Figure 8E.4.2 show the 2022 residential expenditure and consumption data for Virginia for electricity and natural gas, respectively. Figure 8E.4.3 and Figure 8E.4.4 show the associated seasonal regression lines. The slopes of these regression lines are DOE's estimate of the 2022 seasonal residential marginal prices for Virginia for electricity and natural gas, respectively. Table 8E.4.1 and Table 8E.4.2 show the calculated seasonal marginal price (and r-squared value from the linear regression), the corresponding seasonal average price, and the resulting seasonal marginal price factor for Virginia for electricity and natural gas, respectively.

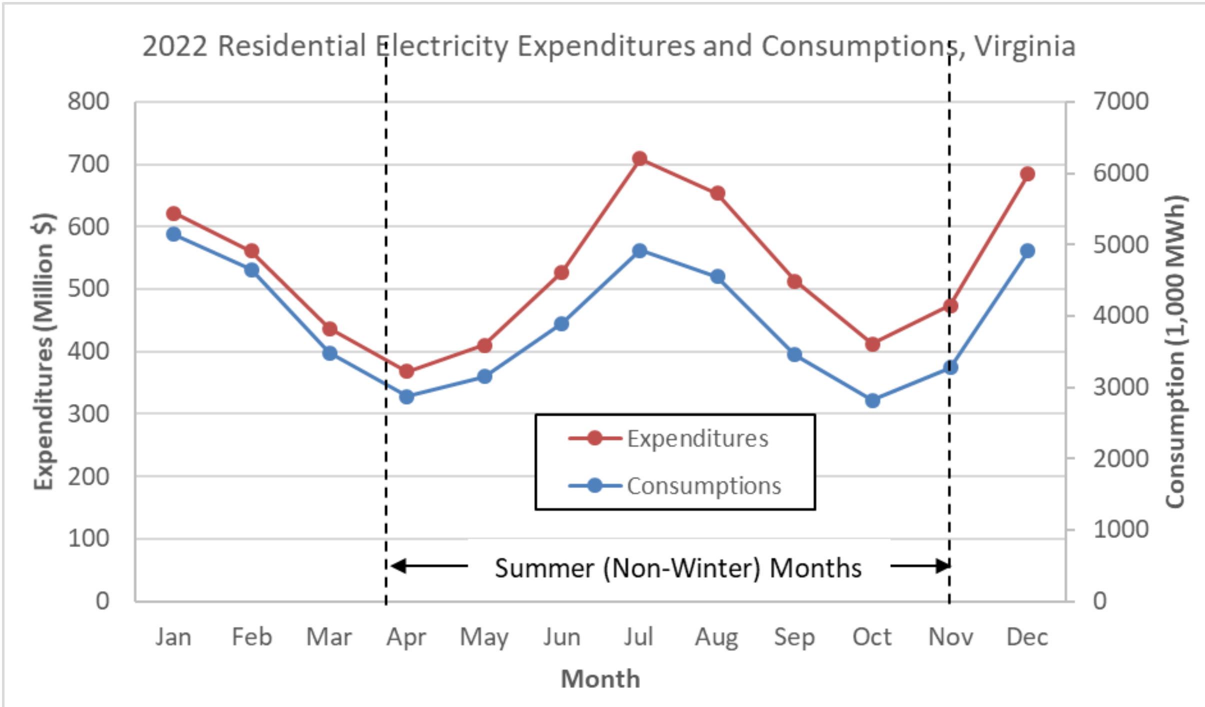

Figure 8E.4.1 2022 Residential Electricty Expenditures and Consumptions, Virginia

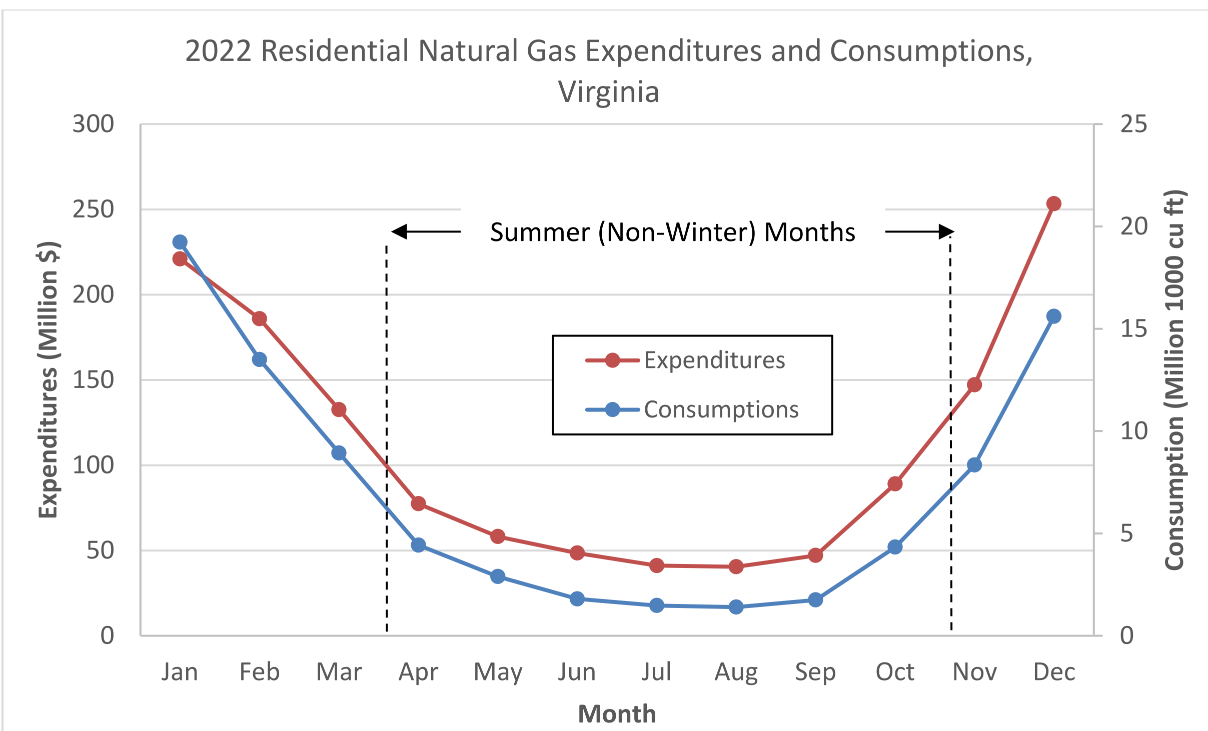

Figure 8E.4.2 2022 Residential Natural Gas Expenditures and Consumptions, Virginia

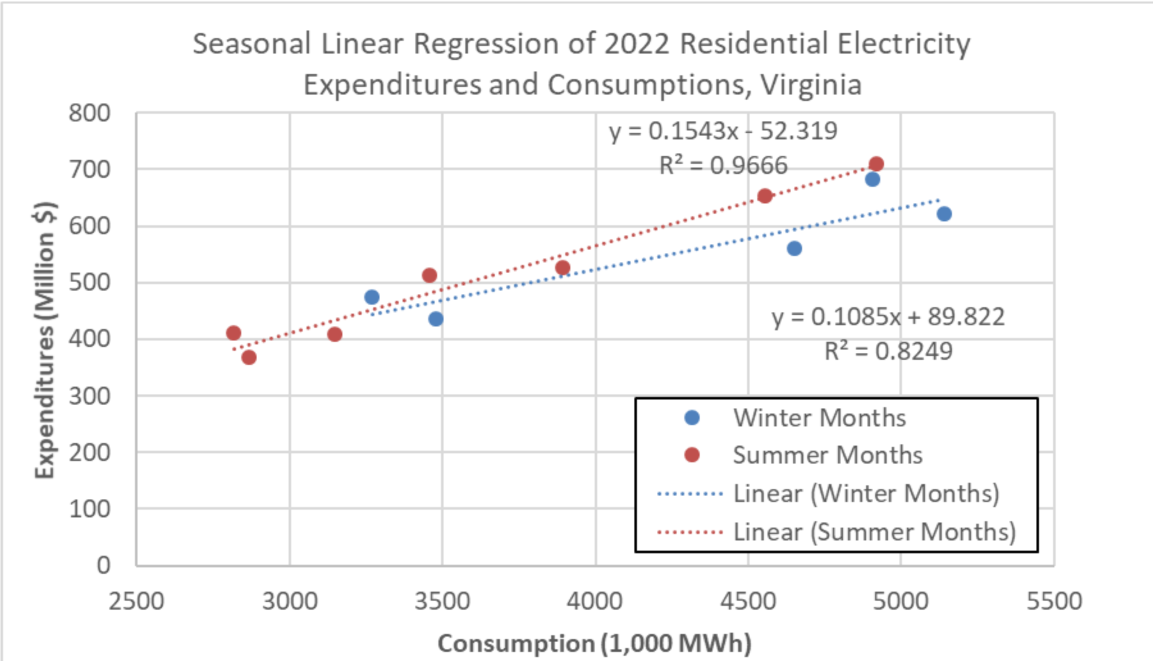

Figure 8E.4.3 Seasonal Linear Regression of 2022 Residential Electricty Expenditures and Consumptions, Virginia

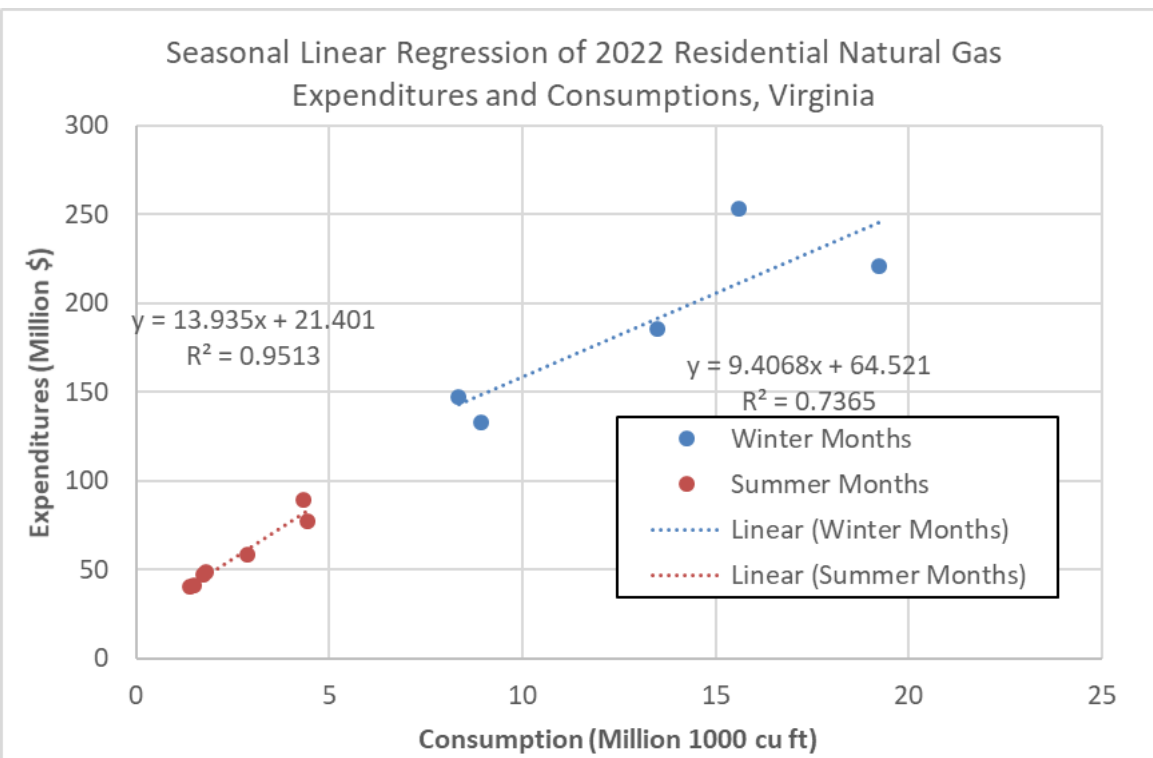

Figure 8E.4.4 Seasonal Linear Regression of 2022 Residential Natural Gas Expenditures and Consumptions, Virginia

Table 8E.4.1 Marginal Electricty Price Results (Residential) for Virginia using 2013-2022 EIA Data

Year	Summer (Non-Winter)				Winter			
	Electricity Price ($/kWh)		Marginal Price Factor	R-Squared for Linear Fit	Electricity Price ($/kWh)		Marginal Price Factor	R-Squared for Linear Fit
	Marginal	Average			Marginal	Average		
2013	0.124	0.113	1.10	0.99	0.077	0.103	0.74	0.97
2014	0.130	0.117	1.12	0.99	0.076	0.105	0.72	0.96
2015	0.120	0.117	1.03	1.00	0.103	0.110	0.94	1.00
2016	0.116	0.117	0.99	0.99	0.094	0.109	0.86	1.00
2017	0.128	0.120	1.07	1.00	0.085	0.110	0.78	0.98
2018	0.131	0.121	1.08	1.00	0.097	0.112	0.86	1.00
2019	0.120	0.124	0.97	1.00	0.103	0.117	0.88	0.99
2020	0.120	0.123	0.98	1.00	0.101	0.117	0.86	0.98
2021	0.128	0.125	1.03	1.00	0.093	0.114	0.82	0.99
2022	0.154	0.140	1.10	0.97	0.109	0.129	0.84	0.82
Average			1.05				0.83	

Table 8E.4.2 Marginal Natural Gas Price Results (Residential) for Virginia using 2013-2022 EIA Data

Year	Summer (Non-Winter)				Winter			
	Natural Gas Price ($/1000 cu ft)		Marginal Price Factor	R-Squared for Linear Fit	Natural Gas Price ($/1000 cu ft)		Marginal Price Factor	R-Squared for Linear Fit
	Marginal	Average			Marginal	Average		
2013	9.14	15.49	0.59	0.98	9.59	10.61	0.90	0.89
2014	9.52	16.99	0.56	0.93	8.31	10.90	0.76	0.98
2015	8.44	16.29	0.52	0.89	8.83	10.47	0.84	0.97
2016	7.10	14.71	0.48	0.91	7.39	9.80	0.75	0.94
2017	10.53	18.37	--*	0.69	8.48	10.78	0.79	0.97
2018	8.57	15.31	0.56	0.94	8.70	10.70	0.81	0.94
2019	8.86	17.85	0.50	0.97	9.92	11.35	0.87	0.98
2020	8.63	15.36	0.56	0.91	10.24	11.84	0.86	0.96
2021	10.04	19.25	0.52	0.98	6.58	12.23	0.54	0.84
2022	13.93	22.23	0.63	0.95	9.41	14.32	--*	0.74
Average			0.55				0.79	

*This value is excluded since r-squared for the linear regression is below 0.75.

8E.4.2 Results for the Seasonal Marginal Electricity and Natural Gas Price Factors

Table 8E.4.3 shows the resulting electricity and natural gas seasonal marginal price factors for both residential and commercial sectors by state.

Table 8E.4.3 Marginal Electricity and Natural Gas Price Factors, EIA 2013-2022 Data

State	Electricity				Natural Gas			
	Residential		Commercial		Residential		Commercial	
	Summer	Winter	Summer	Winter	Summer	Winter	Summer	Winter
Alabama	0.98	0.80	1.05	0.85	0.63	0.85	0.93	0.95
Alaska	0.81	0.90	0.85	0.83	0.81	0.95	0.90	1.01
Arizona	1.00	0.87	1.24	0.92	0.60	0.76	0.97	0.95
Arkansas	1.04	0.77	1.07	0.92	0.53	0.84	0.71	0.98
California	1.25	0.90	1.83	0.91	0.90	1.10	1.08	1.38
Colorado	1.13	0.90	1.31	0.86	0.58	0.82	0.71	0.88
Connecticut	0.86	0.86	0.82	1.23	0.65	0.84	0.75	0.88
Delaware	0.81	0.78	0.80	0.84	0.54	0.82	0.79	0.90
District of Columbia	0.87	0.78	0.89	0.85	0.62	0.81	0.88	0.91
Florida	1.04	1.16	0.97	0.81	0.56	0.65	0.91	0.92
Georgia	1.18	0.83	1.20	1.32	0.54	0.77	0.83	0.92
Hawaii	0.94	0.88	1.04	1.37	1.26	0.62	1.63	1.49
Idaho	1.11	1.02	1.23	0.87	0.81	0.93	0.89	0.94
Illinois	0.87	0.68	0.99	0.82	0.48	0.85	0.35	0.87
Indiana	0.91	0.76	0.95	0.74	0.48	0.81	0.57	0.85
Iowa	1.31	0.80	2.01	0.83	0.56	0.84	0.65	1.01
Kansas	0.99	0.74	1.07	0.60	0.46	0.87	0.61	0.90
Kentucky	0.94	0.81	0.91	0.69	0.40	0.81	0.57	0.87
Louisiana	1.01	0.76	0.96	0.48	0.53	0.75	1.05	1.09
Maine	0.94	0.93	0.93	1.07	0.71	0.99	0.97	1.21
Maryland	0.92	0.91	0.92	1.02	0.58	0.80	0.74	0.85
Massachusetts	0.92	1.02	1.19	1.66	0.95	1.00	1.11	1.07
Michigan	1.04	0.90	1.07	0.72	0.69	0.88	0.70	0.91
Minnesota	1.11	0.85	1.35	0.88	0.65	0.99	0.82	1.06
Mississippi	0.89	0.75	0.88	0.90	0.50	0.77	1.03	0.94
Missouri	1.28	0.73	1.81	0.75	0.46	0.72	0.66	0.84
Montana	0.90	0.88	0.97	0.94	0.75	0.91	0.71	0.92
Nebraska	1.17	0.71	1.37	0.77	0.49	0.85	0.86	1.11
Nevada	0.92	0.82	1.03	0.99	0.58	0.75	0.88	0.79
New Hampshire	0.84	0.91	0.84	1.24	0.70	0.96	0.75	1.01
New Jersey	1.05	1.00	1.26	1.16	0.72	0.97	0.77	0.97
New Mexico	1.15	0.89	1.52	1.05	0.49	0.87	1.06	1.04
New York	1.05	0.92	1.53	1.50	0.57	0.79	1.18	1.16
North Carolina	0.93	0.81	1.13	0.76	0.59	0.80	0.88	0.82
North Dakota	0.78	0.71	1.27	0.79	0.44	0.85	0.76	1.11
Ohio	1.04	0.82	0.93	0.67	0.31	0.69	0.71	0.96
Oklahoma	0.93	0.62	1.31	1.14	0.45	0.72	0.43	0.66
Oregon	0.97	0.94	0.91	0.83	0.75	0.90	0.86	0.97
Pennsylvania	0.99	0.86	0.94	1.10	0.61	0.86	0.72	0.94
Rhode Island	0.84	0.95	0.84	0.87	0.74	0.82	0.73	0.82
South Carolina	0.96	0.83	1.11	0.89	0.48	0.74	1.02	0.93
South Dakota	0.99	0.80	1.20	0.75	0.63	0.86	0.75	1.01
Tennessee	0.99	0.84	1.13	0.98	0.49	0.83	0.82	0.92
Texas	0.97	0.86	1.03	0.76	0.39	0.69	0.74	0.95
Utah	1.14	0.96	1.15	0.65	0.83	1.00	0.97	1.06
Vermont	0.90	0.84	0.86	0.76	0.60	0.82	1.12	1.24
Virginia	1.05	0.83	1.07	1.16	0.55	0.79	0.77	0.94
Washington	0.88	0.95	0.93	0.93	0.76	0.95	0.84	1.05
West Virginia	0.92	0.81	0.73	0.65	0.65	0.89	0.62	0.94
Wisconsin	0.95	0.86	1.15	0.75	0.63	0.98	0.86	1.11
Wyoming	0.85	0.86	0.82	0.58	0.60	0.75	0.86	0.95
United States	1.04	0.81	1.25	0.75	0.56	0.85	0.78	0.98

8E.4.3 Comparison to Natural Gas Tariff Analysis

In the past, DOE received comment about the use of average natural gas prices. The Gas Technology Institute (GTI) commented that, because the monthly fixed charge contributes to the average price, marginal prices may generally be lower than average prices. As described above, DOE developed marginal price factors to account for this difference, but these factors were developed from EIA data, not directly from gas tariff documents. GTI submitted documents describing a total of 23 residential gas tariffs for 13 companies operating in multiple states.[11] DOE used this information to validate the residential natural gas marginal price factors presented in Table 8E.4.3.

8E.4.3.1 Calculation Methodology for Comparison

DOE used the following calculation approach to estimate the ratio of marginal to average prices, or the marginal price factors, for the 23 tariffs submitted by GTI.

Tariffs have one or more tiers. The simplest tariff structure consists of a monthly fixed cost (*FC*) and a commodity cost (i.e., for units of gas) (*CC*). The total monthly bill (*MonthlyBill*) is:

$$MonthlyBill = FC + U \times CC$$

Eq. 8E.3

Where:

FC = monthly fixed cost for natural gas,
U = monthly consumer natural gas usage, and
CC = commodity cost for natural gas.

The average monthly price (*AveragePrice*) is equal to the ratio of the monthly bill to the total monthly usage:

$$AveragePrice = \frac{MonthlyBill}{U} = \frac{FC}{U} + CC$$

Eq. 8E.4

The marginal price is equal to the commodity cost *CC*; therefore, for this type of tariff, the average price exceeds the marginal price by the amount *FC*/*U*:

$$AveragePrice = MarginalPrice + \frac{FC}{U}$$

Eq. 8E.5

Where:

MarginalPrice = marginal price, which is equal to the commodity cost *CC*.

The difference between the average and marginal prices decreases with customer usage *U*, and thus should be larger in the summer, when usage is lower. For tariffs with multiple tiers, the difference depends on tier in which the customer is.

To determine the marginal price factors for each season (summer or winter) ($MarginalPriceFactor_{Season}$) for each of the 23 tariffs, DOE calculated the ratio of the average monthly natural gas price to the marginal price:

$$MarginalPriceFactor_{Season} = \frac{MarginalPrice_{Season}}{AveragePrice_{Season}}$$

Eq. 8E.6

Where:

Season = summer or winter.

8E.4.3.2 Data Inputs

DOE estimated the monthly usage *U* based on the RECS 2020 average annual natural gas consumption by RECS 2020 regions. DOE used monthly natural gas consumption data from EIA's Natural Gas Navigator to allocate natural gas usage to summer and winter months. These data show that on average 70 percent of annual consumption occurs in the winter (the 5 months from November through March) and 30 percent during the rest of the year (the remaining 7 months). Hence, DOE defined summer monthly usage as:

$$Summer\ Monthly\ NG\ Usage = \frac{30\%\ of\ Annual\ NG\ Usage}{7\ summer\ months/year} \times Annual\ Average\ NG\ Usage$$

Eq. 8E.7

and winter monthly usage as:

$$Winter\ Monthly\ NG\ Usage = \frac{70\%\ of\ Annual\ NG\ Usage}{5\ winter\ months/year} \times Annual\ Average\ NG\ Usage$$

Eq. 8E.8

DOE obtained the fixed charges and commodity charges from the tariff documents submitted by GTI. Of these 23 tariffs, eight have more than one tier. For the eight tariffs with multiple tiers, DOE estimated the commodity cost as the average of the two-tier charges.

8E.4.3.3 Comparison Results

Table 8E.4.4 lists the marginal price factors for each of the 23 tariffs submitted by GTI. It also includes the marginal price factors estimated from the EIA data (2013-2022) for comparison (see Table 8E.4.4), and the assumed monthly summer and winter natural gas usage in therms. The EIA data and usage estimates depend only on the region. In general, the tariff-based marginal price factors for winter are less than one, as expected.

The summer and winter price factors used by DOE are generally comparable to those computed from the tariff data, indicating that DOE's marginal price estimates are reasonable at average usage levels. Of the 23 tariffs analyzed, eight have multiple tiers, and of these eight, six have ascending rates and two have descending rates. Because this analysis uses an average of the two tiers as the commodity price, it will generally underestimate the marginal prices for consumers subject to the second tier.

A full tariff-based analysis would require information about the household's total baseline gas usage (to establish which tier the consumer is in), and a weight factor for each tariff that determines how many customers are served by that utility on that tariff. These data are generally not available in the public domain. DOE's use of EIA state-level data effectively averages over all consumer sales in each state, and so incorporates information about all utilities. DOE's approach is therefore more likely to provide prices representative of a typical consumer than any individual tariff.

Table 8E.4.4 Tariff-Based (GTI) and EIA Marginal Price Factors and Natural Gas Consumption by Season

State	Summer		Winter		Natural Gas Consumption *Therms*	
	GTI Tariff Data	EIA Data	GTI Tariff Data	EIA Data	Summer	Winter
Arizona	0.61	0.60	0.84	0.76	13	43
California	0.84	0.90	0.95	1.10	17	57
Colorado	0.70	0.58	0.88	0.82	35	116
Colorado	0.67	0.58	0.87	0.82	35	116
Colorado	0.69	0.58	0.88	0.82	35	116
Connecticut	0.54	0.65	0.79	0.84	33	109
Connecticut	0.59	0.65	0.82	0.84	33	109
Connecticut	0.74	0.65	0.90	0.84	33	109
Delaware	0.66	0.54	0.87	0.82	27	90
District of Columbia	0.60	0.62	0.83	0.81	27	90
Idaho	0.88	0.81	0.96	0.93	34	110
Idaho	0.85	0.81	0.94	0.93	34	110
Iowa	0.61	0.56	0.84	0.84	37	120
Kansas	0.56	0.46	0.81	0.87	33	107
Maryland	0.73	0.58	0.91	0.80	27	90
Maryland	0.73	0.58	0.90	0.80	27	90
Maryland	0.72	0.58	0.89	0.80	27	90
Minnesota	0.76	0.65	0.92	0.99	37	120
Nevada	0.68	0.58	0.87	0.75	23	74
Oregon	0.80	0.75	0.93	0.90	32	105
Pennsylvania	0.65	0.61	0.86	0.86	31	102
Virginia	0.70	0.55	0.89	0.79	28	90
Washington	0.76	0.76	0.91	0.95	32	105

8E.5 HOUSEHOLD ENERGY PRICE ADJUSTMENT FACTOR

Both RECS 2020 and CBECS 2018 report the total annual consumption and expenditure of each energy use type. From this data DOE determined average energy prices per geographical area. To take into account that household energy prices vary inside a state, DOE developed an adjustment factor based on the reported average energy price in RECS 2020 or CBECS 2018 divided by the average energy price of the state, in nominal dollars. This factor was then multiplied times the monthly marginal energy prices (for natural gas and electricity) or the monthly price developed above to come up with the household energy price.

8E.6 BASE YEAR AVERAGE & MARGINAL MONTHLY ENERGY PRICES

For electricity and natural gas, DOE applied the state monthly energy price factors presented in section 8E.3 to annual average prices presented in section 8E.2 to develop residential and commercial average monthly energy prices for 2022 as shown in Table 8E.6.1 through Table 8E.6.4. DOE then applied the marginal price factors presented in section 8E.4 to the monthly average energy prices to develop marginal residential and commercial monthly energy prices for 2022 as shown in Table 8E.6.5 through Table 8E.6.8.

For LPG, DOE applied the Census Region monthly energy price factors presented in section 8E.3 to the annual energy price data presented in section 8E.2 to develop residential and commercial monthly energy prices for 2022 as shown in Table 8E.6.9 through

The following equation summarizes DOE's approach of calculating the energy cost per year using monthly average and marginal energy prices together with monthly energy consumption for each sampled gas-fired instantaneous water heater:

$$EC_t = \left[\sum_m MEC_{BASE,t,m} \times MEP_{AVG,t,m} + \sum_m \Delta MEC_{t,m} \times MEP_{MAR,t,m} \times MEPF_{MAR,t,m}\right] \times EPT_t$$

Eq. 8E.9

Where:

$MEC_{BASE,t,m}$ = monthly energy consumption at the site for baseline design in the month *m* of year *t*,
$MEP_{AVG,t,m}$ = monthly average energy price in the month *m* of year *t*,
$\Delta MEC_{t,m}$ = change in monthly energy consumption from higher efficiency design in the month *m* of year *t*,
$MEP_{MAR,t,m}$ = monthly average marginal energy price in the month *m* of year *t*,
$MEPF_{MAR,t,m}$ = monthly marginal energy price factor for the month *m* of year *t*, and
EPT_t = energy price trend in year *t* (see section 8E.7).

Table 8E.6.1 Residential Average Monthly Electricity Prices for 2022, 2023$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.139	0.143	0.148	0.153	0.151	0.154	0.153	0.155	0.155	0.154	0.150	0.141
Alaska	0.229	0.230	0.235	0.237	0.245	0.247	0.252	0.249	0.244	0.244	0.241	0.238
Arizona	0.123	0.126	0.128	0.135	0.145	0.143	0.143	0.142	0.141	0.139	0.129	0.127
Arkansas	0.111	0.115	0.118	0.124	0.126	0.130	0.129	0.129	0.130	0.125	0.125	0.118
California	0.272	0.270	0.266	0.247	0.272	0.283	0.285	0.286	0.280	0.246	0.278	0.276
Colorado	0.140	0.143	0.144	0.147	0.148	0.154	0.154	0.154	0.155	0.150	0.149	0.145
Connecticut	0.249	0.258	0.258	0.266	0.268	0.264	0.255	0.259	0.264	0.264	0.257	0.250
Delaware	0.133	0.134	0.137	0.143	0.152	0.150	0.145	0.146	0.149	0.155	0.151	0.142
District of Columbia	0.140	0.142	0.144	0.146	0.150	0.154	0.153	0.154	0.153	0.154	0.148	0.146
Florida	0.141	0.143	0.143	0.145	0.142	0.145	0.145	0.145	0.147	0.146	0.148	0.145
Georgia	0.132	0.135	0.140	0.142	0.147	0.156	0.158	0.159	0.153	0.144	0.139	0.131
Hawaii	0.432	0.435	0.437	0.442	0.445	0.450	0.452	0.453	0.454	0.455	0.455	0.454
Idaho	0.104	0.103	0.105	0.105	0.109	0.115	0.116	0.115	0.109	0.112	0.107	0.106
Illinois	0.150	0.156	0.163	0.170	0.175	0.169	0.165	0.167	0.168	0.174	0.169	0.156
Indiana	0.143	0.146	0.152	0.163	0.164	0.158	0.156	0.157	0.161	0.168	0.163	0.152
Iowa	0.120	0.123	0.128	0.135	0.142	0.148	0.152	0.153	0.145	0.137	0.131	0.124
Kansas	0.131	0.138	0.143	0.150	0.152	0.153	0.154	0.154	0.152	0.149	0.146	0.137
Kentucky	0.125	0.127	0.129	0.137	0.137	0.136	0.135	0.136	0.136	0.141	0.139	0.134
Louisiana	0.120	0.124	0.128	0.131	0.134	0.133	0.135	0.137	0.137	0.138	0.131	0.127
Maine	0.232	0.236	0.235	0.237	0.240	0.240	0.237	0.236	0.240	0.239	0.239	0.234
Maryland	0.143	0.144	0.146	0.148	0.152	0.159	0.156	0.156	0.157	0.158	0.150	0.150
Massachusetts	0.271	0.274	0.274	0.273	0.271	0.269	0.263	0.269	0.276	0.269	0.271	0.281
Michigan	0.177	0.178	0.179	0.182	0.186	0.191	0.192	0.193	0.189	0.187	0.183	0.183
Minnesota	0.138	0.139	0.141	0.145	0.150	0.157	0.158	0.157	0.155	0.151	0.145	0.141
Mississippi	0.123	0.126	0.132	0.137	0.138	0.135	0.133	0.133	0.132	0.134	0.136	0.130
Missouri	0.107	0.109	0.116	0.123	0.139	0.147	0.147	0.146	0.134	0.126	0.121	0.113
Montana	0.111	0.112	0.114	0.116	0.120	0.124	0.125	0.124	0.125	0.123	0.119	0.116
Nebraska	0.096	0.101	0.104	0.111	0.116	0.127	0.129	0.129	0.131	0.116	0.111	0.102
Nevada	0.141	0.145	0.147	0.148	0.145	0.141	0.139	0.140	0.142	0.149	0.151	0.145
New Hampshire	0.259	0.264	0.266	0.269	0.272	0.268	0.261	0.265	0.273	0.276	0.273	0.271
New Jersey	0.167	0.169	0.169	0.170	0.172	0.180	0.185	0.185	0.181	0.170	0.170	0.171
New Mexico	0.137	0.140	0.141	0.142	0.143	0.152	0.155	0.157	0.153	0.152	0.142	0.140
New York	0.219	0.224	0.220	0.223	0.230	0.238	0.239	0.237	0.240	0.237	0.230	0.224
North Carolina	0.117	0.122	0.125	0.130	0.128	0.126	0.127	0.129	0.132	0.135	0.127	0.121
North Dakota	0.098	0.101	0.105	0.112	0.122	0.133	0.130	0.131	0.133	0.122	0.112	0.104
Ohio	0.134	0.136	0.140	0.147	0.151	0.154	0.153	0.153	0.150	0.149	0.147	0.140
Oklahoma	0.110	0.122	0.125	0.137	0.133	0.135	0.134	0.137	0.144	0.142	0.128	0.114
Oregon	0.115	0.116	0.116	0.117	0.119	0.120	0.121	0.121	0.121	0.121	0.119	0.117
Pennsylvania	0.158	0.161	0.162	0.166	0.171	0.173	0.172	0.172	0.172	0.172	0.169	0.165
Rhode Island	0.244	0.251	0.247	0.242	0.239	0.237	0.230	0.242	0.254	0.245	0.251	0.258
South Carolina	0.139	0.142	0.144	0.150	0.149	0.149	0.148	0.148	0.150	0.151	0.150	0.144
South Dakota	0.114	0.117	0.119	0.125	0.132	0.137	0.136	0.135	0.138	0.135	0.127	0.120
Tennessee	0.123	0.122	0.126	0.130	0.131	0.130	0.129	0.129	0.128	0.133	0.133	0.130
Texas	0.134	0.136	0.139	0.142	0.143	0.144	0.143	0.144	0.144	0.143	0.142	0.139
Utah	0.107	0.108	0.109	0.110	0.114	0.119	0.121	0.121	0.118	0.112	0.110	0.110
Vermont	0.203	0.205	0.206	0.212	0.213	0.214	0.210	0.210	0.213	0.218	0.216	0.210
Virginia	0.130	0.132	0.136	0.141	0.145	0.147	0.148	0.148	0.147	0.144	0.141	0.134
Washington	0.103	0.104	0.105	0.106	0.107	0.108	0.109	0.109	0.110	0.109	0.108	0.107
West Virginia	0.130	0.132	0.136	0.141	0.144	0.142	0.140	0.141	0.143	0.147	0.143	0.135
Wisconsin	0.154	0.156	0.158	0.162	0.166	0.167	0.164	0.164	0.167	0.165	0.161	0.157
Wyoming	0.107	0.109	0.111	0.114	0.119	0.123	0.123	0.122	0.124	0.123	0.116	0.111
United States	0.147	0.150	0.153	0.157	0.160	0.162	0.162	0.163	0.163	0.160	0.158	0.153

Table 8E.6.2 Commercial Average Monthly Electricity Prices for 2022, 2023$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.136	0.137	0.137	0.138	0.138	0.142	0.141	0.142	0.140	0.140	0.141	0.137
Alaska	0.199	0.201	0.203	0.206	0.211	0.211	0.212	0.209	0.207	0.209	0.208	0.206
Arizona	0.102	0.105	0.104	0.108	0.117	0.119	0.121	0.119	0.117	0.115	0.106	0.105
Arkansas	0.101	0.105	0.104	0.104	0.106	0.110	0.109	0.109	0.108	0.106	0.105	0.104
California	0.197	0.204	0.200	0.204	0.215	0.248	0.258	0.256	0.252	0.234	0.215	0.201
Colorado	0.111	0.116	0.116	0.120	0.121	0.128	0.127	0.127	0.127	0.123	0.123	0.118
Connecticut	0.192	0.199	0.192	0.195	0.194	0.195	0.192	0.195	0.194	0.193	0.191	0.192
Delaware	0.110	0.114	0.114	0.112	0.116	0.118	0.116	0.116	0.116	0.116	0.117	0.115
District of Columbia	0.155	0.159	0.158	0.159	0.162	0.165	0.162	0.163	0.168	0.164	0.162	0.161
Florida	0.115	0.119	0.117	0.116	0.115	0.115	0.115	0.115	0.117	0.118	0.119	0.118
Georgia	0.128	0.129	0.129	0.129	0.129	0.134	0.135	0.135	0.132	0.130	0.130	0.127
Hawaii	0.412	0.409	0.410	0.412	0.416	0.419	0.424	0.428	0.429	0.431	0.432	0.432
Idaho	0.083	0.084	0.085	0.086	0.086	0.091	0.089	0.089	0.085	0.087	0.086	0.083
Illinois	0.115	0.118	0.120	0.121	0.123	0.124	0.125	0.125	0.123	0.124	0.120	0.117
Indiana	0.130	0.134	0.135	0.137	0.136	0.136	0.136	0.137	0.137	0.139	0.140	0.137
Iowa	0.099	0.101	0.103	0.104	0.109	0.118	0.125	0.126	0.116	0.104	0.102	0.100
Kansas	0.112	0.117	0.120	0.121	0.123	0.127	0.128	0.127	0.124	0.122	0.118	0.115
Kentucky	0.118	0.123	0.122	0.125	0.125	0.125	0.124	0.125	0.126	0.125	0.127	0.125
Louisiana	0.119	0.122	0.124	0.123	0.122	0.121	0.123	0.124	0.124	0.126	0.124	0.124
Maine	0.166	0.173	0.169	0.157	0.158	0.157	0.157	0.156	0.159	0.159	0.165	0.169
Maryland	0.128	0.130	0.128	0.127	0.129	0.134	0.135	0.135	0.138	0.134	0.130	0.133
Massachusetts	0.193	0.198	0.195	0.189	0.186	0.198	0.200	0.201	0.204	0.194	0.189	0.197
Michigan	0.124	0.129	0.128	0.128	0.132	0.133	0.132	0.132	0.130	0.130	0.130	0.130
Minnesota	0.118	0.121	0.121	0.124	0.127	0.138	0.137	0.135	0.133	0.125	0.123	0.120
Mississippi	0.124	0.126	0.127	0.127	0.127	0.126	0.124	0.125	0.124	0.125	0.128	0.128
Missouri	0.088	0.090	0.092	0.093	0.108	0.119	0.120	0.119	0.105	0.095	0.093	0.092
Montana	0.107	0.108	0.110	0.110	0.112	0.113	0.113	0.112	0.114	0.114	0.113	0.111
Nebraska	0.085	0.087	0.089	0.089	0.092	0.099	0.100	0.099	0.099	0.091	0.089	0.088
Nevada	0.099	0.102	0.100	0.100	0.098	0.098	0.099	0.100	0.103	0.102	0.101	0.100
New Hampshire	0.193	0.199	0.196	0.195	0.195	0.194	0.192	0.192	0.195	0.196	0.195	0.198
New Jersey	0.137	0.138	0.138	0.138	0.144	0.157	0.157	0.159	0.152	0.139	0.137	0.138
New Mexico	0.110	0.113	0.112	0.111	0.113	0.121	0.123	0.124	0.120	0.118	0.114	0.113
New York	0.178	0.181	0.178	0.177	0.183	0.200	0.207	0.205	0.205	0.194	0.182	0.180
North Carolina	0.091	0.095	0.095	0.093	0.093	0.094	0.097	0.097	0.097	0.097	0.094	0.095
North Dakota	0.087	0.089	0.090	0.092	0.094	0.100	0.098	0.100	0.101	0.096	0.093	0.090
Ohio	0.106	0.109	0.110	0.111	0.111	0.110	0.110	0.110	0.111	0.111	0.111	0.107
Oklahoma	0.099	0.102	0.099	0.101	0.103	0.115	0.116	0.118	0.117	0.111	0.100	0.099
Oregon	0.095	0.097	0.097	0.098	0.098	0.097	0.096	0.095	0.095	0.098	0.098	0.096
Pennsylvania	0.110	0.112	0.112	0.112	0.113	0.114	0.113	0.113	0.113	0.112	0.113	0.111
Rhode Island	0.174	0.180	0.173	0.164	0.165	0.166	0.165	0.168	0.168	0.166	0.170	0.178
South Carolina	0.119	0.122	0.120	0.120	0.120	0.125	0.124	0.124	0.125	0.121	0.125	0.125
South Dakota	0.100	0.104	0.103	0.105	0.107	0.110	0.111	0.111	0.110	0.108	0.106	0.104
Tennessee	0.123	0.123	0.125	0.125	0.125	0.127	0.127	0.127	0.126	0.127	0.128	0.128
Texas	0.093	0.098	0.097	0.096	0.095	0.097	0.096	0.097	0.096	0.095	0.095	0.094
Utah	0.081	0.083	0.084	0.085	0.092	0.096	0.091	0.090	0.094	0.091	0.084	0.080
Vermont	0.177	0.178	0.180	0.182	0.184	0.183	0.181	0.179	0.182	0.184	0.183	0.182
Virginia	0.097	0.097	0.098	0.097	0.099	0.099	0.100	0.101	0.100	0.100	0.100	0.100
Washington	0.099	0.099	0.100	0.098	0.098	0.098	0.098	0.098	0.099	0.101	0.101	0.101
West Virginia	0.104	0.109	0.110	0.111	0.110	0.107	0.106	0.107	0.109	0.112	0.114	0.107
Wisconsin	0.117	0.120	0.118	0.121	0.123	0.126	0.125	0.125	0.126	0.121	0.121	0.118
Wyoming	0.094	0.097	0.098	0.100	0.102	0.103	0.101	0.100	0.102	0.103	0.100	0.094
United States	0.124	0.127	0.127	0.127	0.129	0.135	0.136	0.136	0.135	0.132	0.129	0.127

Table 8E.6.3 Residential Average Monthly Natural Gas Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	16.10	15.94	16.56	18.58	21.12	23.43	24.48	24.73	24.64	23.71	19.87	17.29
Alaska	10.85	10.99	10.83	11.16	11.91	13.07	13.71	13.44	12.22	11.33	10.90	11.29
Arizona	15.15	16.08	17.18	19.00	21.24	23.61	25.70	26.32	25.59	22.70	18.79	16.20
Arkansas	14.38	14.29	15.00	16.77	19.81	23.48	25.68	26.79	26.00	23.39	17.64	15.43
California	20.38	20.03	19.34	19.47	20.53	20.97	21.26	21.25	20.98	20.92	19.99	20.61
Colorado	11.78	11.91	12.50	12.96	15.04	18.95	21.28	21.46	19.05	14.52	12.99	12.30
Connecticut	17.46	17.65	18.05	19.29	21.69	25.04	27.31	28.60	27.72	23.58	19.54	18.35
Delaware	13.91	14.22	14.94	16.29	18.92	22.95	25.63	27.03	26.06	22.76	16.54	14.79
District of Columbia	17.02	16.89	17.50	18.62	21.47	23.97	26.25	25.96	25.25	22.35	19.26	17.56
Florida	22.60	22.61	24.16	25.54	27.81	30.21	32.01	32.92	32.18	31.55	28.37	24.87
Georgia	16.45	17.36	18.49	21.77	27.00	32.26	34.22	34.49	34.54	27.78	20.07	17.80
Hawaii	53.52	55.52	57.02	57.29	58.87	59.25	59.64	59.58	59.62	60.33	58.11	56.92
Idaho	7.93	7.96	8.19	8.33	8.71	9.39	9.97	10.16	9.58	8.66	8.09	8.03
Illinois	13.35	13.39	14.44	15.83	19.51	23.94	27.89	28.29	26.10	18.56	15.17	13.90
Indiana	10.31	10.51	11.78	13.39	15.57	20.28	21.39	21.13	18.99	12.68	10.58	10.34
Iowa	11.35	11.64	12.88	13.08	15.59	20.01	22.86	23.88	22.74	16.67	13.12	11.59
Kansas	13.56	13.91	14.76	17.67	21.28	26.76	28.83	30.67	28.51	21.74	15.48	14.16
Kentucky	14.03	14.07	14.98	17.17	22.79	27.87	30.02	31.04	29.47	21.38	16.15	15.04
Louisiana	14.59	14.69	15.73	17.74	20.40	22.62	23.48	24.01	23.19	22.40	18.64	15.99
Maine	23.07	23.78	23.57	24.23	24.40	27.94	31.35	32.52	31.34	25.51	23.34	23.76
Maryland	15.96	15.92	16.48	18.29	21.79	25.72	27.51	28.11	27.11	21.67	17.79	17.00
Massachusetts	21.35	21.32	21.36	22.01	22.25	21.97	24.07	24.98	24.17	20.84	21.51	22.23
Michigan	10.76	10.87	11.19	11.90	13.77	16.20	17.55	18.14	16.53	13.08	11.68	11.28
Minnesota	12.73	12.82	13.12	13.02	15.16	18.13	19.37	19.17	17.95	14.02	13.36	13.00
Mississippi	14.34	14.50	15.63	17.43	20.14	22.65	22.49	23.16	23.13	21.63	17.26	15.36
Missouri	11.73	11.70	12.42	14.61	17.90	23.85	27.84	29.16	27.29	22.35	15.51	12.94
Montana	10.34	10.47	10.58	10.93	11.55	13.10	15.16	16.26	14.77	12.06	11.03	10.64
Nebraska	12.04	12.27	12.55	13.77	15.78	20.11	23.31	24.54	23.81	19.69	14.74	13.08
Nevada	11.41	11.78	12.37	13.74	14.97	16.10	17.62	18.37	17.63	16.00	13.67	12.02
New Hampshire	20.92	20.63	20.75	21.81	22.75	24.56	29.20	31.02	30.37	25.88	22.56	22.63
New Jersey	12.23	12.17	12.22	12.37	13.66	15.05	15.90	16.36	15.92	14.53	13.38	12.69
New Mexico	12.02	12.01	12.41	13.37	15.26	18.95	21.10	21.55	21.46	19.05	14.49	12.73
New York	15.75	15.54	15.97	16.78	19.12	22.99	24.92	25.34	24.81	21.70	18.17	16.55
North Carolina	15.42	15.59	16.43	19.14	23.73	27.66	29.51	28.80	28.58	23.64	17.67	16.85
North Dakota	11.46	11.58	12.09	12.82	15.57	22.27	27.45	27.57	23.35	14.69	12.49	11.81
Ohio	13.28	13.47	13.91	15.65	19.91	28.06	31.82	33.21	30.92	21.11	15.61	14.18
Oklahoma	12.87	13.12	13.91	17.45	22.31	28.32	33.02	36.05	34.49	30.54	19.77	13.91
Oregon	12.55	12.48	12.84	13.29	14.32	15.36	16.74	17.81	16.52	14.23	13.23	12.69
Pennsylvania	13.70	13.80	14.15	15.02	17.19	21.10	23.65	24.59	23.19	18.33	15.21	14.26
Rhode Island	16.67	16.81	17.16	18.28	19.80	21.79	23.78	24.73	24.31	22.00	18.92	17.68
South Carolina	13.83	14.27	15.14	18.05	23.20	26.36	28.11	27.90	27.45	21.99	15.82	14.86
South Dakota	10.23	10.43	11.11	11.09	12.02	15.16	17.93	18.62	17.47	12.72	11.13	10.26
Tennessee	11.75	11.68	12.06	13.62	16.32	19.64	21.64	22.68	21.36	18.88	14.14	12.41
Texas	14.63	14.56	15.89	19.55	23.48	26.54	28.55	30.52	29.70	26.63	20.19	16.67
Utah	10.32	10.53	10.61	10.32	10.12	11.16	12.23	12.79	12.50	11.29	10.66	10.82
Vermont	15.09	14.80	15.13	15.67	17.32	20.84	23.91	25.23	24.32	20.53	17.25	16.02
Virginia	14.99	15.10	15.33	17.21	20.84	24.69	27.11	27.21	26.47	21.67	17.07	16.04
Washington	12.28	12.33	12.48	12.95	14.07	15.41	16.76	17.36	16.04	13.70	12.89	12.58
West Virginia	11.69	11.77	11.94	12.84	15.12	19.04	21.03	21.36	18.95	14.51	12.59	12.17
Wisconsin	11.61	11.63	12.17	12.18	13.70	16.85	18.09	18.59	16.87	12.11	12.24	11.92
Wyoming	12.93	13.11	13.40	13.92	15.03	18.34	24.23	25.82	23.47	17.68	14.62	13.62
United States	14.07	14.16	14.70	15.80	18.15	21.29	23.15	23.78	22.65	18.39	15.63	14.76

Table 8E.6.4 Commercial Average Monthly Natural Gas Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	13.23	13.21	13.33	13.90	14.05	14.25	14.30	14.41	14.66	14.62	14.32	13.77
Alaska	10.52	10.50	10.27	10.12	10.05	10.36	10.45	10.52	10.40	10.59	10.56	10.74
Arizona	10.57	10.74	10.93	11.01	11.26	11.21	11.28	11.30	11.33	11.30	11.02	10.78
Arkansas	12.37	12.22	12.42	12.84	13.55	14.15	14.28	14.33	13.89	13.30	13.39	12.94
California	17.24	16.66	16.42	15.64	15.25	15.78	16.12	16.06	15.70	15.64	16.41	17.64
Colorado	11.26	11.21	11.41	11.59	12.46	13.53	14.60	14.53	14.16	12.60	12.10	11.65
Connecticut	12.77	12.82	12.93	13.64	14.41	15.34	15.08	15.06	14.96	14.74	13.44	12.93
Delaware	11.60	11.90	12.37	12.98	13.82	14.57	15.19	15.36	15.03	14.41	12.65	12.09
District of Columbia	16.06	16.24	16.42	16.82	16.72	17.01	17.27	16.85	16.62	16.40	16.99	16.29
Florida	14.25	14.26	14.26	14.20	14.22	14.31	14.40	14.28	14.34	14.20	14.20	14.30
Georgia	10.67	10.80	11.13	11.74	12.47	13.00	13.19	13.23	13.06	12.41	11.55	10.62
Hawaii	40.65	42.44	43.83	43.87	44.95	45.94	45.97	45.31	45.30	45.75	44.25	43.09
Idaho	7.00	6.99	7.10	7.29	7.34	7.39	7.51	7.52	7.47	7.27	7.18	7.12
Illinois	12.35	12.38	13.11	14.29	17.31	19.90	21.37	21.67	19.81	15.31	13.57	12.85
Indiana	8.77	8.82	9.76	10.40	11.34	12.42	12.53	12.29	10.73	8.78	8.62	8.64
Iowa	10.86	11.07	11.75	11.13	12.25	13.39	13.86	13.91	13.40	10.88	11.29	11.26
Kansas	11.82	12.05	12.57	14.28	15.96	17.51	18.36	18.38	18.40	15.50	12.81	12.13
Kentucky	12.51	12.43	12.90	14.03	15.89	17.19	17.47	17.80	17.23	15.27	13.81	13.27
Louisiana	14.07	13.51	13.61	13.15	13.45	13.65	13.79	13.53	13.38	13.72	14.03	14.33
Maine	18.48	18.81	18.36	18.38	17.09	16.65	17.63	18.01	17.29	16.04	17.09	18.28
Maryland	14.71	14.79	14.84	15.17	16.10	16.65	16.76	16.77	16.76	16.02	15.42	15.45
Massachusetts	16.93	17.00	17.08	17.23	16.30	14.94	15.39	15.42	15.46	14.39	16.10	17.42
Michigan	10.19	10.25	10.46	10.62	11.48	12.54	13.01	13.09	12.67	11.30	10.79	10.59
Minnesota	12.03	11.97	12.12	11.54	12.14	13.08	13.26	13.07	12.65	11.36	11.90	11.98
Mississippi	13.17	13.06	13.35	13.11	12.94	12.53	12.56	12.35	12.49	13.38	13.52	13.29
Missouri	10.80	10.64	10.87	11.58	12.23	13.60	14.47	14.58	14.01	13.40	12.42	11.48
Montana	10.28	10.41	10.50	10.74	11.32	12.52	13.37	13.58	13.17	11.45	10.83	10.55
Nebraska	11.54	11.50	11.48	11.18	10.80	11.27	11.96	12.04	12.03	11.36	11.39	11.87
Nevada	9.16	9.26	9.33	9.60	9.83	9.91	10.25	10.43	10.28	10.07	9.76	9.40
New Hampshire	17.54	17.35	17.51	18.07	18.22	18.53	20.96	21.49	21.20	18.84	18.23	18.71
New Jersey	14.40	14.16	14.32	12.72	13.40	14.22	14.55	14.05	13.54	13.96	14.93	14.81
New Mexico	10.68	10.62	10.56	10.47	10.96	11.75	12.48	12.63	12.43	12.40	11.93	11.26
New York	11.29	11.26	11.32	10.82	10.56	10.29	9.84	9.58	9.82	10.36	10.83	11.38
North Carolina	11.90	11.77	11.81	12.37	12.76	13.23	13.44	12.92	12.93	12.83	12.96	13.09
North Dakota	10.00	10.02	10.09	9.69	10.47	11.74	12.39	12.27	11.55	9.85	10.22	10.20
Ohio	8.51	8.50	8.48	8.84	9.55	10.27	10.45	10.52	10.24	9.48	8.77	8.73
Oklahoma	10.61	10.70	11.14	13.39	15.85	18.55	20.22	21.49	20.54	19.45	15.04	11.33
Oregon	10.15	10.05	10.24	10.39	10.55	10.81	10.98	11.29	10.99	10.63	10.49	10.43
Pennsylvania	12.10	12.30	12.59	12.75	13.85	14.64	15.01	14.78	14.37	13.12	12.40	12.45
Rhode Island	14.20	14.39	14.61	15.32	16.50	18.63	20.13	20.73	20.28	18.64	16.05	15.22
South Carolina	12.86	12.10	12.41	12.46	12.11	12.53	12.72	12.39	12.44	12.54	13.17	13.70
South Dakota	9.27	9.36	9.76	9.12	9.44	10.43	11.11	11.27	10.64	9.18	9.30	9.28
Tennessee	11.79	11.64	11.60	11.91	12.29	12.86	13.34	13.63	13.25	13.32	12.71	12.34
Texas	11.39	11.48	11.49	11.87	12.39	12.86	13.09	13.20	13.30	13.19	12.74	12.26
Utah	9.01	9.13	9.14	8.68	8.17	8.51	9.04	9.31	9.19	8.85	8.98	9.45
Vermont	9.26	9.35	9.11	8.97	8.89	8.53	8.53	8.58	8.79	8.56	8.95	9.35
Virginia	11.78	11.77	11.46	11.70	12.21	12.86	12.83	12.74	12.83	12.12	11.84	12.14
Washington	10.20	10.21	10.19	10.34	10.61	10.97	11.37	11.53	11.17	10.62	10.51	10.46
West Virginia	9.06	9.11	9.21	9.69	10.57	11.51	11.63	11.74	11.25	10.28	9.49	9.41
Wisconsin	10.70	10.73	10.88	10.40	10.20	10.96	10.92	10.86	10.66	9.29	10.74	10.92
Wyoming	11.63	11.60	11.69	11.56	11.72	12.46	13.54	13.76	13.61	12.90	12.43	12.09
United States	11.56	11.57	11.78	11.84	12.23	12.70	12.89	12.83	12.69	12.11	11.93	11.92

Table 8E.6.5 Residential Marginal Monthly Electricity Prices for 2022, 2023$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.111	0.115	0.118	0.151	0.148	0.152	0.151	0.153	0.153	0.152	0.120	0.113
Alaska	0.206	0.207	0.211	0.192	0.198	0.200	0.204	0.201	0.197	0.198	0.218	0.215
Arizona	0.107	0.110	0.112	0.135	0.145	0.143	0.143	0.142	0.142	0.140	0.113	0.111
Arkansas	0.086	0.089	0.091	0.129	0.131	0.135	0.134	0.135	0.135	0.130	0.097	0.091
California	0.245	0.244	0.240	0.310	0.341	0.355	0.357	0.359	0.351	0.309	0.250	0.249
Colorado	0.126	0.129	0.129	0.166	0.167	0.174	0.175	0.174	0.176	0.169	0.133	0.130
Connecticut	0.214	0.222	0.222	0.229	0.230	0.227	0.219	0.223	0.227	0.227	0.221	0.215
Delaware	0.103	0.104	0.107	0.116	0.123	0.121	0.117	0.118	0.120	0.125	0.118	0.110
District of Columbia	0.110	0.111	0.112	0.126	0.131	0.134	0.133	0.134	0.133	0.134	0.116	0.115
Florida	0.164	0.167	0.166	0.151	0.148	0.151	0.151	0.152	0.154	0.153	0.171	0.168
Georgia	0.110	0.112	0.116	0.168	0.174	0.184	0.187	0.188	0.181	0.171	0.115	0.109
Hawaii	0.379	0.382	0.384	0.414	0.417	0.422	0.424	0.425	0.426	0.427	0.400	0.399
Idaho	0.106	0.106	0.107	0.117	0.122	0.128	0.129	0.128	0.122	0.125	0.109	0.109
Illinois	0.102	0.106	0.110	0.148	0.152	0.147	0.143	0.145	0.146	0.151	0.114	0.105
Indiana	0.109	0.111	0.115	0.148	0.149	0.143	0.141	0.143	0.146	0.152	0.124	0.115
Iowa	0.096	0.098	0.102	0.177	0.186	0.193	0.199	0.201	0.190	0.180	0.104	0.099
Kansas	0.098	0.103	0.107	0.148	0.150	0.151	0.152	0.153	0.150	0.147	0.108	0.102
Kentucky	0.101	0.102	0.104	0.128	0.129	0.128	0.127	0.127	0.128	0.132	0.112	0.108
Louisiana	0.091	0.094	0.097	0.132	0.136	0.134	0.137	0.138	0.138	0.139	0.099	0.096
Maine	0.216	0.220	0.219	0.224	0.226	0.226	0.223	0.223	0.226	0.225	0.223	0.218
Maryland	0.130	0.131	0.133	0.136	0.140	0.146	0.143	0.143	0.144	0.145	0.137	0.136
Massachusetts	0.278	0.281	0.281	0.252	0.250	0.248	0.242	0.248	0.255	0.248	0.277	0.288
Michigan	0.159	0.161	0.161	0.190	0.194	0.200	0.200	0.202	0.197	0.195	0.165	0.165
Minnesota	0.117	0.119	0.120	0.160	0.166	0.174	0.175	0.173	0.172	0.167	0.124	0.121
Mississippi	0.093	0.095	0.099	0.121	0.122	0.120	0.118	0.118	0.117	0.118	0.102	0.098
Missouri	0.078	0.079	0.084	0.157	0.177	0.188	0.188	0.187	0.170	0.161	0.088	0.082
Montana	0.099	0.099	0.101	0.104	0.107	0.111	0.112	0.111	0.112	0.110	0.105	0.102
Nebraska	0.068	0.071	0.074	0.130	0.135	0.148	0.150	0.151	0.152	0.136	0.078	0.073
Nevada	0.116	0.119	0.120	0.136	0.134	0.129	0.128	0.128	0.131	0.137	0.124	0.119
New Hampshire	0.234	0.239	0.241	0.227	0.229	0.226	0.220	0.223	0.231	0.233	0.248	0.246
New Jersey	0.167	0.169	0.169	0.178	0.180	0.189	0.193	0.194	0.189	0.178	0.170	0.171
New Mexico	0.122	0.125	0.126	0.163	0.164	0.175	0.178	0.180	0.175	0.174	0.127	0.124
New York	0.202	0.207	0.203	0.233	0.241	0.249	0.250	0.248	0.251	0.247	0.213	0.207
North Carolina	0.096	0.100	0.101	0.120	0.119	0.116	0.118	0.119	0.122	0.125	0.104	0.098
North Dakota	0.069	0.072	0.074	0.088	0.095	0.104	0.102	0.102	0.104	0.095	0.079	0.074
Ohio	0.110	0.112	0.115	0.153	0.158	0.160	0.160	0.159	0.156	0.156	0.120	0.115
Oklahoma	0.069	0.076	0.078	0.127	0.124	0.126	0.125	0.127	0.134	0.132	0.080	0.071
Oregon	0.107	0.109	0.109	0.114	0.116	0.117	0.118	0.117	0.118	0.118	0.112	0.110
Pennsylvania	0.136	0.139	0.140	0.164	0.169	0.171	0.170	0.170	0.170	0.170	0.146	0.143
Rhode Island	0.232	0.239	0.234	0.202	0.201	0.198	0.193	0.203	0.212	0.205	0.238	0.245
South Carolina	0.115	0.118	0.119	0.144	0.143	0.143	0.142	0.142	0.144	0.145	0.124	0.119
South Dakota	0.091	0.093	0.094	0.124	0.131	0.136	0.135	0.134	0.136	0.134	0.101	0.096
Tennessee	0.104	0.103	0.106	0.129	0.130	0.129	0.128	0.128	0.127	0.132	0.113	0.109
Texas	0.115	0.117	0.120	0.138	0.138	0.140	0.139	0.139	0.140	0.139	0.123	0.120
Utah	0.103	0.104	0.104	0.125	0.130	0.135	0.138	0.138	0.134	0.127	0.106	0.105
Vermont	0.170	0.173	0.174	0.191	0.192	0.193	0.189	0.189	0.192	0.196	0.182	0.176
Virginia	0.108	0.110	0.113	0.148	0.151	0.154	0.155	0.155	0.154	0.151	0.117	0.112
Washington	0.098	0.099	0.099	0.093	0.093	0.095	0.095	0.095	0.096	0.095	0.102	0.101
West Virginia	0.105	0.106	0.110	0.129	0.132	0.131	0.128	0.129	0.131	0.135	0.115	0.109
Wisconsin	0.132	0.134	0.135	0.154	0.158	0.158	0.156	0.156	0.159	0.157	0.138	0.134
Wyoming	0.092	0.094	0.095	0.097	0.101	0.104	0.105	0.104	0.105	0.104	0.100	0.096
United States	0.119	0.121	0.124	0.163	0.166	0.168	0.169	0.170	0.170	0.166	0.128	0.124

Table 8E.6.6 Commercial Marginal Monthly Electricity Prices for 2022, 2023$/kWh

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	0.116	0.118	0.117	0.145	0.144	0.149	0.148	0.149	0.147	0.147	0.120	0.117
Alaska	0.164	0.165	0.167	0.176	0.180	0.180	0.180	0.178	0.177	0.178	0.171	0.170
Arizona	0.094	0.097	0.096	0.134	0.145	0.148	0.149	0.147	0.144	0.142	0.097	0.097
Arkansas	0.093	0.097	0.096	0.111	0.114	0.118	0.117	0.117	0.116	0.114	0.097	0.096
California	0.180	0.186	0.183	0.374	0.395	0.455	0.473	0.470	0.462	0.430	0.196	0.183
Colorado	0.095	0.099	0.100	0.158	0.158	0.169	0.167	0.167	0.167	0.162	0.105	0.101
Connecticut	0.236	0.245	0.237	0.161	0.160	0.161	0.158	0.161	0.160	0.159	0.236	0.236
Delaware	0.093	0.096	0.096	0.090	0.093	0.095	0.093	0.093	0.093	0.093	0.099	0.097
District of Columbia	0.133	0.136	0.134	0.142	0.145	0.148	0.145	0.146	0.150	0.147	0.138	0.137
Florida	0.093	0.097	0.095	0.113	0.111	0.112	0.111	0.112	0.113	0.114	0.097	0.096
Georgia	0.169	0.171	0.170	0.155	0.156	0.160	0.162	0.163	0.158	0.157	0.172	0.168
Hawaii	0.566	0.563	0.564	0.429	0.433	0.436	0.442	0.445	0.446	0.449	0.594	0.594
Idaho	0.072	0.073	0.074	0.105	0.106	0.112	0.109	0.109	0.105	0.107	0.074	0.072
Illinois	0.095	0.097	0.099	0.119	0.121	0.122	0.123	0.123	0.121	0.122	0.099	0.096
Indiana	0.097	0.099	0.100	0.130	0.129	0.129	0.129	0.130	0.130	0.132	0.104	0.101
Iowa	0.082	0.084	0.085	0.210	0.219	0.237	0.251	0.253	0.233	0.210	0.085	0.083
Kansas	0.068	0.071	0.073	0.130	0.132	0.137	0.137	0.137	0.134	0.131	0.072	0.069
Kentucky	0.082	0.085	0.085	0.113	0.113	0.114	0.113	0.114	0.115	0.113	0.088	0.087
Louisiana	0.056	0.058	0.059	0.118	0.117	0.116	0.118	0.119	0.119	0.121	0.059	0.059
Maine	0.178	0.186	0.181	0.147	0.148	0.146	0.146	0.146	0.149	0.149	0.177	0.181
Maryland	0.131	0.134	0.131	0.117	0.119	0.124	0.124	0.125	0.127	0.123	0.133	0.136
Massachusetts	0.321	0.329	0.323	0.226	0.222	0.236	0.238	0.240	0.244	0.231	0.314	0.326
Michigan	0.089	0.093	0.092	0.137	0.141	0.142	0.142	0.141	0.140	0.140	0.093	0.093
Minnesota	0.104	0.107	0.106	0.166	0.171	0.185	0.185	0.183	0.179	0.168	0.109	0.106
Mississippi	0.112	0.114	0.114	0.112	0.111	0.111	0.109	0.110	0.109	0.110	0.115	0.115
Missouri	0.067	0.068	0.070	0.169	0.195	0.217	0.217	0.216	0.191	0.172	0.071	0.070
Montana	0.100	0.102	0.103	0.107	0.109	0.109	0.109	0.108	0.110	0.111	0.106	0.104
Nebraska	0.065	0.067	0.069	0.123	0.126	0.135	0.137	0.136	0.136	0.125	0.068	0.068
Nevada	0.098	0.100	0.099	0.103	0.101	0.100	0.102	0.102	0.106	0.105	0.100	0.099
New Hampshire	0.238	0.245	0.242	0.164	0.164	0.163	0.161	0.162	0.165	0.165	0.241	0.244
New Jersey	0.159	0.160	0.160	0.174	0.181	0.198	0.198	0.200	0.192	0.175	0.159	0.159
New Mexico	0.115	0.118	0.117	0.169	0.171	0.184	0.187	0.189	0.182	0.180	0.120	0.118
New York	0.267	0.271	0.267	0.270	0.279	0.306	0.316	0.313	0.313	0.297	0.272	0.270
North Carolina	0.069	0.072	0.072	0.104	0.105	0.106	0.110	0.109	0.110	0.110	0.071	0.072
North Dakota	0.068	0.071	0.071	0.117	0.120	0.127	0.125	0.127	0.128	0.121	0.073	0.071
Ohio	0.070	0.073	0.073	0.103	0.103	0.103	0.102	0.102	0.103	0.104	0.074	0.072
Oklahoma	0.113	0.116	0.113	0.132	0.134	0.151	0.152	0.155	0.154	0.145	0.115	0.113
Oregon	0.079	0.080	0.081	0.089	0.089	0.088	0.088	0.087	0.086	0.089	0.081	0.080
Pennsylvania	0.121	0.124	0.123	0.106	0.107	0.107	0.107	0.107	0.106	0.106	0.125	0.123
Rhode Island	0.151	0.156	0.150	0.139	0.139	0.140	0.139	0.142	0.142	0.140	0.147	0.154
South Carolina	0.106	0.109	0.107	0.133	0.133	0.139	0.138	0.137	0.138	0.135	0.111	0.111
South Dakota	0.076	0.078	0.078	0.126	0.128	0.133	0.133	0.133	0.133	0.130	0.080	0.078
Tennessee	0.121	0.121	0.123	0.142	0.142	0.144	0.144	0.144	0.143	0.144	0.126	0.126
Texas	0.071	0.075	0.074	0.099	0.098	0.100	0.100	0.100	0.099	0.098	0.072	0.071
Utah	0.052	0.054	0.055	0.098	0.106	0.110	0.104	0.104	0.108	0.104	0.055	0.052
Vermont	0.134	0.135	0.137	0.156	0.158	0.157	0.155	0.154	0.156	0.158	0.139	0.138
Virginia	0.112	0.112	0.113	0.105	0.106	0.106	0.107	0.108	0.108	0.108	0.116	0.115
Washington	0.092	0.093	0.093	0.091	0.091	0.091	0.091	0.091	0.092	0.094	0.095	0.094
West Virginia	0.067	0.070	0.071	0.082	0.081	0.078	0.078	0.079	0.080	0.082	0.073	0.069
Wisconsin	0.088	0.090	0.089	0.139	0.141	0.145	0.144	0.144	0.145	0.139	0.091	0.088
Wyoming	0.055	0.056	0.057	0.082	0.083	0.084	0.082	0.081	0.083	0.084	0.058	0.055
United States	0.093	0.096	0.096	0.158	0.161	0.168	0.170	0.170	0.169	0.165	0.097	0.095

Table 8E.6.7 Residential Marginal Monthly Natural Gas Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	13.71	13.58	14.11	11.73	13.33	14.79	15.45	15.60	15.55	14.96	16.92	14.72
Alaska	10.33	10.47	10.31	9.06	9.68	10.62	11.14	10.92	9.93	9.21	10.38	10.75
Arizona	11.55	12.26	13.10	11.43	12.78	14.21	15.47	15.84	15.40	13.66	14.33	12.35
Arkansas	12.03	11.95	12.55	8.92	10.54	12.49	13.65	14.25	13.82	12.44	14.76	12.91
California	22.41	22.02	21.27	17.48	18.43	18.82	19.08	19.08	18.83	18.78	21.98	22.66
Colorado	9.65	9.76	10.24	7.53	8.74	11.01	12.37	12.47	11.07	8.44	10.64	10.08
Connecticut	14.62	14.78	15.12	12.46	14.01	16.17	17.64	18.47	17.90	15.23	16.37	15.37
Delaware	11.42	11.68	12.26	8.86	10.29	12.49	13.95	14.70	14.18	12.38	13.58	12.14
District of Columbia	13.80	13.69	14.19	11.53	13.30	14.84	16.26	16.08	15.64	13.84	15.62	14.24
Florida	14.68	14.69	15.69	14.29	15.56	16.90	17.90	18.41	18.00	17.65	18.43	16.16
Georgia	12.59	13.29	14.15	11.71	14.53	17.36	18.41	18.56	18.58	14.95	15.36	13.62
Hawaii	33.34	34.59	35.53	72.24	74.23	74.71	75.20	75.13	75.18	76.08	36.20	35.46
Idaho	7.40	7.43	7.65	6.71	7.02	7.57	8.03	8.19	7.72	6.98	7.55	7.49
Illinois	11.29	11.32	12.21	7.62	9.39	11.52	13.41	13.61	12.56	8.93	12.83	11.75
Indiana	8.34	8.50	9.52	6.46	7.51	9.79	10.33	10.20	9.16	6.12	8.55	8.36
Iowa	9.49	9.73	10.76	7.27	8.67	11.13	12.71	13.28	12.65	9.27	10.97	9.69
Kansas	11.81	12.11	12.85	8.20	9.88	12.42	13.38	14.23	13.23	10.09	13.48	12.33
Kentucky	11.33	11.36	12.09	6.91	9.17	11.22	12.09	12.50	11.86	8.61	13.04	12.14
Louisiana	10.91	10.98	11.76	9.40	10.81	11.99	12.44	12.72	12.29	11.87	13.93	11.95
Maine	22.95	23.66	23.45	17.11	17.23	19.74	22.14	22.97	22.13	18.01	23.22	23.64
Maryland	12.81	12.77	13.23	10.60	12.63	14.91	15.95	16.29	15.71	12.56	14.27	13.64
Massachusetts	21.38	21.35	21.39	20.87	21.10	20.83	22.82	23.69	22.92	19.76	21.54	22.26
Michigan	9.43	9.53	9.82	8.19	9.48	11.15	12.07	12.48	11.37	9.00	10.24	9.89
Minnesota	12.57	12.65	12.95	8.46	9.85	11.78	12.58	12.46	11.66	9.11	13.18	12.83
Mississippi	11.07	11.20	12.07	8.77	10.14	11.40	11.32	11.66	11.64	10.88	13.33	11.86
Missouri	8.39	8.37	8.88	6.70	8.20	10.93	12.76	13.37	12.51	10.24	11.10	9.26
Montana	9.42	9.54	9.64	8.24	8.71	9.88	11.43	12.26	11.14	9.09	10.05	9.70
Nebraska	10.23	10.43	10.67	6.77	7.76	9.89	11.46	12.07	11.71	9.68	12.53	11.12
Nevada	8.56	8.84	9.28	7.91	8.62	9.27	10.15	10.58	10.15	9.21	10.26	9.02
New Hampshire	20.05	19.77	19.89	15.26	15.92	17.18	20.43	21.70	21.25	18.11	21.62	21.69
New Jersey	11.83	11.78	11.82	8.93	9.86	10.85	11.47	11.80	11.48	10.49	12.95	12.28
New Mexico	10.41	10.40	10.75	6.59	7.52	9.34	10.40	10.62	10.58	9.39	12.55	11.02
New York	12.39	12.23	12.57	9.58	10.91	13.12	14.22	14.47	14.16	12.39	14.30	13.02
North Carolina	12.37	12.51	13.18	11.25	13.95	16.26	17.35	16.93	16.80	13.90	14.18	13.52
North Dakota	9.79	9.88	10.32	5.59	6.79	9.72	11.98	12.03	10.19	6.41	10.67	10.08
Ohio	9.19	9.33	9.63	4.90	6.23	8.78	9.95	10.39	9.67	6.61	10.80	9.82
Oklahoma	9.22	9.40	9.97	7.88	10.08	12.79	14.91	16.28	15.58	13.79	14.17	9.97
Oregon	11.30	11.23	11.55	9.91	10.69	11.46	12.50	13.29	12.33	10.62	11.91	11.42
Pennsylvania	11.72	11.80	12.10	9.10	10.42	12.79	14.33	14.90	14.06	11.11	13.01	12.19
Rhode Island	13.66	13.78	14.07	13.52	14.65	16.13	17.60	18.30	17.99	16.28	15.51	14.49
South Carolina	10.27	10.60	11.25	8.75	11.24	12.78	13.63	13.52	13.31	10.66	11.75	11.04
South Dakota	8.83	9.00	9.59	6.98	7.57	9.54	11.28	11.72	10.99	8.01	9.61	8.85
Tennessee	9.78	9.73	10.04	6.65	7.97	9.59	10.57	11.08	10.43	9.22	11.78	10.33
Texas	10.14	10.10	11.02	7.62	9.15	10.34	11.12	11.89	11.57	10.37	14.00	11.56
Utah	10.30	10.51	10.59	8.58	8.41	9.27	10.17	10.63	10.39	9.38	10.64	10.79
Vermont	12.31	12.07	12.34	9.45	10.44	12.57	14.42	15.21	14.67	12.38	14.07	13.07
Virginia	11.89	11.98	12.16	9.40	11.39	13.49	14.81	14.87	14.47	11.84	13.54	12.72
Washington	11.72	11.76	11.91	9.79	10.64	11.65	12.67	13.12	12.13	10.35	12.30	12.00
West Virginia	10.40	10.48	10.62	8.34	9.82	12.36	13.65	13.87	12.31	9.42	11.20	10.83
Wisconsin	11.34	11.36	11.89	7.65	8.60	10.58	11.36	11.67	10.60	7.60	11.96	11.64
Wyoming	9.67	9.80	10.02	8.32	8.98	10.96	14.48	15.43	14.03	10.56	10.93	10.18
United States	11.95	12.02	12.48	8.79	10.10	11.84	12.88	13.23	12.60	10.23	13.27	12.53

Table 8E.6.8 Commercial Marginal Monthly Natural Gas Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	12.52	12.50	12.62	12.91	13.05	13.24	13.29	13.39	13.62	13.58	13.55	13.03
Alaska	10.63	10.61	10.38	9.14	9.08	9.36	9.44	9.50	9.40	9.56	10.68	10.85
Arizona	10.00	10.16	10.33	10.71	10.95	10.90	10.97	10.99	11.01	10.98	10.42	10.19
Arkansas	12.11	11.97	12.17	9.09	9.59	10.02	10.11	10.15	9.83	9.42	13.11	12.67
California	23.76	22.97	22.65	16.95	16.52	17.10	17.46	17.40	17.01	16.95	22.62	24.32
Colorado	9.94	9.90	10.07	8.26	8.88	9.64	10.40	10.35	10.09	8.97	10.68	10.28
Connecticut	11.25	11.30	11.39	10.26	10.84	11.54	11.35	11.33	11.25	11.09	11.84	11.39
Delaware	10.40	10.66	11.08	10.20	10.86	11.44	11.94	12.06	11.81	11.32	11.33	10.83
District of Columbia	14.59	14.76	14.92	14.84	14.76	15.01	15.24	14.87	14.67	14.47	15.44	14.81
Florida	13.16	13.18	13.17	12.92	12.94	13.02	13.11	12.99	13.05	12.93	13.12	13.22
Georgia	9.82	9.93	10.23	9.69	10.29	10.73	10.89	10.92	10.78	10.24	10.62	9.77
Hawaii	60.59	63.26	65.33	71.66	73.41	75.03	75.07	74.00	73.98	74.72	65.96	64.23
Idaho	6.60	6.59	6.70	6.51	6.57	6.60	6.72	6.72	6.68	6.50	6.78	6.72
Illinois	10.80	10.82	11.46	4.93	5.98	6.87	7.38	7.48	6.84	5.28	11.87	11.24
Indiana	7.43	7.47	8.27	5.94	6.47	7.09	7.15	7.01	6.12	5.01	7.30	7.32
Iowa	10.95	11.16	11.84	7.25	7.99	8.73	9.03	9.07	8.73	7.09	11.38	11.34
Kansas	10.66	10.87	11.34	8.77	9.80	10.75	11.27	11.28	11.29	9.51	11.55	10.94
Kentucky	10.91	10.84	11.25	7.98	9.03	9.78	9.93	10.12	9.80	8.68	12.04	11.57
Louisiana	15.28	14.67	14.77	13.81	14.13	14.34	14.48	14.21	14.05	14.41	15.22	15.55
Maine	22.42	22.81	22.27	17.87	16.61	16.19	17.14	17.51	16.81	15.59	20.72	22.17
Maryland	12.54	12.61	12.65	11.30	12.00	12.40	12.48	12.50	12.49	11.93	13.15	13.17
Massachusetts	18.15	18.23	18.32	19.05	18.02	16.51	17.02	17.05	17.09	15.91	17.26	18.68
Michigan	9.32	9.38	9.57	7.46	8.07	8.81	9.14	9.20	8.90	7.94	9.87	9.69
Minnesota	12.76	12.70	12.86	9.44	9.93	10.70	10.85	10.69	10.35	9.29	12.62	12.71
Mississippi	12.38	12.28	12.55	13.50	13.32	12.90	12.93	12.72	12.86	13.78	12.72	12.49
Missouri	9.05	8.92	9.11	7.60	8.03	8.93	9.50	9.57	9.20	8.79	10.41	9.62
Montana	9.48	9.61	9.68	7.58	7.99	8.83	9.43	9.58	9.29	8.08	9.99	9.73
Nebraska	12.78	12.74	12.72	9.63	9.31	9.71	10.30	10.37	10.37	9.79	12.61	13.14
Nevada	7.21	7.28	7.35	8.46	8.66	8.74	9.03	9.20	9.06	8.88	7.68	7.40
New Hampshire	17.70	17.51	17.68	13.53	13.65	13.88	15.70	16.09	15.87	14.11	18.40	18.88
New Jersey	13.93	13.70	13.86	9.77	10.30	10.93	11.18	10.80	10.41	10.73	14.45	14.32
New Mexico	11.13	11.06	11.00	11.14	11.65	12.50	13.27	13.43	13.22	13.19	12.43	11.73
New York	13.14	13.10	13.18	12.78	12.47	12.15	11.62	11.32	11.60	12.23	12.60	13.24
North Carolina	9.78	9.67	9.70	10.92	11.26	11.68	11.87	11.41	11.42	11.32	10.65	10.75
North Dakota	11.11	11.13	11.20	7.39	7.99	8.95	9.45	9.36	8.81	7.51	11.35	11.33
Ohio	8.15	8.14	8.11	6.32	6.83	7.34	7.47	7.52	7.32	6.77	8.39	8.35
Oklahoma	7.02	7.08	7.38	5.78	6.85	8.02	8.73	9.29	8.88	8.40	9.96	7.50
Oregon	9.84	9.75	9.93	8.98	9.12	9.34	9.49	9.76	9.50	9.19	10.18	10.11
Pennsylvania	11.34	11.52	11.79	9.22	10.02	10.59	10.86	10.70	10.40	9.50	11.62	11.66
Rhode Island	11.67	11.83	12.01	11.21	12.07	13.63	14.72	15.16	14.83	13.64	13.19	12.51
South Carolina	11.92	11.22	11.51	12.76	12.39	12.82	13.02	12.68	12.73	12.83	12.21	12.70
South Dakota	9.34	9.43	9.83	6.81	7.05	7.79	8.30	8.42	7.94	6.86	9.37	9.35
Tennessee	10.82	10.68	10.65	9.75	10.06	10.53	10.92	11.15	10.84	10.90	11.66	11.33
Texas	10.77	10.85	10.87	8.73	9.11	9.46	9.62	9.71	9.78	9.70	12.05	11.59
Utah	9.54	9.66	9.68	8.42	7.93	8.26	8.77	9.03	8.91	8.59	9.51	10.00
Vermont	11.47	11.58	11.28	10.01	9.92	9.52	9.52	9.57	9.81	9.55	11.08	11.57
Virginia	11.07	11.06	10.77	8.96	9.35	9.85	9.82	9.76	9.83	9.28	11.13	11.41
Washington	10.67	10.69	10.66	8.66	8.90	9.20	9.53	9.66	9.36	8.90	11.00	10.95
West Virginia	8.53	8.57	8.67	6.04	6.59	7.18	7.26	7.32	7.02	6.41	8.93	8.85
Wisconsin	11.87	11.90	12.07	8.96	8.79	9.44	9.41	9.36	9.19	8.00	11.91	12.11
Wyoming	11.06	11.03	11.12	9.93	10.06	10.70	11.62	11.81	11.68	11.08	11.82	11.51
United States	11.39	11.40	11.60	9.27	9.57	9.94	10.09	10.04	9.93	9.48	11.75	11.74

Table 8E.6.9 Residential Monthly LPG Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	32.81	32.92	32.42	31.79	31.29	30.70	30.00	29.43	30.17	31.42	32.40	33.45
Alaska	40.19	40.26	39.57	38.67	37.74	36.66	35.34	34.89	36.27	38.44	39.68	41.22
Arizona	36.92	36.98	36.35	35.52	34.67	33.67	32.46	32.05	33.32	35.31	36.45	37.87
Arkansas	31.97	32.07	31.58	30.97	30.48	29.91	29.23	28.67	29.39	30.61	31.56	32.58
California	37.62	37.69	37.05	36.20	35.33	34.32	33.08	32.67	33.96	35.99	37.15	38.59
Colorado	28.54	28.59	28.10	27.46	26.80	26.03	25.09	24.78	25.76	27.30	28.18	29.27
Connecticut	37.96	38.35	38.56	38.58	39.18	39.56	39.69	39.45	39.42	39.59	39.20	39.17
Delaware	30.25	30.35	29.89	29.31	28.85	28.31	27.66	27.14	27.81	28.97	29.87	30.84
District of Columbia	34.81	34.92	34.39	33.72	33.19	32.57	31.82	31.22	32.00	33.33	34.36	35.48
Florida	41.89	42.02	41.38	40.58	39.94	39.19	38.29	37.57	38.51	40.11	41.35	42.69
Georgia	31.50	31.60	31.12	30.52	30.04	29.47	28.80	28.25	28.96	30.16	31.10	32.11
Hawaii	60.90	61.01	59.97	58.60	57.19	55.55	53.55	52.88	54.97	58.26	60.13	62.47
Idaho	31.26	31.32	30.78	30.08	29.36	28.52	27.49	27.15	28.22	29.90	30.87	32.07
Illinois	26.13	26.13	25.81	25.41	25.09	24.21	23.49	23.42	23.97	24.68	25.80	26.94
Indiana	30.01	30.00	29.64	29.18	28.82	27.81	26.98	26.90	27.52	28.34	29.62	30.94
Iowa	23.45	23.44	23.15	22.79	22.51	21.72	21.07	21.01	21.50	22.14	23.14	24.17
Kansas	25.85	25.84	25.53	25.13	24.82	23.95	23.23	23.17	23.70	24.41	25.52	26.65
Kentucky	32.32	32.42	31.93	31.31	30.82	30.24	29.55	28.99	29.71	30.95	31.91	32.94
Louisiana	37.58	37.70	37.13	36.41	35.84	35.16	34.36	33.71	34.55	35.99	37.10	38.31
Maine	32.10	32.42	32.60	32.62	33.12	33.45	33.56	33.35	33.33	33.48	33.14	33.12
Maryland	34.71	34.82	34.30	33.63	33.10	32.48	31.74	31.14	31.91	33.24	34.27	35.38
Massachusetts	38.88	39.28	39.49	39.52	40.12	40.52	40.65	40.40	40.37	40.55	40.14	40.12
Michigan	28.11	28.10	27.76	27.33	26.99	26.04	25.27	25.19	25.78	26.54	27.75	28.98
Minnesota	27.28	27.27	26.94	26.53	26.20	25.28	24.52	24.45	25.02	25.76	26.93	28.12
Mississippi	35.34	35.45	34.92	34.24	33.70	33.07	32.31	31.70	32.49	33.84	34.89	36.02
Missouri	27.68	27.67	27.33	26.91	26.57	25.64	24.88	24.80	25.38	26.13	27.32	28.53
Montana	26.31	26.36	25.91	25.32	24.71	24.00	23.14	22.85	23.75	25.17	25.98	26.99
Nebraska	24.43	24.42	24.12	23.75	23.45	22.63	21.96	21.89	22.40	23.06	24.11	25.18
Nevada	37.20	37.27	36.63	35.80	34.94	33.94	32.71	32.30	33.58	35.59	36.73	38.16
New Hampshire	31.48	31.80	31.97	31.99	32.48	32.80	32.91	32.70	32.68	32.83	32.50	32.47
New Jersey	39.57	39.97	40.19	40.21	40.83	41.24	41.37	41.11	41.08	41.27	40.85	40.82
New Mexico	32.31	32.37	31.81	31.09	30.34	29.47	28.41	28.05	29.16	30.91	31.90	33.14
New York	35.67	36.03	36.23	36.25	36.81	37.17	37.29	37.06	37.04	37.20	36.83	36.80
North Carolina	34.58	34.69	34.17	33.50	32.98	32.36	31.61	31.02	31.79	33.11	34.14	35.25
North Dakota	23.56	23.55	23.26	22.90	22.62	21.83	21.17	21.11	21.60	22.24	23.25	24.28
Ohio	33.62	33.60	33.20	32.68	32.28	31.15	30.22	30.13	30.83	31.74	33.18	34.65
Oklahoma	27.57	27.66	27.24	26.71	26.29	25.80	25.21	24.73	25.35	26.40	27.22	28.10
Oregon	35.00	35.06	34.46	33.68	32.87	31.92	30.77	30.39	31.59	33.48	34.55	35.90
Pennsylvania	30.92	31.23	31.40	31.42	31.90	32.22	32.32	32.12	32.10	32.24	31.92	31.90
Rhode Island	36.46	36.83	37.03	37.06	37.63	38.00	38.12	37.89	37.86	38.03	37.65	37.62
South Carolina	35.82	35.93	35.39	34.70	34.16	33.51	32.74	32.13	32.93	34.30	35.36	36.51
South Dakota	26.20	26.20	25.88	25.48	25.16	24.28	23.55	23.48	24.03	24.74	25.87	27.01
Tennessee	32.96	33.06	32.56	31.93	31.43	30.84	30.13	29.56	30.30	31.56	32.54	33.59
Texas	35.28	35.39	34.86	34.19	33.65	33.01	32.26	31.65	32.44	33.79	34.83	35.96
Utah	29.94	30.00	29.48	28.81	28.12	27.31	26.33	26.00	27.03	28.64	29.56	30.71
Vermont	31.07	31.39	31.56	31.58	32.06	32.38	32.49	32.28	32.26	32.40	32.08	32.06
Virginia	34.66	34.77	34.25	33.58	33.05	32.43	31.69	31.09	31.87	33.19	34.22	35.33
Washington	32.05	32.11	31.56	30.84	30.10	29.24	28.18	27.83	28.93	30.66	31.64	32.88
West Virginia	35.28	35.39	34.86	34.18	33.64	33.01	32.26	31.65	32.44	33.78	34.83	35.96
Wisconsin	26.46	26.45	26.13	25.72	25.40	24.51	23.78	23.71	24.26	24.98	26.11	27.27
Wyoming	29.13	29.19	28.69	28.03	27.36	26.58	25.62	25.30	26.29	27.87	28.76	29.88
United States	31.03	31.23	31.02	30.81	30.83	30.20	28.85	28.19	29.05	29.99	30.96	31.89

Table 8E.6.10 Commercial Monthly LPG Prices for 2022, 2023$/MMBtu

State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Alabama	30.10	30.20	29.74	29.17	28.71	28.17	27.52	27.00	27.68	28.83	29.72	30.68
Alaska	31.00	31.06	30.53	29.83	29.11	28.28	27.26	26.92	27.98	29.66	30.61	31.80
Arizona	33.01	33.07	32.50	31.76	31.00	30.11	29.03	28.66	29.79	31.58	32.59	33.86
Arkansas	29.91	30.00	29.55	28.98	28.52	27.98	27.34	26.83	27.50	28.64	29.53	30.49
California	33.25	33.31	32.74	31.99	31.23	30.33	29.24	28.87	30.01	31.81	32.83	34.11
Colorado	28.87	28.93	28.43	27.78	27.11	26.34	25.39	25.07	26.06	27.62	28.51	29.62
Connecticut	29.29	29.59	29.75	29.76	30.22	30.52	30.62	30.43	30.41	30.54	30.24	30.22
Delaware	29.83	29.92	29.47	28.90	28.44	27.91	27.27	26.76	27.42	28.56	29.45	30.40
District of Columbia	31.62	31.71	31.24	30.63	30.15	29.58	28.90	28.36	29.07	30.27	31.21	32.22
Florida	31.60	31.70	31.22	30.62	30.13	29.57	28.89	28.35	29.05	30.26	31.20	32.21
Georgia	31.00	31.09	30.62	30.03	29.56	29.00	28.34	27.80	28.50	29.68	30.60	31.59
Hawaii	32.24	32.30	31.74	31.02	30.28	29.41	28.35	27.99	29.10	30.84	31.83	33.07
Idaho	29.74	29.79	29.28	28.62	27.93	27.13	26.15	25.82	26.84	28.45	29.36	30.51
Illinois	27.97	27.96	27.62	27.20	26.86	25.92	25.14	25.07	25.65	26.41	27.61	28.84
Indiana	28.17	28.16	27.82	27.39	27.05	26.10	25.32	25.25	25.83	26.60	27.81	29.04
Iowa	26.77	26.77	26.44	26.03	25.71	24.81	24.07	24.00	24.55	25.28	26.43	27.60
Kansas	26.89	26.88	26.56	26.15	25.82	24.92	24.17	24.10	24.66	25.39	26.55	27.72
Kentucky	28.93	29.02	28.59	28.03	27.59	27.07	26.45	25.95	26.60	27.70	28.56	29.49
Louisiana	29.34	29.43	28.99	28.43	27.98	27.45	26.82	26.32	26.97	28.09	28.97	29.91
Maine	29.05	29.35	29.51	29.52	29.98	30.27	30.37	30.19	30.16	30.30	29.99	29.97
Maryland	31.62	31.71	31.24	30.63	30.15	29.58	28.90	28.36	29.07	30.27	31.21	32.22
Massachusetts	29.26	29.56	29.72	29.73	30.19	30.49	30.59	30.40	30.38	30.51	30.21	30.19
Michigan	27.91	27.90	27.56	27.14	26.80	25.86	25.09	25.01	25.60	26.35	27.55	28.77
Minnesota	26.99	26.99	26.66	26.25	25.92	25.01	24.26	24.19	24.75	25.49	26.65	27.83
Mississippi	30.98	31.07	30.60	30.01	29.54	28.98	28.32	27.78	28.48	29.66	30.58	31.57
Missouri	26.32	26.31	25.99	25.59	25.27	24.39	23.66	23.59	24.14	24.85	25.98	27.13
Montana	28.07	28.12	27.64	27.01	26.36	25.60	24.68	24.37	25.33	26.85	27.71	28.79
Nebraska	26.64	26.63	26.31	25.90	25.58	24.69	23.95	23.88	24.43	25.16	26.30	27.46
Nevada	33.39	33.45	32.88	32.13	31.36	30.46	29.36	28.99	30.14	31.94	32.97	34.25
New Hampshire	27.55	27.83	27.98	28.00	28.43	28.71	28.80	28.62	28.60	28.73	28.44	28.42
New Jersey	30.88	31.20	31.36	31.38	31.87	32.18	32.29	32.09	32.06	32.21	31.88	31.86
New Mexico	29.22	29.28	28.77	28.12	27.44	26.66	25.70	25.37	26.38	27.95	28.85	29.98
New York	30.12	30.42	30.59	30.61	31.08	31.38	31.49	31.29	31.27	31.41	31.09	31.07
North Carolina	31.22	31.32	30.85	30.25	29.77	29.21	28.54	28.01	28.70	29.90	30.82	31.82
North Dakota	26.53	26.52	26.20	25.79	25.47	24.58	23.84	23.77	24.32	25.04	26.18	27.34
Ohio	27.83	27.83	27.49	27.06	26.73	25.79	25.02	24.95	25.53	26.28	27.48	28.69
Oklahoma	27.68	27.77	27.35	26.82	26.40	25.90	25.31	24.83	25.45	26.50	27.33	28.21
Oregon	31.00	31.06	30.53	29.83	29.11	28.28	27.26	26.92	27.98	29.66	30.61	31.80
Pennsylvania	30.69	31.00	31.17	31.19	31.67	31.98	32.09	31.89	31.86	32.01	31.69	31.66
Rhode Island	29.46	29.76	29.92	29.94	30.40	30.70	30.81	30.61	30.59	30.73	30.42	30.40
South Carolina	31.60	31.70	31.22	30.62	30.13	29.57	28.89	28.35	29.05	30.26	31.20	32.21
South Dakota	26.39	26.38	26.07	25.66	25.34	24.45	23.72	23.65	24.20	24.92	26.05	27.21
Tennessee	29.20	29.29	28.85	28.29	27.85	27.32	26.70	26.19	26.85	27.96	28.83	29.76
Texas	29.85	29.94	29.49	28.92	28.46	27.93	27.29	26.77	27.44	28.58	29.47	30.42
Utah	29.77	29.82	29.31	28.65	27.96	27.16	26.18	25.85	26.87	28.48	29.39	30.54
Vermont	29.20	29.50	29.66	29.67	30.13	30.43	30.53	30.34	30.32	30.45	30.15	30.12
Virginia	31.39	31.49	31.01	30.41	29.93	29.37	28.70	28.16	28.86	30.06	30.99	31.99
Washington	33.01	33.07	32.50	31.76	31.00	30.11	29.03	28.66	29.79	31.57	32.59	33.86
West Virginia	31.60	31.70	31.22	30.62	30.13	29.57	28.89	28.35	29.05	30.26	31.20	32.21
Wisconsin	27.65	27.64	27.31	26.88	26.55	25.62	24.85	24.78	25.36	26.11	27.30	28.50
Wyoming	29.18	29.23	28.73	28.07	27.40	26.61	25.66	25.33	26.33	27.91	28.81	29.93
United States	29.64	29.82	29.63	29.42	29.45	28.85	27.56	26.93	27.74	28.64	29.57	30.46

8E.7 ENERGY PRICE TRENDS

DOE used AEO 2023 Reference Case scenarios for the nine census divisions. DOE applied the projected energy price for each of the nine census divisions to each household or buliding in the sample based on the household's or building's location.

To project prices in future years, DOE multiplied the prices described in the preceding section by the forecast of annual average price changes in EIA's AEO 2023. DOE converted the forecasted energy prices into energy price factors, with 2023 as the base year. Figure 8E.7.1 shows the national residential and commercial price factor trends. Figure 8E.7.2 through Figure 8E.7.7 show the residential and commercial regional energy price factor trends, disaggregated by the nine census divisions.

To project price trends after 2050, DOE used simple extrapolations of the average annual growth rate in prices from 2046 to 2050 based on the methods used in the 2022 Life-Cycle Costing Manual for the Federal Energy Management Program (FEMP).[12]

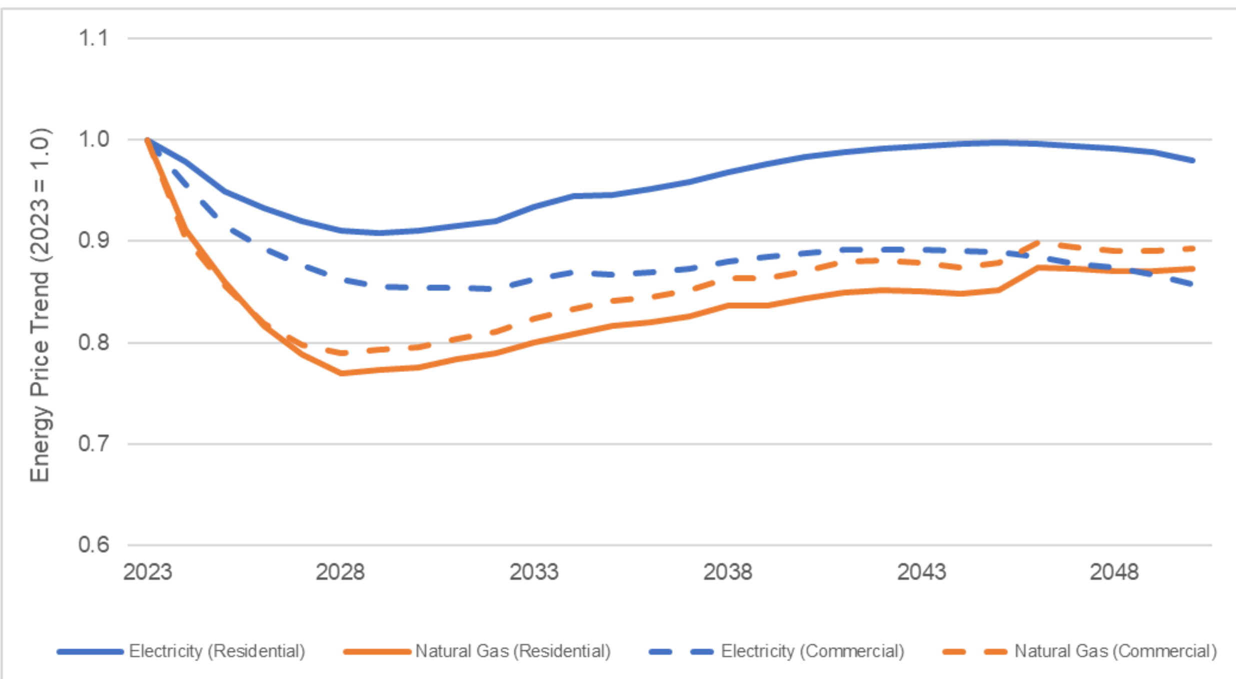

Figure 8E.7.1 Projected National Residential and Commercial Price Factors

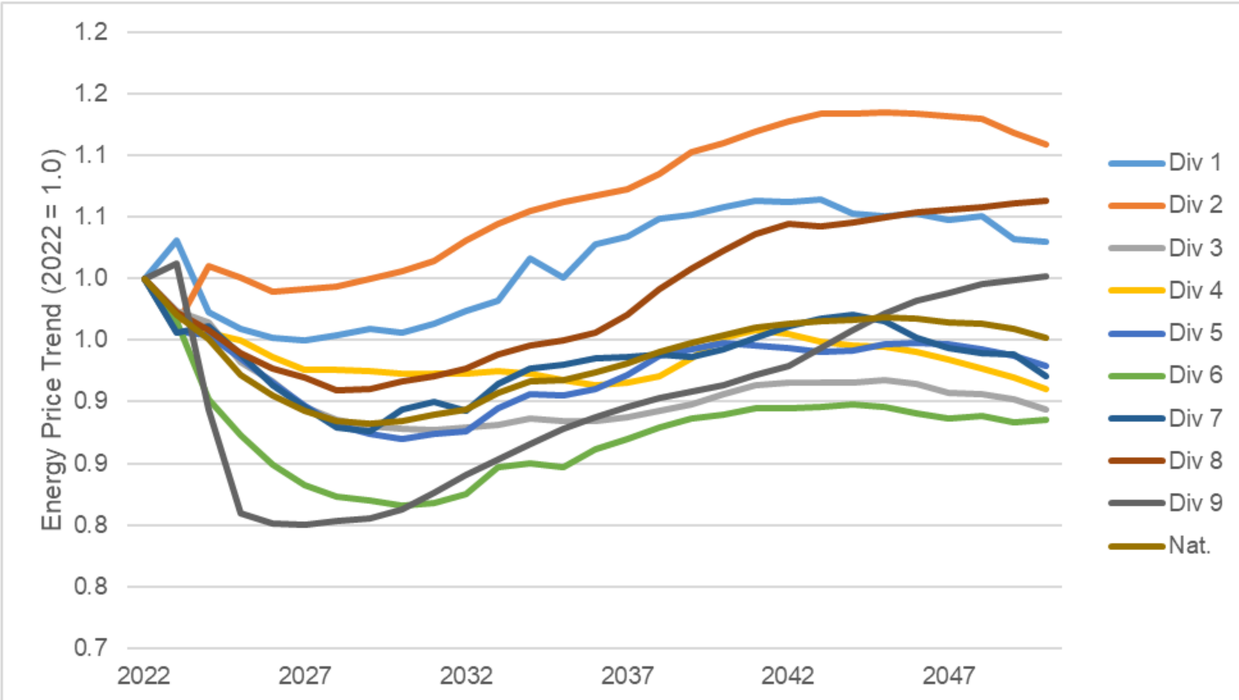

Figure 8E.7.2 Projected Residential Electricity Price Factors by Census Division

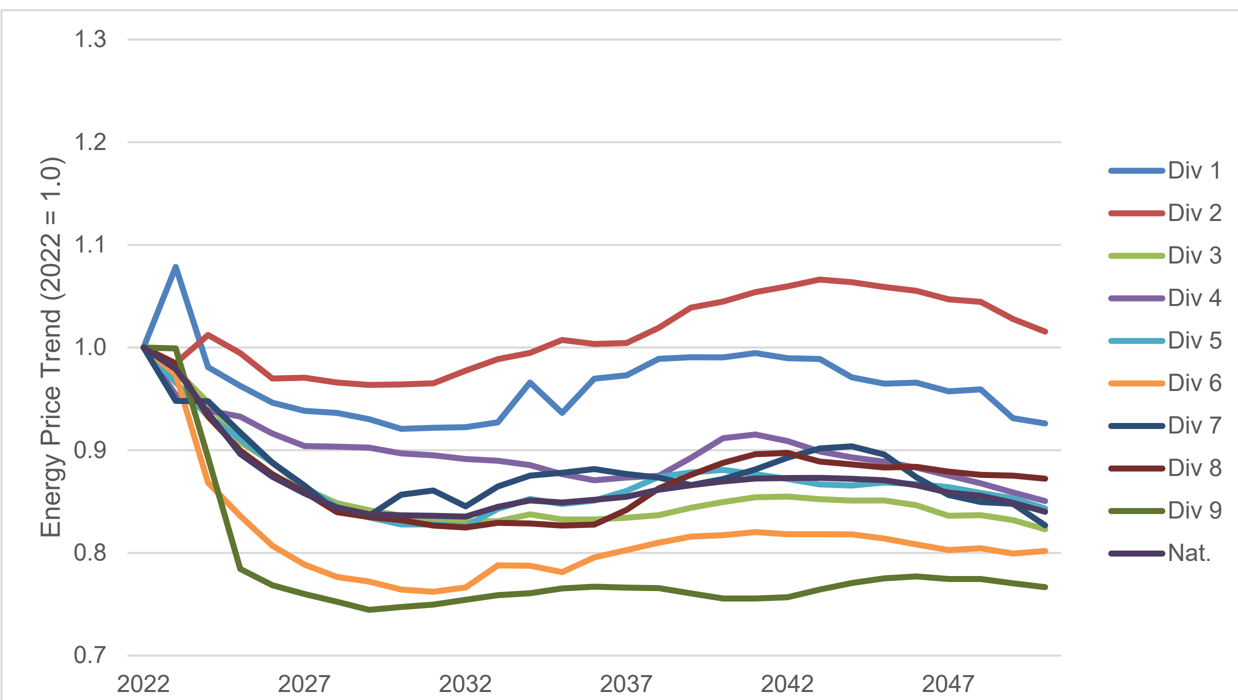

Figure 8E.7.3 Projected Commercial Electricity Price Factors by Census Division

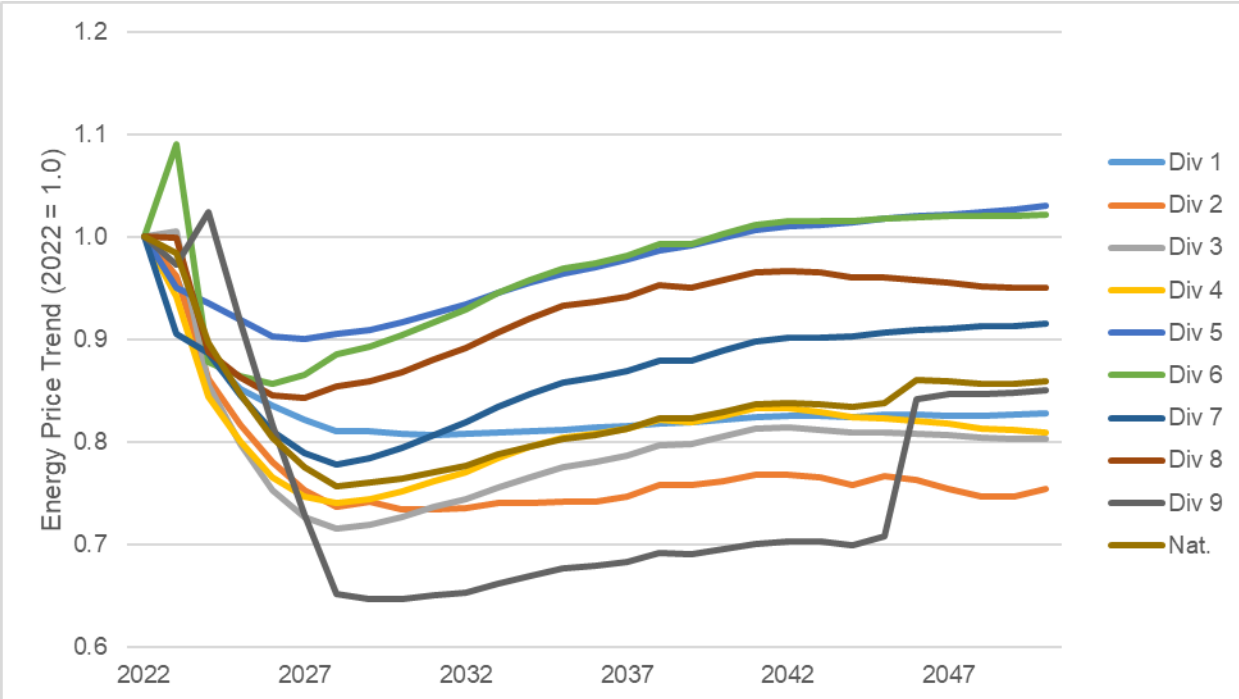

Figure 8E.7.4 Projected Residential Natural Gas Price Factors by Census Division

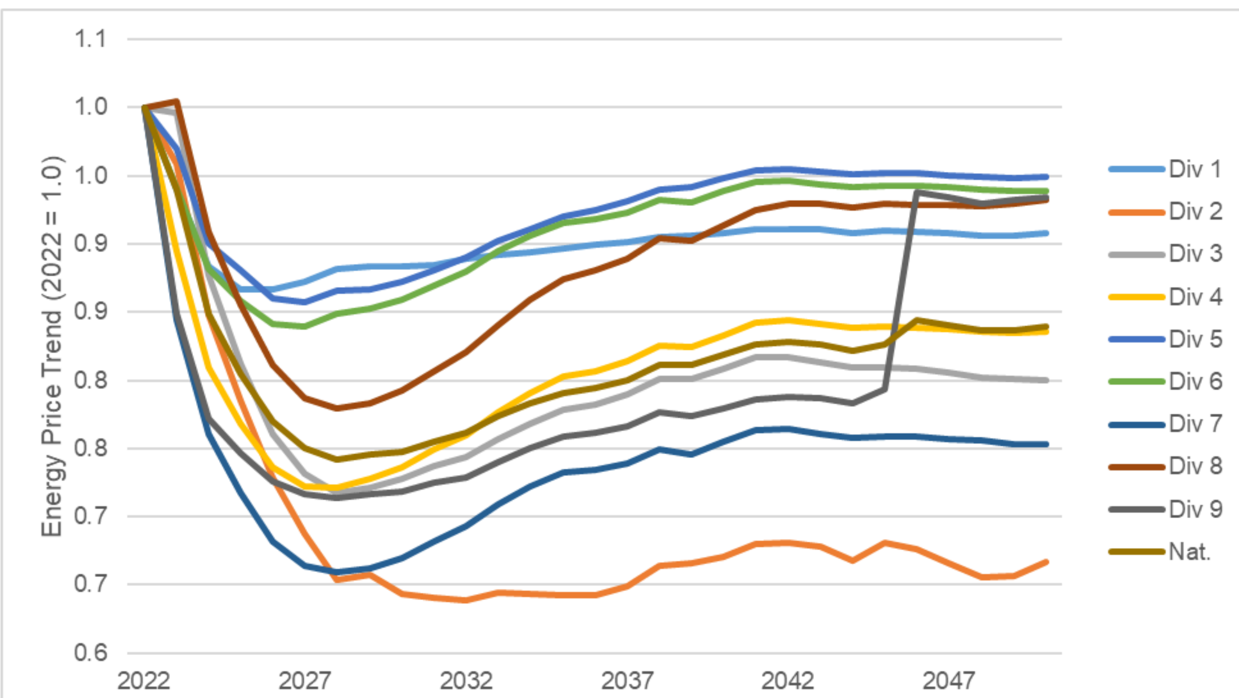

Figure 8E.7.5 Projected Commercial Natural Gas Price Factors by Census Division

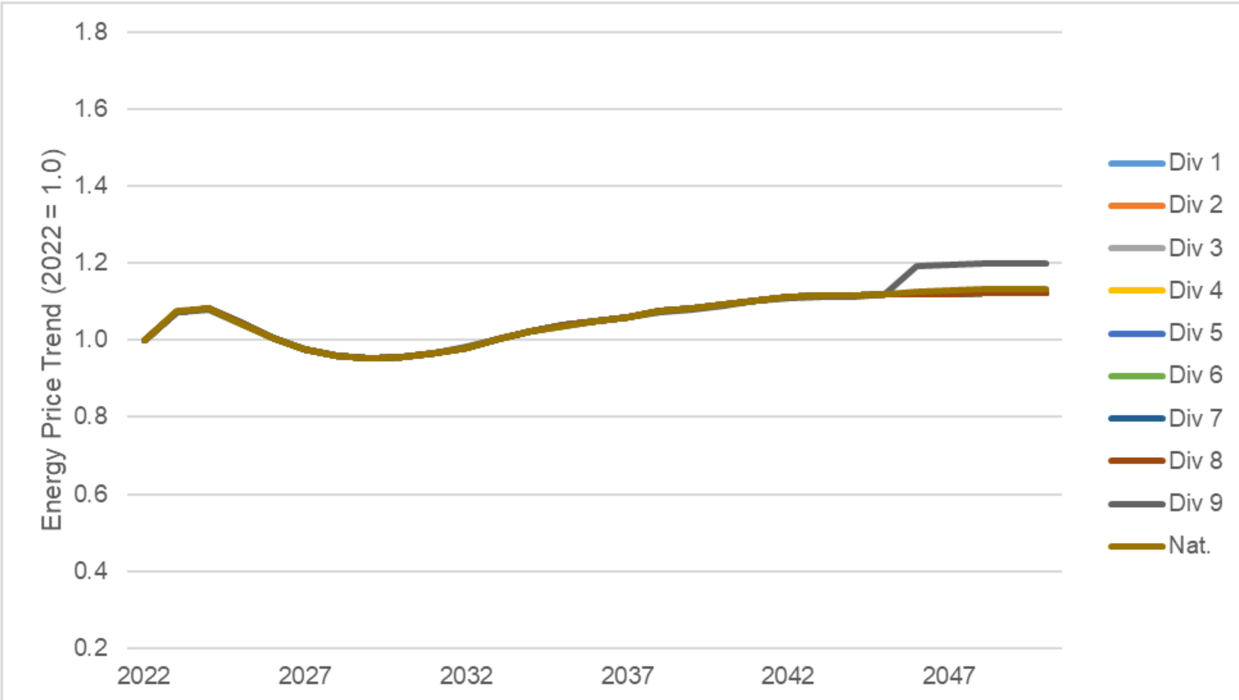

Figure 8E.7.6 Projected Residential LPG Price Factors by Census Division

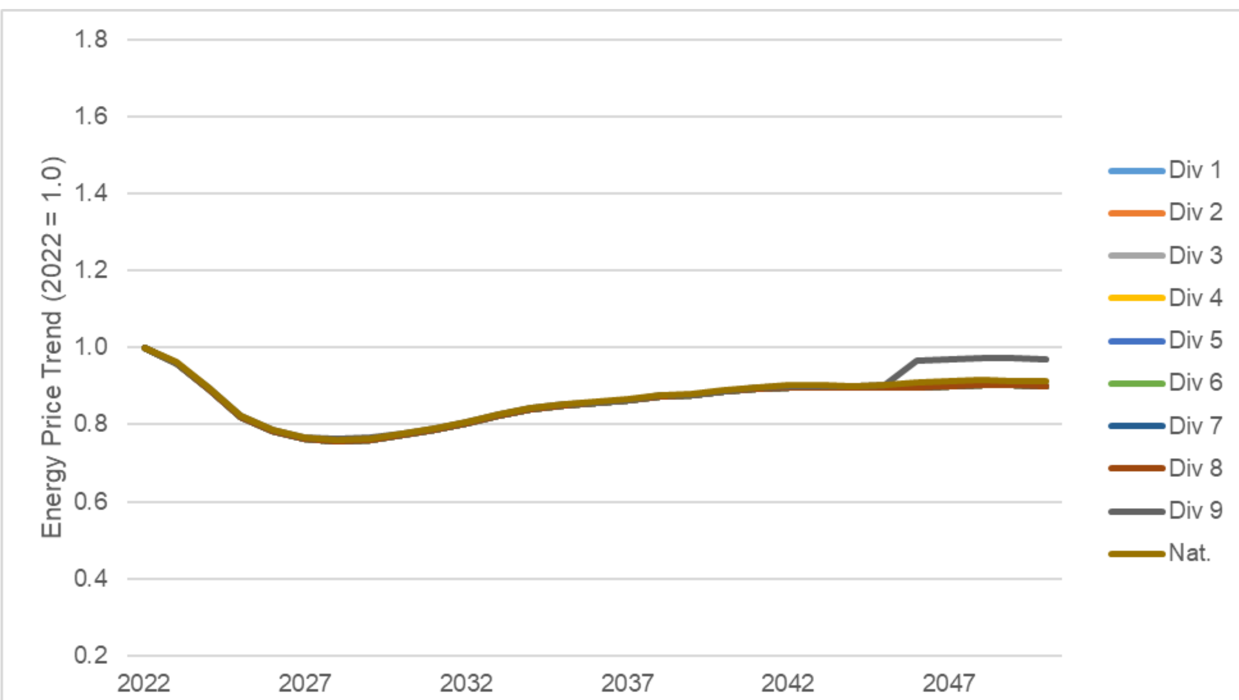

Figure 8E.7.7 Projected Commercial LPG Price Factors by Census Division

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APPENDIX 8F. MAINTENANCE AND REPAIR COST DETERMINATION FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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APPENDIX 8F. MAINTENANCE AND REPAIR COST DETERMINATION FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

8F.1 INTRODUCTION

This appendix provides further details about the derivation of maintenance and repair costs for consumer gas-fired instantaneous water heaters (GIWHs). The maintenance cost is the price of regular scheduled product maintenance. The repair cost is the price to repair the product when it fails. These costs cover all labor and material costs associated with the maintenance or repair of existing products. The calculation of the repair cost involves determining the cost and the service life of the components that are likely to fail and includes the labor and the materials associated with the replacement.

The Department of Energy (DOE) estimated maintenance and repair costs for gas-fired instantaneous water heaters based on RSMeans, a well-known and respected construction cost estimation method, as well as manufacturer literature and consultant report (attached to this appendix). Table 8F.1.1 offers an example of the cost calculation method. All labor costs are derived using the latest residential repair and remodeling 2023 RSMeans labor costs by crew type.[1] Maintenance and repair cost tables include a trip charge, which is often charged by contractors and calculated to be equal to one half hour of labor per crew member. Labor hours (or person-hours) are based on RSMeans data and expert data. Bare costs are all the costs without any markups. Material costs are based on RSMeans data, expert data, or internet sources. The total includes overhead and profit (O&P), which is calculated using labor and material markups from RSMeans. Values reported in this appendix are based on national average labor costs. In its analysis, DOE used weighted average state labor costs to more accurately estimate maintenance costs by state. DOE applied the appropriate labor cost, as described in section 8F.4, to each sample household or building in 2020 Residential Energy Consumption Survey (RECS 2020)[2] and 2018 Commercial Building Energy Consumption Survey (CBECS 2018).[3]

Table 8F.1.1 Example Cost Table

Description	Crew	Labor Hours	Unit	Bare Costs *(2023$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	CREW1	0.5	-	0.00	26.42	26.42	1	41.20
Description of Installation Item	CREW1	0.5	Ea.	15.00	26.42	41.42	1	57.70
Total		1.0		15.00	52.83	57.83		**98.90**

8F.2 MAINTENANCE COST FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

The maintenance cost is the routine annual cost to the consumer of general maintenance for product operation. DOE estimated maintenance costs at each considered efficiency level using a variety of sources, including *2023 RSMeans Facilities Repair and Maintenance Data*,[1] manufacturer literature, and consultant report available in section 8F.5. Note that for the maintenance fractions below, DOE assumed that half are performed by a contractor and the other half of the time it is performed by the homeowner.

The analysis assumes that there is an annual maintenance of gas-fired instantaneous water heaters associated mainly with de-liming the heat exchanger. Manufacturers recommend that these water heaters be delimed annually to minimize deposition of sediment in the heat exchanger, maintain operating efficiency, and prolong product life. DOE assumed that this is done in 50 percent of households[a]. During this service, additional tasks may be performed by the services contractor including inspection of ignition device, gas valve, controls, thermostat, and venting. Table 8F.2.1 shows the cost example for this annual maintenance using the national average labor costs.

Table 8F.2.1 Gas-Fired Instantaneous Water Heater Deliming (Annually)

Description	Crew	Labor Hours	Unit	Bare Costs *(2023$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	Q-1*	0.5	-	0.00	32.43	32.43	1	49.98
Deliming and visual inspection of major components	Q-1*	1.5	Ea.	0.00	97.28	97.28	1	149.93
Total		2.0		0.00	129.71	129.71		**199.91**

* Q-1 means one plumber and one plumber apprentice.

In addition, DOE assumes that an additional 10 percent of customers perform every two to three years deliming plus a more complete inspection/cleaning of the major components (ignition device, gas valve, controls, and venting). Table 8F.2.2 shows the cost example for this maintenance using the national average labor costs.

Table 8F.2.2 Gas-Fired Instantaneous Water Heater Regular Maintenance (Every 2-3 Years)

Description	Crew	Labor Hours	Unit	Bare Costs *(2023$)*			Quantity	Total incl. O&P
				Material	Labor	Total		
Trip Charge	Q-1*	0.5	-	0.00	32.43	32.43	1	49.98
Deliming and visual inspection of major components	Q-1*	2.0	Ea.	0.00	129.70	129.70	1	199.90
Total		2.5		0.00	162.13	162.13		**249.88**

* Q-1 means one plumber and one plumber apprentice.

For condensing instantaneous water heater design options, DOE assumed higher maintenance cost to take into account additional inspection of the condensate withdrawal system and replacement of the condensate neutralizer filter, if applicable.

[a] Often manufacturers offer very easy instructions of how to perform it and contractors install valves for more convenient maintenance.

- For 15 percent of installations, the additional labor hours added to the tables above to perform the maintenance for condensate management is 0.25 hours plus the material cost for a neutralizer refill (if a neutralizer is used). According to the market research, cost for neutralizer refill is on average $41.17.
- For an additional 10 percent of customers that do not perform the regular maintenance of deliming and checkup of major components, DOE assumes that there would require a standalone maintenance trip mainly associated with the condensate withdrawal system as shown in Table 8F.2.3.

Table 8F.2.3 Gas-Fired Instantaneous Water Heater Condensate Withdrawal Maintenance (Every 2-5 Years)

Description	Crew	Labor Hours	Unit	Bare Costs *(2023$)*			Quantity	Total incl. O&P
				Material**	Labor	Total		
Trip Charge	Q-1*	0.5	-	0.00	32.43	32.43	1	49.98
Condensate withdrawal maintenance and visual inspection of major components	Q-1*	1.0	Ea.	41.17***	64.85	106.02	1	145.24
Total		1.5		0.00	97.28	138.45		**195.22**

* Q-1 means one plumber and one plumber apprentice.
** Example cost table assumes a national average material markup of 10 percent on top of the bare cost.
*** Example cost table assumes the use of neutralizer and therefore the need of a neutralizer refill.

8F.3 REPAIR COST FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

The repair cost is the cost to the consumer for replacing or repairing components in the water heater that have failed. DOE estimated repair costs at each considered efficiency level using a variety of sources, including *2023 RSMeans Facilities Repair and Maintenance Data*,[1] manufacturer literature, and consultant report. DOE accounts for regional differences in labor costs, as discussed in appendix 8D. DOE considered components most likely to be repaired include the ignition system, gas valve, combustion blower, controls, vent system components, and heat exchangers.

The determination of the repair cost also involves determining the service life of the components that are likely to fail and comparing it to the lifetime of the product. Figure 8F.3.1 shows the methodology for determining repair costs for an individual sampled household. Both component and equipment lifetimes are given by Weibull distributions. During the lifetime of the equipment only a fraction of the sampled households will see a repair cost.

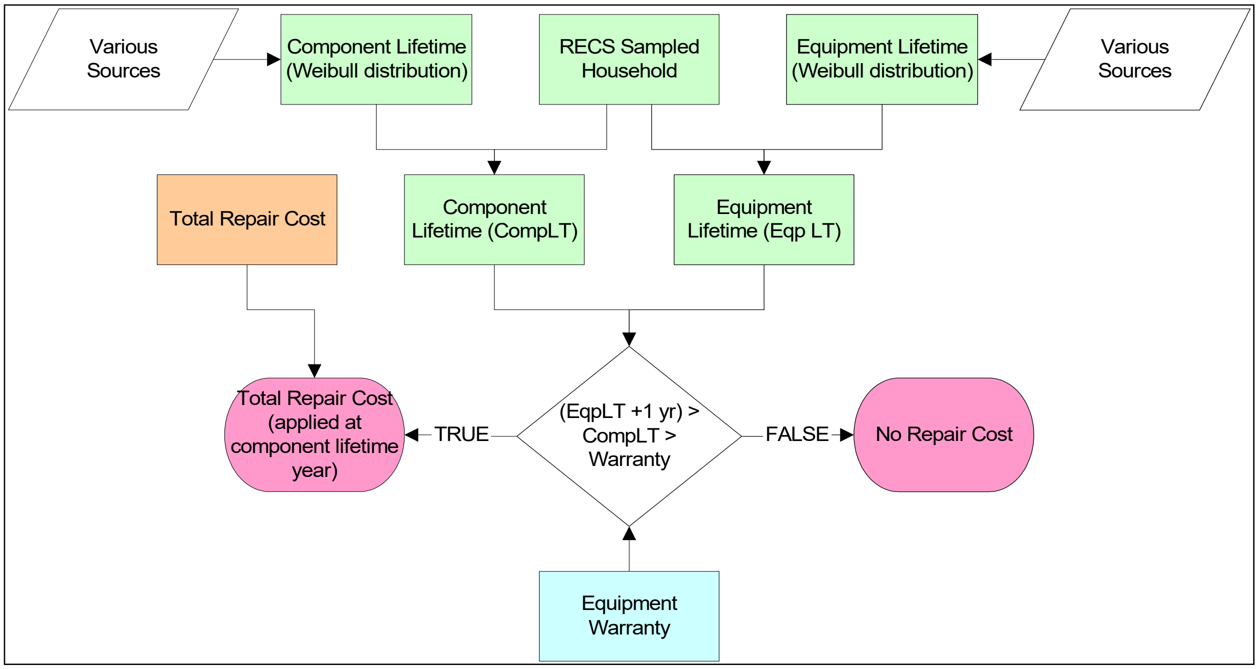

Figure 8F.3.1 Methodology for Calculating Repair Costs

To simplify the analysis, DOE grouped different individual components into component groups that either share a similar lifetime, rate of repair, or part of an assembly. For example, main burner assembly includes whole assembly replacement as well as individual gas valve or ignition device failures. Table 8F.3.1 shows the repair component groups, their average lifetime, and the cost assumptions that DOE used in its analysis. The failure year distribution was assumed to be a Weibull function for each component group.

Gas-fired instantaneous water heater lifetime and component lifetime are not independent variables. Often once the component fails the equipment is not repaired and it represents the end of the product life. Therefore, a correlation variable must be applied in order to account for this. DOE notes that this factor does not simply represent the probability of the failure of the component. The correlation factor is presented as the fraction of total failures calculated by simply using the component lifetime and equipment lifetime which are actual failures. For the repair groups for GIWHs, the correlation factor is estimated to be 12.5 percent.

Additionally, for condensing GIWHs, given the complexity in the technology and control relative to the non-condensing models, DOE applied a cost factor of 1.15 to the repair cost to account for the increase of labor and material possibly needed.

Table 8F.3.1 Summary Repair Component Average Lifetime, Component Cost Range and Labor Hour Range

Product Class	Water Heater Component Failure	Average Lifetime (years)	Material Cost (2023$)*	Labor Hours (hours)**
GIWHs	Main burner assembly (electronic ignition): igniter assembly, sensor, wiring, gas valve and thermostat.	12	$208.26	2.8
	Blower assembly	15	$312.39	3

* Does not include sales tax or markups by trade from RSMeans.
** Includes trip charge.

8F.4 REGIONAL MATERIAL AND LABOR COSTS

DOE used regional material and labor costs to more accurately estimate installation, maintenance, and repair costs by region. RSMeans provides average national labor costs for different trade groups. DOE used the residential repair and remodeling labor cost from RSMeans crew type Q1 (1 Plumber, 1 Plumber Apprentice) for all repair and maintenance labor cost calculations, as shown in Table 8F.4.1.[1] Bare costs are given in RSMeans, while labor costs including overhead and profit (O&P) are the bare costs multiplied by the RSMeans markups by trade shown in Table 8F.4.2.

Table 8F.4.1 RSMeans 2023 National Average Labor Costs by Crew

Crew Type	Crew Description	Laborers per Crew	Cost per Labor-Hour	
			Bare Costs	Incl. O&P*
2023 RS Means Labor Costs Data (Residential, Repair/Remodeling, 2023$)				
Q1	1 Plumber, 1 Plumber Apprentice	2	$64.85	$99.95

* O&P includes markups in Table 8F.4.2.

Table 8F.4.2 RSMeans Labor Cost Markups by Trade

Trade	Workers Comp.	Aver Fixed Overhead	Overhead	Profit	Total
Plumber (Repair/Remodel)	4.6%	18.5%	16.0%	15.0%	54.1%

RSMeans also provides material and labor cost factors for 295 cities and towns in the U.S. To derive average labor cost values by state, DOE weighted the price factors by city or town population size using 2021 census data. The location adjustment factors from RSMeans can be found in appendix 8D.

8F.5 CONSULTANT REPORT (CDS CONSULTING)

The following is the consumer water heaters maintenance and repair report prepared by CDS Consulting,[b] for Lawrence Berkeley National Laboratory (LBNL) on October 19, 2021.

8F.5.1 Introduction

This report is developed based on a request from LBNL to provide water heater maintenance and repair cost examples for different water heater types and technologies, as well as information about maintenance and repair practices and issues based on my 40+ year experience in the water heater industry and recent research. The main sections separately address maintenance, repair, and warranty/service contracts. The maintenance and repair sections include a description of typical maintenance/repair activities and items as well as example cost tables.

The maintenance and repair costs are developed using the following common assumptions:

- Many of the material costs are derived from available information of retail water heaters and related installation parts suppliers such as Home Depot and Lowe's. Contractors actively involved in maintaining and repairing water heaters were also contacted to derive typical labor hours or material costs. Data was also used from HomeAdvisor.com and RS Means.

- For all the cost tables below a national average labor cost of $60 per hour is assumed. Note that mobile home maintenance and repair costs are typically closer to plumber rates than mobile home specific rates for replacement or new installation of mobile home water heaters. There are significant regional labor cost differences that need to be taken into account when considering regional costs for maintaining and repairing water heaters.

- All cost values are rounded to the nearest whole dollars.

- Most recent building codes and safety requirements are taken into account.

Important to note that manufacturers do not get a lot of water heaters returned for inspection of failure, but all manufacturers have an audit program especially for certain problem areas.

[b] Drew Smith is founder of CDS Consulting and has more than 40 years of experience in the consumer water heater industry (including sixteen years in sales and marketing and nineteen years in engineering design and development). He was previously Director of Residential Engineering and Product Safety, Certification and Standards at A.O. Smith until 2007 and previously Vice President of Product Development and Research at State Industries until 2001.

8F.5.2 Maintenance Costs

8F.5.2.1 Typical Maintenance Steps, Cost Items, and Frequency

Typically, homeowners are not accustomed to doing maintenance on residential tank type water heaters (with exception of Oil WHs - cleaning burner, heat pumps, and tankless WHs - deliming). New technologies for water heaters using electronic controls, external power, fans, dampers and refrigeration systems to heat water have created more complex operating systems to maintain and service. With this said, manufacturers are motivated to explain in detail through their installation and operation instructions, training and website information, how to maintain and service their products. There are also regional issues and differences that need to be taken into account with water quality, air quality, unique codes or customs, earthquake awareness, flooding and other conditions that affect the operation and life of water heaters that must be considered when maintaining or servicing water heaters.

In Table 8F.5.1, typical costs for maintenance items are summarized. Depending on the type of maintenance contracts, Oil-fired (and LPG) storage water heaters are usually very commonly serviced. The supply companies are more likely to do maintenance and to do it in coordination with Oil/LPG filling up. For gas and electric storage water heaters, maintenance is more rarely done. It is important to note that the total labor hours should not be summed using the individual items labor hours in Table 8F.5.1 (in cases when the maintenance is performed as part of a maintenance contract or during an occasional checkup of the water heater). In such cases, the total labor hours could be much less because some of the preparatory (and other) activities need to be done only once.

Table 8F.5.1 Typical Maintenance Items

No.	Typical Maintenance Items	Corresponding Product Classes	Total Cost		Recommended Frequency (yrs)	Fraction of Homes doing Maint.
			Labor (hr)	Matl. ($)		
-	Trip Charge	All Types	$50		1	10%
1	Visual inspection	All Types	0.5	0	1	10%
2	Drain 5 gal. water or flush the tank	Storage WH only	1.5	0	1	10%
3	Check the anode rod	Storage WH only	0.75	0 (not replace)	2	≤5%
4	Clean/inspect burner, combustion chamber, and arrestor/screen*	GSWH	1.5	0	2	10%
		OSWH	2	25	2	50%
5	Pilot maintenance, electronic ignition, and clean the air intake filter	GSWH	1.5	0	1	20%
6	Check continuity of heating elements	ESWH	1	0	2	10%
7	Check internal flue and venting	GSWH	0.75	0	3	10%
		OSWH	1	0	2	30%
8	Delime heat exchanger	GIWH	1.5	20	≤1	60%
9	Inspect condensate drain	Power Vent GSWH	0.75	0	3	15%
		Condensing GSWH	1	0**	2	20%
		Condensing GIWH	1	0**	2	20%
10	Test the pressure relief valve	Storage WH only	0.5	0***	1	15%
11	Gas valve	GSWH	0.75	0	3	10%
		GIWH	0.75	0	3	25%
12	Evaporator and refrigeration system	HPWH	2	0	1	25%
13	Electronic controls	All modern Types	1	0	3	20%
14	Thermostat	Storage WH only	1	0	3	10%

* Note: Differences between FVIR and non-FVIR products for gas-fired water heaters. For oil-fired water heaters the whole burner assembly has to be pulled out to inspect.
** If the neutralizer is changed, the material cost is $20.
*** If the pressure relief valve leaks, the replacement valve is $18.
Note: All costs are average retail selling for natural gas components and can vary significantly by outlet. Wholesale cost is 25% - 50% less.

Description of each maintenance line item and cost assumptions:

- **Visual Inspection -** The area around the water heater should be clean, no flammable or combustible materials in the area, vent system intact, no leaks in piping, clean combustion air intake openings (and filters if equipped), no discoloration or corrosion of the outer jacket/cabinet material, normal flame appearance through viewport, T&P or Pressure relief valve clean, operable and unrestricted**.**
- **Drain 5 gal. water** - When draining storage water heaters, the dip tube (end fittings) helps circulate the water to remove sediment, which targets loose material. Manufacturers recommend that water heaters be drained and flushed annually to minimize deposition of sediment, maintain operating efficiency, and prolong product life. In certain areas with lower water quality (like Southern California), if draining is not done regularly, it could cause overheating and water leaking from the tank in extreme cases, which could shorten the life of the water heater. Experience shows that this process is seldom done as part of routine maintenance. Estimation is that only 10% of the homeowners do draining annually. If evidence of mineral buildup occurs on faucets and shower heads, best practice is to flush the water heater tank and have the condition of the anode checked. This better ensures longer life of the water heater. Draining the water heater will probably not remove minerals that deposit on the internal flue. Usually, maintenance contractors know the water situation in that area to determine if it will properly flush.
- **Flush the Tank -** Complete tank flushing or periodic partial draining cam remove sediment build up in the bottom of the tank. This sediment impairs proper heat transfer in the lower portion of the tank and can eventually cause a tank leak. Manufacturers have a recommended process for flushing the tank and their recommendations should be followed to insure a safe and thorough cleaning. Self-cleaning storage water heaters function by increasing incoming water velocity to draw out some of the loose sediments, but typically are not as good at removing lime or hard sediments that stick to tank walls.
- **Check the Anode Rod -** The anode rod is internal in the water heater tank. The material is designed to sacrificially corrode to protect the tank from corrosion. Water condition, set point temperature and the amount of water flowing through the tank can affect the life of the anode. Some water heater designs use two anode rods or electric resistors in the rod to extend the anode life. Anode rod is hard to loosen up and inspect, you then have to replace it and make sure it doesn't leak. It might appear more often in problem areas. Estimation is that less than 5 percent of installations check and replace anode rod. Follow the water heater manufacturers' recommendations for checking or replacing the anode.
- **Clean/inspect burner, combustion chamber, and arrestor/screen -** The air intake openings should be clean and unobstructed (including any filters or screens), the burner removed, cleaned and the combustion chamber cleaned of any foreign debris. If equipped with a flame arrestor, both the interior and exterior should be clean. Note: All new gas-fired storage water heaters are equipped with Flammable Vapor Ignition Resistant (FVIR) technology. Having a visual port that allows maintenance contractors to inspect the combustion chamber visually, without having to remove any metal doors. Refer to the manufacturer's instructions for proper cleaning of its design.

- **Pilot maintenance -** The pilot is an integral part of the burner assembly. Standing pilots are burning continually and need periodic inspection and cleaning. Intermittent pilots are only burning during main burner ignition and may require less maintenance than standing pilots. However, the gas burner, including the pilot, should be inspected periodically per the manufacturer's instructions. If necessary, the pilot, or other main burner assembly parts can be replaced if found to be damaged, corroded or malfunctioning. Parts are available from the water heater manufacturer and other supply companies.
- **Electronic Ignition -** There are several designs of electronic ignition systems incorporated in modern water heaters. Spark to pilot, hot surface to pilot, hot surface to main burner, and others are in use. Most require external electricity for these systems to function. Hot surface and spark use step down transformers to convert the 110V house current to low voltage for operation. A control module is incorporated to operate these ignition systems with the gas valve and thermostatic temperature control. The ignition components which are part of the main burner assembly require periodic maintenance to ensure long term reliability. The water heater manufacturers using these systems make available maintenance recommendations and troubleshooting diagnostics for repair on their website and installation and operation instructions supplied with their water heaters.
- **Clean the Air Intake Filter -** Some water heaters designed with FVIR technology use porous foam filters or metal/plastic screens to prevent foreign materials from entering the combustion chamber or flame arrestor. Annual inspection of these filters is necessary to insure proper combustion of the burner. Refer to the manufacturer's instructions for the specific model water heater to insure proper cleaning and timely maintenance.
- **Check continuity of heating elements -** Heating elements should show continuity between the terminals (with the wires disconnected). And show no continuity from each terminal to the element hex head (ground).
- **Check internal flue and venting -** With the flue baffle (if equipped) removed, the flue should be open and clean from the combustion chamber to the flue outlet. The draft hood or flue collar should be seated properly and the vent pipe should have fasteners securing it to the water heater draft hood/ flue outlet. The vent pipe should be clean and properly inclined from the water heater to the vent system with no signs of corrosion or damage.
- **Delime heat exchanger -** Instantaneous water heater manufacturers recommend annual (or more frequent) de-liming of the heat exchanger for their gas-fired water heaters. If not done regularly, it could cause issues in piping and appliances and could significantly shorten life to the water heater. Follow the manufacturer's instructions for the cleaning process. Some designs are equipped with water conditioning devices built into the water heater at the factory. These products may still recommend periodic maintenance of those devices. Follow the manufacturers recommendations. Some of these tankless water heaters have valves to be able to more easily do the process of deliming. Some installers might also install valves to make this deliming process easier.
- **Inspect Condensate drain -** The non-condensing power vent should have a condensate drain at the junction of the vent system to the water heater vent outlet. The

vent pipe should be inclined away from the water heater vent outlet to ensure condensation flows back to the drain. Condensing water heaters have provision for combustion condensate to be piped to an appropriate drain. Some codes require this condensate to be neutralized before entering a drainage system. The neutralizer (sometimes part of the water heater) must be maintained as outlined by the water heater manufacturer.

- **Test the Pressure Relief Valve -** The T&P or Pressure Relief Valve should be opened to insure an unobstructed flow of water. Caution should be used since the water will be hot and the resulting water drainage won't cause any damage. Recommended to test annually. To test the valve, open it and cycle water and then close the valve. Sometimes this will cause a clog in the valve, which will cause dripping and replacement of the valve. Probably most valve testing and replacing are not done by contractors, unless visible mineral building up. Temperature relief valves cannot be tested. It costs $10-15 to replace.
- **Gas Valve -** The designs of gas valves used in water heaters vary from mechanical operation to millivolt to 110V external power supply. Now only a few still have mechanical valves (about 5%) and the remaining are using more modern Honeywell valve designs (immersion element + electronic portion, could be replaced separately). The gas valve functions to turn the gas flow off or on, to the burner, as called for by the thermostat. The gas valve may have thermostatic capability built into the valve or simply be in the electric circuit of a more complex control system. Generally, gas valves are very dependable, require no maintenance and perform a long service life. Indications of gas valve malfunction are when no hot water is being produced. However, in most cases the failure is due to some other component not allowing the valve to function. Water heater manufacturers provide troubleshooting guides to determine if there is truly a gas valve malfunction.
- **Evaporator and Refrigeration System (HPWH only)** - Manufacturers recommend preventative maintenance be performed on the refrigeration section of heat pump water heaters. The fans, motors, evaporator coil, water circulation pump, sensors and controls should be checked annually for proper operation and cleanliness. Some manufacturers use filters or screens to keep debris out of these components. These should be inspected and cleaned annually or more often if in a dirty environment. Each manufacturer outlines the process for these inspections and cleaning. Follow their instructions to insure a long life of the system.
- **Electronic Controls -** Many modern water heater designs use electronic control systems to operate thermostatic devices, temperature sensors, fans, dampers, heating elements, ignition systems, pumps, compressors, and other components in the water heater system. Circuit boards, transformers, contactors, relays and related wiring connect all the components. These electronic devices are relatively maintenance free. However, one component failure can cause the entire system to shut down. Manufacturer troubleshooting information is essential to finding the inoperable component. Diagnostic equipment, similar to water heater service equipment, is necessary for this process.
- **Thermostat -** The thermostat may be an integral part of the gas valve on baseline storage type water heaters or simply a component of a complex electronic control system on other designs. Its function is to determine the off/on function of the heating

system. Be that in gas or electric water heaters. There is no maintenance necessary with most thermostats. However, some thermostats incorporate surface mount sensors that must be in good/clean contact with components. These sensors may become loose or dislodged and must be re-affixed and should be part of normal maintenance routine.

8F.5.2.2 Additional Topics

Flushing Tank. My estimation is that 10% of all tank type water heaters are flushed regularly. Homeowners rely on tank warranty that precludes attention to flushing. In areas where water heaters only last five years or less because of sediment accumulation, the flush rate may be higher and Maintenance Contracts may influence flushing tanks when it isn't necessary. Rural areas using individual wells as water source have a higher rate of sediment accumulation. Also, areas known to have "hard" water (high dissolved solids) have more mineral buildup inside the tank.

50% of flushing is done by the homeowner and 50% by plumber. If there is a maintenance contract, the water heater is probably flushed yearly. If left to the homeowner, they would do flushing every 5 years at best. Again, homeowners are cognizant of the warranty period and don't flush if the warranty is in effect.

FVIR Maintenance. All gas water heaters with FVIR technology require FVIR maintenance. FVIR apparatus, whether flame arrestor, snorkel, sensor, radiant burner, etc. must be clean, unobstructed and functioning. The combustion chamber and incoming air seals must be intact to ensure air only gets to the burner through the designed route. The individual design predicates the manufacturers specific maintenance procedure.

Clean, well-kept environment around the water heater that's free from dust, animal hair, clutter etc. are in need of much less maintenance regarding the FVIR and once per year is adequate. Attic, basement, garage, utility room, and other similar installation areas generate more airborne dust and dirt, lint, oil residue, aerosols and contaminates which can contaminate filters, screens, flame arrestors, combustion airways. These installations require at least twice per year or more visual inspection.

Deliming for Instantaneous Water Heaters. All instantaneous water heaters except those with in home water treatment or built-in factory devices as part of the water heater require deliming. Some of these water heaters have valves to be able to more easily do the process of deliming. Most installers might install valves to make this easier.

"Hard" water (high dissolved solids) is the worst-case scenario. Private well systems frequently provide hard water to the home. There are sources for water data both for municipal water supplies and for well systems. In "hard" water markets, it has to be done once per year. Other areas are three to five years. Plumbers know the areas that historically have minerals build up in the pipes and plumbing fixtures over time.

Usually, 80% of flushing deliming is done by contractors. This process is not simple and the water heater has to be installed with a series of valves to circulate treated water through the water heater. Maintenance contracts routinely include this service on instantaneous water heaters.

8F.5.3 Repair Costs

8F.5.3.1 Typical Repair Steps, Cost Items, and Frequency

The repair cost reflects the cost to the consumer for a service call when a product component fails. In some cases (depending on the age of the water heater and if it has been repaired before), if the equipment fails, residential homeowners tend to replace the equipment rather than having them serviced. This is especially true for water heaters. However, there could be design options considered for which the components may need repair during the lifetime of the equipment.

Table 8F.5.2 lists water heater components, approximate service life, component cost (at retail) and labor hours to replace/repair.

One major difference between gas-fired and oil-fire storage water heaters and electric storage water heaters is that the heating element is replaceable in electric storage water heaters, while for gas-fired and oil-fired storage water heaters that heat exchanger cannot be repaired. The hot surfaces of a heating element collect mineral deposits and even if the heating element fails it can be replaced, while the hot surface (tank bottom and the flue tube) of a gas-fired or oil-fired water heater cannot be replaced.

It is important to note that sometime diagnosis of the repair issue is not very good and often replace the whole component instead of smaller item (replace controls or gas valve instead of another item). Often there are no onboard diagnostics and the contractors do not want to do additional troubleshooting, since it increases labor and requires more knowledge or training. Some newer water heater designs are equipped with newer controls that can better help troubleshoot errors or issues.

Table 8F.5.2 Summary Repair Components

	Water Heater Components	Approximate Service Life (yrs)	Component Cost (at retail) ($)	Labor Hours to Replace/Repair (hrs)
Pre-FVIR GSWHs	Gas control valve/thermostat	15	$80	2
	Pilot assembly	12	$20	1.5
	Main burner assembly with pilot	12	$65	1.5
FVIR GSWHs	Main burner assembly with pilot, piezo, thermocouple, sensor/wire, door and gasket.	10	$135	2
	Gas control valve/thermostat	12	$155	2
FVIR Power Vent GSWHs (with electronic controls)	Gas valve with ignition module	10	$210	2
	Igniter assembly with sensor, wire, and door gasket	7	$95	2.5
	Main burner assembly with igniter, sensor, wiring, door and gasket	7	$145	2
	Blower assembly	7	$190-$320	2.5
ESWHs	Standard heating element	5	$12	2
	Stainless steel heating element	10	$29	2
	Thermostat	7	$22	1
HPWHs	Thermostatic controls	15	$150-$250	2-3
	Temperature sensors	15	$10-$25	2
	Electric heating element	5-15	$28-$40	2
	Compressor	15	$250-$450	3
	Evaporator fan	12	$80-$130	2
	Circulating pump	15	$120-$250	3
	Digital display	15	$90-$350	2
OSWHs	Oil burner assembly	15	$550	3
	Oil pump	15	$70	1.5
	Thermostat	15	$95	1.5
GIWHs (standing pilot)	Gas valve	15	$78	2
	Pilot assembly	12	$35	2
GIWHs (electronic)	Gas valve with ignition module	10	$225	2
	Igniter assembly	7	$105	2
	Blower assembly	7	$290	2.5

Note: All costs are average retail selling for natural gas components and can vary significantly by outlet. Wholesale cost is 25% - 50% less.

Main burner assembly - The main burner assembly is the burner, pilot or ignitor, gas manifold tube, and any sensors with wire leads. For repair or replacement due to malfunction or corrosion, the water heater is turned off, the outer cover is removed and fastening hardware loosened to remove it from the water heater. When reassembled, it must be tested for gas leaks, air bled from the assembly and the water heater reignited and then checked for proper operation.

Oil burner assembly - This is a combination motor driven device that pumps the oil into the burner, has a fan that injects combustion air, an off/on electric relay device, a nozzle that injects the oil into the flame and an ignitor to fire the injected oil/air mixture. It weighs 35 to 45 lbs. and mounts to a heavy-duty flange on the water heater. Components on the burner assembly can be serviced or replaced without the burner being removed from the water heater. However, the burner must be removed to inspect or replace the nozzle.

Oil Pump - This pump can be removed from the burner assembly to be cleaned or replaced.

Gas valve with ignition module - Some water heaters have the thermostatic temperature control, gas valve and ignitor power supply as an integral assembly. Generally, these components are not individually serviceable or replaceable. The entire assembly must be replaced when it is determined to be inoperable.

Pilot assembly - The pilot assembly can be always lit or intermittently lit and is used to ignite the main burner. It can be removed from the main burner assembly if it is found to be corroded or inoperable.

Igniter assembly - Similar to a pilot assembly, this device is used to ignite the main burner. Generally, it is either hot surface or spark and is electrically energized by the control system. The ignitor assembly can be removed from the main burner if corroded, broken or inoperable.

Blower assembly - An electric blower may be used to exhaust combustion products from the water heater and is interlocked into the control system such that the blower must be running before the burner can be ignited. Since the blower is motor driven if the motor fails the water heater will not operate. Some blowers are designed so that the motor can be replaced. With other designs the entire blower assembly must be replaced.

Electric heating element - The heating element can be either the only water heating source or it can be used for supplemental heating as back up to the primary heat source. This element mounts into the tank through a threaded fitting in the tank. If the element is found to be inoperable or is encrusted with scale, the water heater has to be turned off, water drained, and the element replaced.

HPWH Specific Repairs

Compressor - The compressor is used as a reverse cycle heat generating device like a home heat pump heating system. It pressurizes a refrigeration system where the heat from surrounding air is absorbed into the refrigerant in a forced air coil and transferred to another coil which circulates water from the water heater thereby heating the tank water. Compressors are generally not serviceable and must be replaced if inoperable.

Evaporator fan - The fan forces air over the coil to transfer heat from the air into the tank water. The fan is not serviceable and if found inoperable, must be replaced.

Other repair items could also occur:

Faulty T&P (temperature and pressure) relief valve - The T&P valve is a safety device to relieve an over temperature or over pressure condition in the water heater tank. This valve is threaded into a fitting in the top portion of the tank. The valve may fail gradually by emitting water in drips or a stream when the water heater temperature or pressure is normal. Sometimes scale can form on the valve seat and cause it to leak. The valves should be replaced if leaking or scaled.

Leak from a plumbing connection - Plumbing connections can leak over time from thermal expansion and contraction or movement of the piping. Any water weeping at a connection should be addressed with tightening or replacement of the leaking fitting.

Faulty thermostat (both gas and electric) - A faulty thermostat can generate an under or over temperature condition of the stored or outlet water. If outlet water from the water heater is cooler or hotter than the "set point" temperature, it may indicate a coming failure of the thermostat. However, logical troubleshooting can verify if it is the thermostat or some other component causing the condition.

Broken drain valve - The drain valve is threaded into a fitting, close to the bottom of the tank. The purpose of the valve is to provide the ability to drain water from the tank. If the valve is dripping or has a broken handle, it should be replaced. Unfortunately, the water heater must be turned off, water allowed to cool, and be drained to replace the valve. These valves may be plastic or metal and replacing it could avoid a serious leak at a later date if they are leaking.

Damaged or disconnected dip tube - The dip tube is a tube inside the cold water fitting of the tank and is designed to direct the incoming water to the tank bottom where it is most efficiently heated. If the dip tube is damaged in shipment, dislodged from the cold water fitting or broken, the cold incoming water can circulate in the upper portion of the tank and cool the hot water leaving the outlet of the water heater. Thus, the appropriate supply of hot water is circumvented, and the homeowner will complain of "not enough hot water". The remedy is to remove the cold water inlet pipe and check that the dip tube is in the tank fitting and is at least the length of half the tank height.

8F.5.3.2 Additional Topics

Electric heating elements. About half of all electric storage water heaters will need heating element replacement during its lifetime. There are options for distributors to order ESWH with stainless steel heating elements. Also, homeowners have access to these elements as do water heater repair companies. Stainless steel heating elements life is 8 to 12 years compared to standard copper elements that last 5 to 7 years. The life of the heating element is mostly dependent on water conditions of the local water supply (minerals). When minerals deposit on the heating element, it impairs heat transfer and the tubing material can split from overheating. Stainless steel, Incoloy and other higher temperature materials resist this overheating much more than copper (the standard material for heating elements).

For standard copper elements, in high dissolved solids (minerals) water areas, it's not unusual for a homeowner to need heating element replacement every three to five years. Two to five times over the water heater life.

Electric thermostat. Approximately one fifth (20%) of electric water heaters will need replacement of one or both thermostats during the lifetime of the WH. These are mechanical devices and over time can malfunction due to weakening of bimetals, moisture, eroding contacts, etc.

Over the water heater lifetime, these thermostats could be replaced once or twice. Unfortunately, service personnel find it cheaper to replace these inexpensive parts rather than spend time troubleshooting the cause of cold water complaints.

Pilot light. GSWH gas valve replacement is required less than 20% during the water heater life, for mechanical type gas valve/thermostats (older production). Only one replacement is normal for the lifetime.

GSWH electronic valve with standing pilot is replaced at less than 10% during water heater lifetime. This type valve has a troubleshooting diagnostic system to aid in fault determination and therefore allows better determination of the need for replacement. Only one replacement is normal for the lifetime.

Electronic ignition. Electronic ignition is used on GSWH that require external 110V electric supply. i.e. power vent, electronic damper, electronic thermostats with external temperature sensors, etc. These electronic systems are much more long term reliable but are more complex to troubleshoot for service. Some systems offer diagnostic capability which helps avoid replacing components as a diagnostic process. In some cases, under 5%, the control board must be replaced. Generally, system failure is caused by a component rather than the control board. Flame sensors, hot surface ignitors, spark electrodes and other components may be replaced once over the water heater life.

8F.5.4 Warranty, Extended Warranties, and Service Contracts

8F.5.4.1 Warranty

Warranties change from year to year with manufacturers. Tank warranties can range from one year to lifetime. Parts can be warranted from one year to lifetime. Labor is sometimes covered for one year but in most cases, there is no labor coverage.

Take Energy Star warranty criteria as an example, Energy Star requires a 6 year minimum on tanks for electric and gas storage, 6 year on a heat exchanger, and 5 year on parts for instantaneous water heaters. Labor is not covered.

Table 8F.5.3 Energy Star Warranty Criteria

Product Type	Warranty
ESWH	≥ 6 years on sealed system
GSWH	≥ 6 years on system (including parts)
GIWH	≥ 6 years on heat exchanger,≥ 5 years on parts
High Capacity (Light Duty EPACT-Covered) GSWH	≥ 6 years on system

8F.5.4.2 Service Contracts and Extended Warranties

Service contracts are sold by both retailers and contractors. Extended warranties are offered by these companies and even by credit card companies.

Some coverage is sold on a prorated scale, meaning the latter duration of the coverage is less compensating to the homeowner. There are also independent companies like American Home Shield that cover several of the home appliances such as water heaters, furnaces, heat pumps, washers, dryers, ranges, ovens, refrigerators and so on. Specific to Oil Fired water heaters, the heating oil supplier is the usual service contract agent and can be added into the upfront cost of the water heater or on a monthly basis.

Ordinarily, retailers sell service contracts to a homeowner buying a water heater from the retailer. If a plumber is the seller, then, the plumber may use a third-party contract. Or, if they are a very large contractor, they may have their own program. These contracts may cover only labor, parts and labor, or all this and replacement labor should the entire appliance need to be replaced. There is a plethora of programs in the marketplace beyond what this report can address. Estimation is that 20% of water heaters are covered under some sort of service agreement.

Usually, the homeowner incurs no cost for the specified labor and parts to repair. Or there may be a deductible. Any work done not directly covered in the contract wording would be at the homeowners expense.

When fully replacing a water heater, the labor is not covered by the factory, if the water heater is in factory warranty. In case of a service agreement, it may cover this labor cost. However, very few service contracts cover product replacement if the water heater is in warranty. They leave the product replacement up to the manufacturer but may cover installation labor. Manufacturers only cover water heater replacement if the storage tank is confirmed to leak.

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APPENDIX 8G. CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS LIFETIME DETERMINATION

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8G.1 INTRODUCTION

The product lifetime is the age at which a product is retired from service. Because product lifetime varies, U.S. Department of Energy (DOE) used a lifetime distribution to characterize the probability a product will be retired from service at a given age. DOE took into account published studies and manufacturer input, but because the basis for the estimates in the literature was uncertain, DOE developed a method using shipments and survey data to estimate the distribution of consumer water heater lifetimes in the field. This appendix includes the lifetime literature review, information from an expert consultant about lifetime, and DOE's lifetime methodology for the consumer water heater analysis.

8G.2 LIFETIME LITERATURE REVIEW

DOE performed a lifetime literature review. Many factors can impact the lifetime of gas-fired instantaneous water heaters. Based on various sources and consultant input (available in this appendix), DOE identified the following factors that affect water heaters lifespan:

- Lifetime is primarily impacted by water quality and chemistry (leading to excess sediment or mineral deposits), which varies by region. Lack of adequate maintenance could have an impact for certain U.S. regions.
- Frequency of use of a water heater can impact lifetime, but hot water use tends to be very similar between regions (so does not impact overall average lifetime).
- Proactive or early replacements could be due to many factors including changes in customer needs and preferences (e.g., not getting enough hot water), a major household remodel, or incentives for installing high efficiency water heater or switching fuels. Clear Seas Research's Water Heater Study reports that a good fraction of replacements are proactive (around 40 percent in 2022).[1]
- Improper installation of the water heater.

Lifetime values and sources for instantaneous[a] water heaters are presented in Table 8G.2.1.

Table 8G.2.1 Water Heaters: Product Lifetime Estimates and Sources

Typical/Avg. Lifetime or Range (years)	Source
Instantaneous Water Heaters (Unspecified Fuel Type) (average range from sources:10 to 20+ years)	
10	InterNACHI[2]
<10 to 20+, an average of 12.7	Clear Seas Research (2022)[1]
Up to 20	A.J. Alberts Plumbing[3]

[a] Instantaneous water heaters are also referred to as tankless water heaters.

Typical/Avg. Lifetime or Range (years)	Source
About 20	Brewer (2019);[4] Taylor et al. (2021)[5]
20	American Home Water and Air;[6] TRC (2016)[7]
More than 20	National Association of House Builders (NAHB) (2007)[8]
Gas Instantaneous Water Heaters (average range from sources:18 to 20 years)	
18 to 20	InspectAPedia[9]
20	Trinh (2021)[10]
20 (Weibull distribution)	DOE (2010)[11]
Oil Instantaneous Water Heaters (average range from sources:18 to 20 years)	
18 to 20	InspectAPedia[9]
Electric Instantaneous Water Heaters (average range from sources: 20 years)	
20	Trinh (2021)[10]
20	TRC (2016)[7]
Internal Instantaneous Coils (average range from sources: 10 to 15+ years)	
10 to 15+	Tiger Home Inspection[12]
External Instantaneous Unit (average range from sources: 10 to 20+ years)	
10 to 20+	Tiger Home Inspection[12]

8G.3 CONSULTANT INFORMATION (CDS CONSULTING)

The following is the markup and distribution channel report prepared by CDS Consulting,[b] for Lawrence Berkeley National Laboratory (LBNL) on October 19, 2021. See appendix 8F for consultant report about repair and maintenance costs that includes additional information about consumer water heater lifetime and warranties.

8G.3.1 Consultant Information

Lifetime is primarily related to water quality. Water use is very similar between regions (so does not significantly impact lifetime). Water heater set point temperature can also have an impact on the tank lifetime. The raising of operating temperature within the water heater does have an "erosion" effect on the tank lining and shorten the anode life. Maintenance, or lack of, could have an impact in certain aggressive water regions. Larger anodes, multiple anodes or different anode material could offset the long-term corrosion effects.

In the past it was more common for manufacturers to optimize products design to address potential lifetime issues for certain regions, but more testing has increased the quality and durability up to a certain point (economic breaking point). Manufacturers do not want to add

[b] Drew Smith is founder of CDS Consulting and has more than 40 years of experience in the consumer water heater industry (including sixteen years in sales and marketing and nineteen years in engineering design and development). He was previously Director of Residential Engineering and Product Safety, Certification and Standards at A.O. Smith until 2007 and previously Vice President of Product Development and Research at State Industries until 2001.

multiple product lines (which can cause inefficient stocking of products). Manufacturers have to balance with the cost of warranty and warranty replacement.

8G.4 DETERMINATION OF CONSUMER WATER HEATER LIFETIME

8G.4.1 Overview

DOE's lifetime methods are based on the approach described in Lutz *et al*. (2011)[13] and Franco *et al*. (2018).[14] The following flowchart summarizes DOE's approach for determining a lifetime distribution for consumer water heaters.

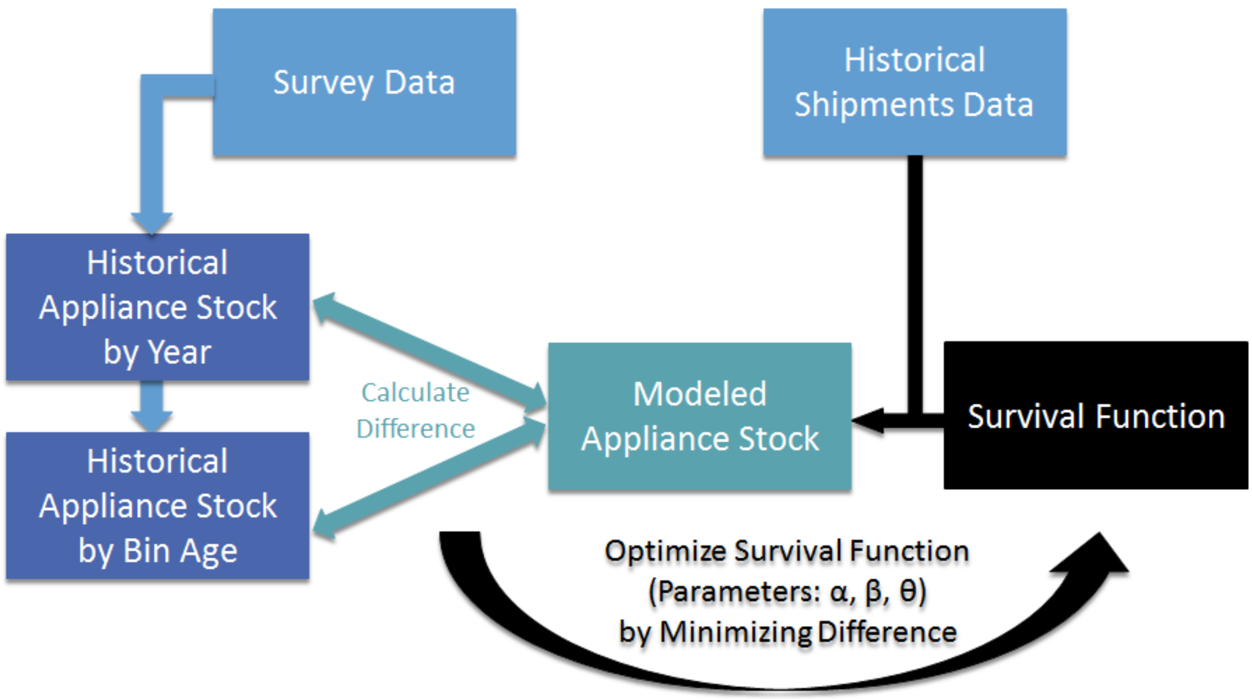

Figure 8G.4.1 Flowchart of Approach for Determining Lifetime Distribution for Consumer Water Heaters

DOE derived a Weibull distribution for water heater lifetime as part of the water heater shipments model (described in chapter 9), primarily using historical shipments data and consumer water heater stock and age data from U.S. Census's biennial *American Housing Survey* (AHS) from 1974-2019[15] and Energy Information Administration (EIA)'s Residential Energy Consumption Survey (RECS) 1987-2020.[16] DOE assumed that the distribution of lifetimes would account for the impact of the water quality on the life of the product, the level of maintenance of a consumer water heater, and the other factors impacting the lifetime of the water heater as discussed in previous sections.

8G.4.2 Data Inputs

RECS has been conducted every 3 or 4 years for the last several decades. For this analysis, DOE used the RECS surveys conducted in 1990, 1993, 1997, 2001, 2005, 2009, 2015, and 2020.[16] For several appliances, including consumer water heaters, the survey asks respondents to place the appliance's age into one of these bins:[c]

- less than 2 years;
- 2 to 4 years;
- 5 to 9 years;
- 10 to 19 years; and
- more than 20 years.

AHS has been conducted every one to two years from 1974-2019.[15] AHS surveyed all housing, including vacant and second homes, noting the presence of a range of appliances. AHS has a larger sample size than RECS and AHCS, with correspondingly smaller sampling error. Using AHS data allowed DOE to adjust the RECS and AHCS data to reflect some appliance use outside of primary residences, thereby better match the total installed stock.

DOE adjusted the RECS and AHS survey data in several ways to align the timing of the survey data with the historical shipment data. In particular, DOE adjusted for the fact that the RECS survey is scaled to July of its reference year, the AHS survey is conducted in the middle portion of the year, and shipment data are provided for each calendar year. DOE also used the AHS and RECS surveys household-level micro-data to account for households with shared water heaters, multiple consumer water heaters, and households likely using their boiler for water heating. Adjustments included:

- DOE modeled the additional retirement of older appliances and their replacement by new ones that took place in the latter half of the survey year (after a given respondent had been surveyed), using the survival function. This had the effect of moving households from the older RECS age bins to the youngest age bin.
- For appliances installed directly in new construction, such as water heaters, DOE added units to the youngest RECS age bin and to the AHS total stock to represent half of the new construction for the final year of the survey, which were known to have installed the appliance type in question, using data from the U.S. Census for new construction starts.
- Households that did not know the age of their appliances were allocated among the remaining age bins according to the distribution of respondents who did report their appliance age.
- Consumer water heaters serving multiple housing units. Mostly impacts multi-family buildings that are either reported as having a shared water heater in RECS from 1990-2009 or as the water heater not being installed inside the apartment in RECS 2015-2020.

[c] For RECS 2009 and 2015, the 10 to 19 year bin is split into two bins (10 to 14 years and 15 to 19 years).

- Boilers used for water heating including indirect tanks and combination systems. Not directly reported by RECS or AHS, but DOE assumed a fraction of households with same fuel type reported for space heating boiler and water heater.
- Commercial water heaters used in residential applications. Not directly reported by RECS or AHS, but DOE assumed that it impacts larger homes and multi-family buildings.
- Multiple water heaters per housing unit. Not directly reported by RECS or AHS, but DOE assumed a fraction households based on available data.[17]
- Consumer water heaters used as secondary water heating equipment as reported by RECS data.

Figure 8G.4.2 and Figure 8G.4.3 summarizes the fraction of gas-fired and electric storage water heater in residential applications by age bin and product class based on 1990–2020 RECS data. Similar data for oil-fired storage and gas-fired instantaneous water heaters was not available due to small sample sizes. Figure 8G.4.3 summarizes the total stock of consumer water heater in residential applications by product class based on 1990–2019 AHS data, RECS 1990-2020, and shipments model. By combining these survey results with the historical shipments data DOE estimated the fraction of appliances of a given age still in operation. Figure 8G.4.4 shows the historical consumer water heater shipments data, which is described in more detail in chapter 9.[d]

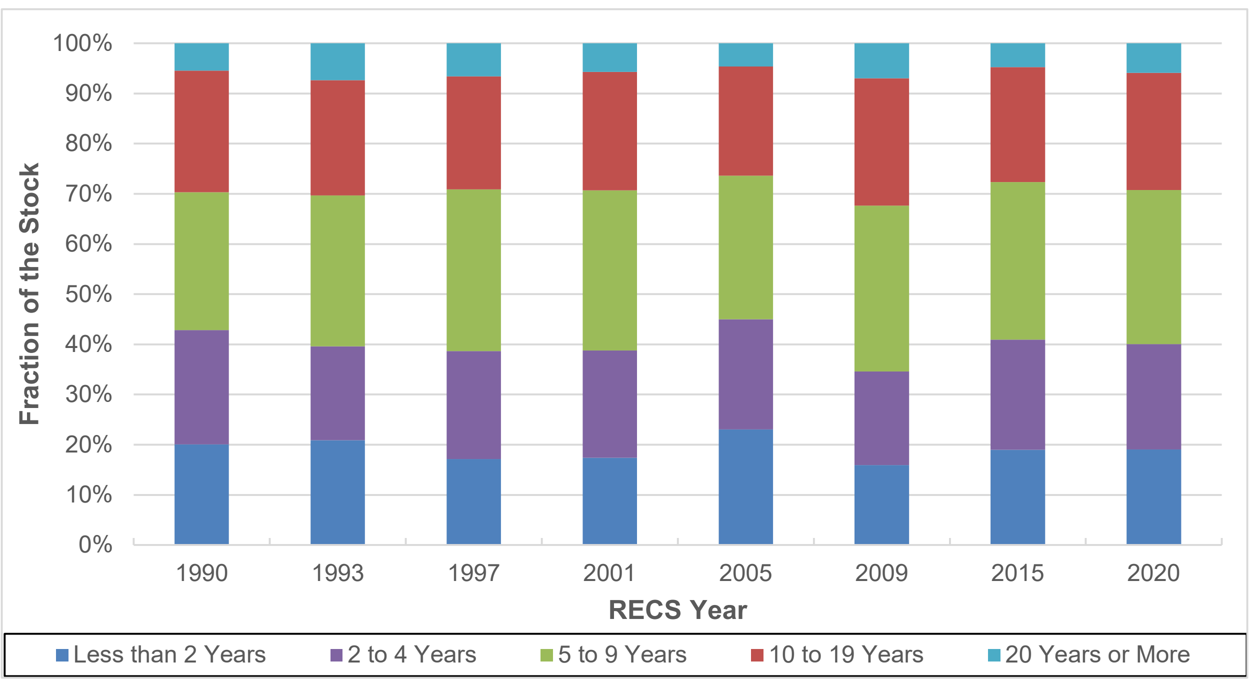

Figure 8G.4.2 Fraction of Gas-Fired Storage Water Heaters by Age Bin in Residential Applications, 1990-2020

[d] Consumer water heater shipments include shipments to residential and commercial applications. Only shipments to residential applications are used to compare to RECS and AHS data.

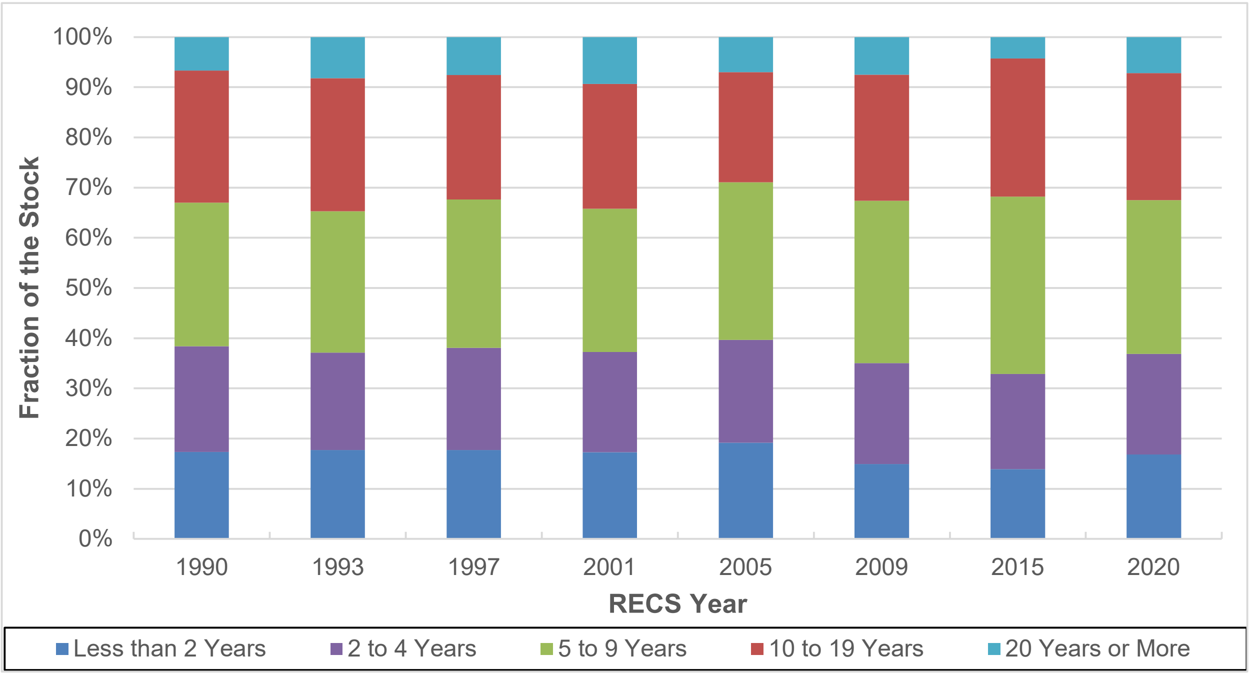

Figure 8G.4.3 Fraction of Electric Storage Water Heaters by Age Bin in Residential Applications, 1990-2020

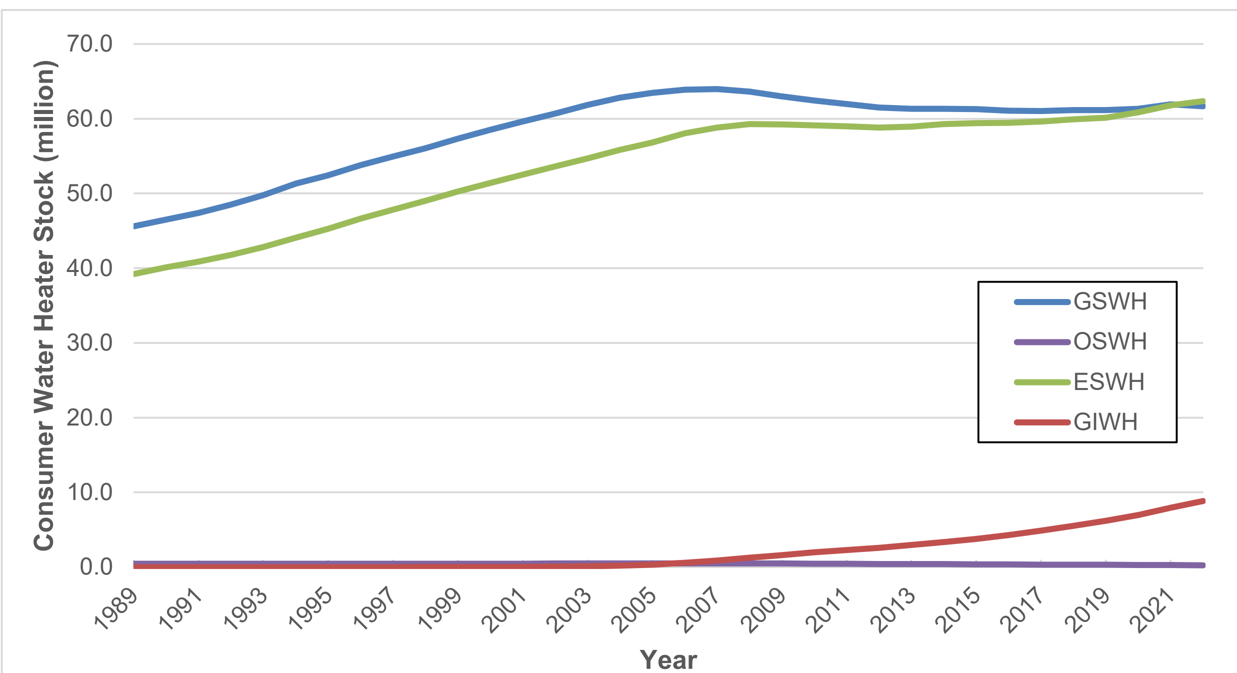

Figure 8G.4.4 Total Stock of Consumer Water Heaters in Residential Applications by Product Class, 1989-2022

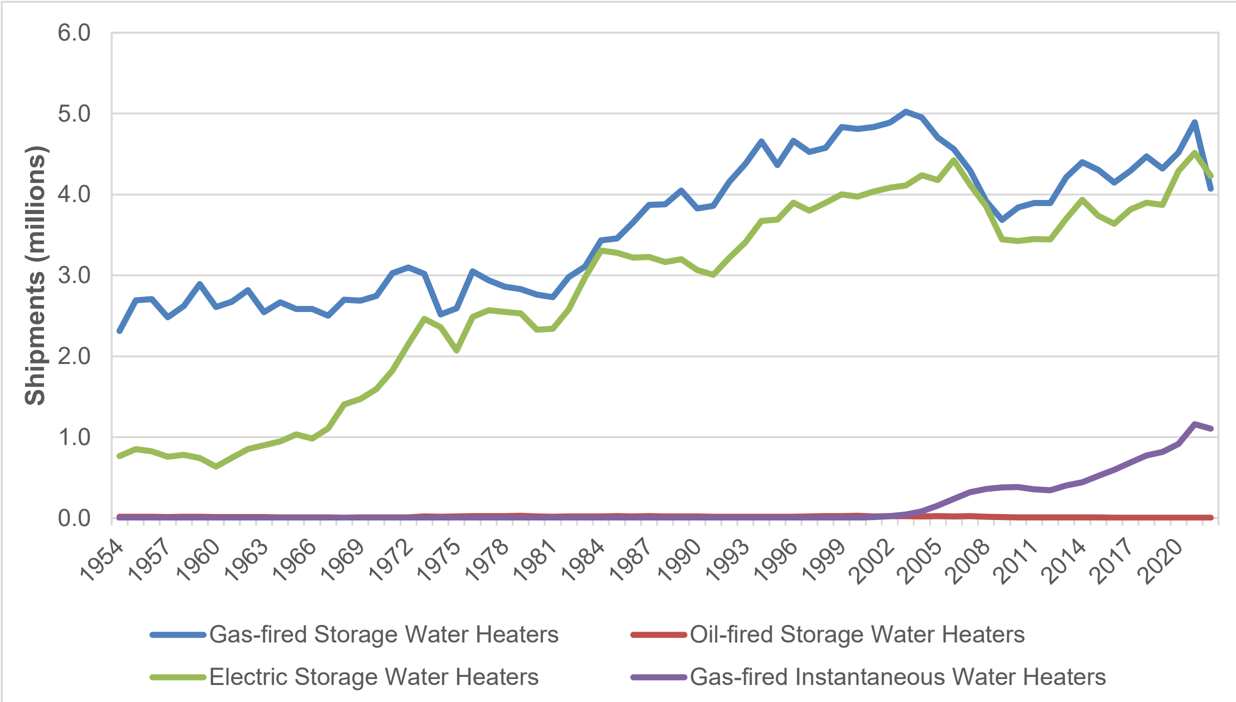

Figure 8G.4.5 Historical Shipments of Consumer Water Heaters in Residential Applications by Product Class, 1954-2022

8G.4.3 Calculation Methodology

DOE used appliance age data derived from RECS, AHS total installed stock data, and the historical consumer water heater shipments to generate an estimate of the survival function. For example, DOE summed the total shipments from 5 to 9 years prior to the RECS survey, and compared this number with the number of units of those ages still in use, to calculate one approximation of the surviving appliance fraction within that age bin. The AHS total stock acts as an "all ages" bin. By combining the age bins from AHS and RECS surveys with shipments data, DOE had enough data to build a fit to a Weibull distribution and find the parameters (α, β, θ) that best approximate the surviving units, using a least-squares method.

DOE weighted each bin's contribution to the sum of squares by the inverse of the variance in the survey results, which controls for the changes in sample size between RECS bins, between RECS and AHS, and within each survey over time.[18] RECS and AHS have complicated error models; DOE used only the error due to finite sample size to determine the variance used to weight each data point's contribution. The error due to sampling is less than 1 percent for AHS survey data and is typically about 5 percent for RECS age bins. The equation for the sum of squares DOE minimized is therefore:

$$\sum_i \frac{\left(\boldsymbol{RECS}_i - \boldsymbol{Surv}_i\right)^2}{\sigma^2_{i,RECS}} + \sum_j \frac{\left(\boldsymbol{AHS}_j - \boldsymbol{Surv}_j\right)^2}{\sigma^2_{j,AHS}}$$

Eq. 8G.1

Where:

i = the identifier for a bin from a single RECS,
j = the identifier for a single AHS survey,
$RECS_i$ = the number of appliances reported by RECS in age bin i,
AHS_j = the number of appliances reported by AHS in survey year j,
$Surv_i$ = the number of surviving appliances in age bin i predicted by the Weibull distribution applied to the number of appliances shipped (a function of α, β, and θ),
$Surv_j$ = the number of surviving appliances in year j predicted by the Weibull distribution applied to the number of appliances shipped (a function of α, β, and θ),
$\sigma_{i,RECS}$ = the standard error (square root of the variance) of the RECS data point for age bin i, and
$\sigma_{j,AHS}$ = the standard error (square root of the variance) of the AHS data point for year j.

DOE assumed that the probability function for the annual survival of consumer water heaters would take the form of a Weibull distribution. A Weibull distribution is a probability distribution commonly used to measure failure rates.[18] Its form is similar to an exponential distribution, which models a fixed failure rate, except that a Weibull distribution allows for a failure rate that changes over time in a specific fashion. The cumulative Weibull distribution takes the form:

$$P(x) = e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \text{ for } x > \theta \text{, and}$$

$$P(x) = 1 \text{ for } x \leq \theta$$

Eq. 8G.2

Where:

$P(x)$ = probability that the appliance is still in use at age x,
x = age of appliance in years,
θ = delay parameter, which allows for a delay before any failures occur,
α = scale parameter, which would be the decay length in an exponential distribution, and
β = shape parameter, which determines the way in which the failure rate changes through time.

When $\beta = 1$, the failure rate is constant over time, giving the distribution the form of a cumulative exponential distribution. In the case of appliances, β commonly is greater than 1, reflecting an increasing failure rate as appliances age. DOE estimated a minimum delay parameter of $\theta = 1$ year, based on the on the fact that typical manufacturer warranty period for consumer water heaters is one year or greater.

In this analysis, modeled total stock $Surv_j$ and stock in an age bin $Surv_i$ are calculated using historical shipments and the Weibull survival function:

$$Surv_j = \sum_{x \in X} P(x) \cdot h(y-x) = \sum_{x \in X} e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \cdot h(y-x) \text{, and}$$
$$Surv_i = \sum_{x \in X_i} P(x) \cdot h(y-x) = \sum_{x \in X_i} e^{-\left(\frac{x-\theta}{\alpha}\right)^{\beta}} \cdot h(y-x).$$

Eq. 8G.3

Where:

$h(y-x)$ = historical shipments in year $(y-x)$,
$P(x)$ = survival function with the Weibull distribution parameters α, β, and θ,
X_i = the ith age bin $[x_{i,1}, x_{i,2}]$, $i = 1,2,\cdots,N$, and $X = \bigcup_{i=1}^{N} X_i$.

8G.4.4 Calculation Method Assumptions

DOE's lifetime-calculation technique depends on several assumptions:

- Appliance lifetime can be modeled by a survival function. In particular, a Weibull distribution is an appropriate survival function.
- The appliance survival function does not change over time.
- The survival function is independent of other household factors (such as household size, region, etc.) as well as product class.
- The age bin for the appliance as reported by the RECS and AHCS respondent is correct and that distribution of appliance ages across bins is the same for those respondents that provided this information and for those who did not.
- The appliance type as reported by the AHS, RECS, and AHCS respondent is correct.
- The historical shipment data is correct.
- The Weibull delay parameter, θ, is limited to between 1 and 5 years.

Three of these assumptions are of particular importance. The first is the assumption that a Weibull distribution is the correct distribution to use for appliance retirement rates. This distribution is the standard distribution for use in lifetime analysis, but it is not guaranteed to reflect actual consumer behavior. The second assumption is that consumer behavior and mechanical appliance lifetime have not changed over time. This assumption required DOE to treat all observations different AHS and RECS surveys equally, despite the vintage of the survey. Using only recent surveys (to potentially better reflect recent consumer behavior and appliance lifetime) would result in attempted least-squares fits using a small number of data points, leading to large statistical uncertainty.

DOE limited the delay parameter to between 1 and 5 years to reflect the range of common appliance warranties. A delay of less than 1 year would imply that some appliances fail or are replaced within their initial year of use, a period during which they are commonly covered by parts and labor warranties. A delay of greater than 5 years implies that no appliances are replaced for some length of time after the end of the longest standard warranty. Fits with $\theta > 5$ also commonly show nonsensical behavior with sharp changes in consumer behavior or appliance survival immediately following the "delay" period.

There are limited data about gas-fired instantaneous water heaters. DOE assumed 20 year average lifetime with same shape as gas-fired storage water heaters for GIWHs based from the June 2024 Consumer Water Heater Final Rule.[19]

8G.4.5 Results

Table 8G.4.1 shows the Weibull distribution parameters for GIWHs. The table also shows the estimates average and median appliance lifetime. Figure 8G.4.6 shows the Weibull probability distribution (DOE's calculated survival function) for GIWHs.

DOE assumed that the lifetime of all consumer water heaters would be the same across different efficiency levels. The resulting average and median appliance lifetime from the derived Weibull distributions are also provides in the table and are within the range of the values found in DOE's literature review.

Table 8G.4.1 Lifetime Parameters for Consumer Water Heaters

Product Class	Weibull Parameters			Distribution Statistics	
	Alpha (scale)	Beta (shape)	Location (delay)	Mean	Median
Gas-fired Instantaneous Water Heater*	21.3	1.76	1.0	20.0	18.3

*Gas-fired instantaneous water heaters have limited data so DOE assumed a 20-year average lifetime with same shape as gas-fired storage water heaters.

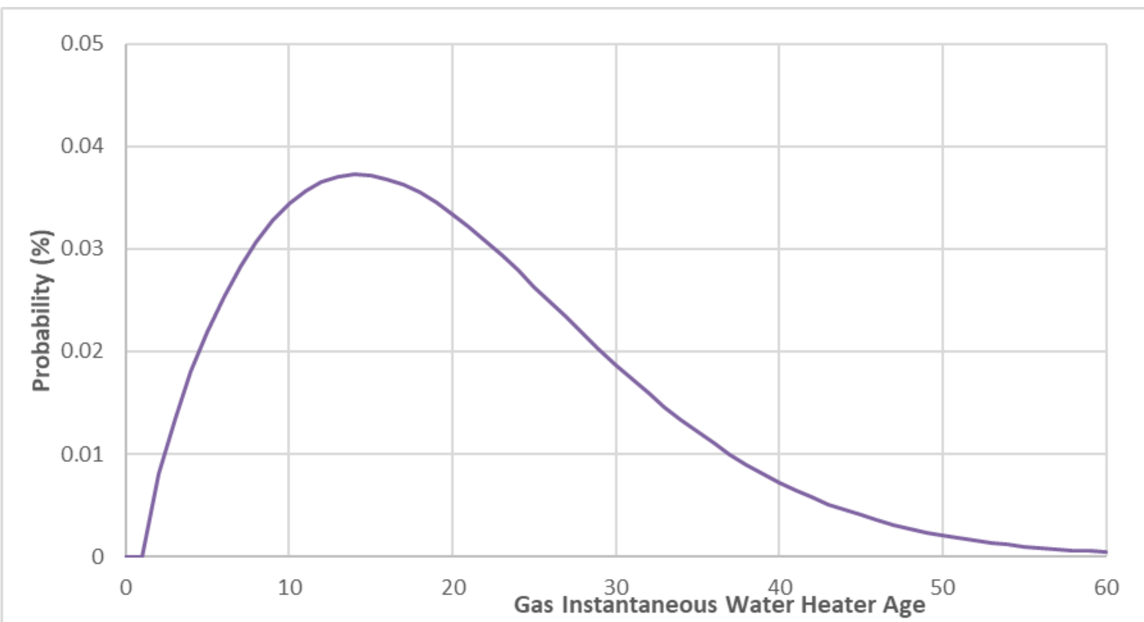

Figure 8G.4.6 Lifetime Distribution for Consumer Water Heaters

8G.5 SENSITIVITY ANALYSIS

DOE conducted a sensitivity analysis for its lifetime estimates to assess the impact of varying lifetime on consumer LCC savings.

Table 8G.5.1 Lifetime Scenarios

Scenario	Description	Average Lifetime *years*
Reference	Default scenario based on lifetime analysis discussed in section 8G.4	GIWH:20
Low	Shorter lifetime assumption	GIWH:18
High	Longer lifetime assumption	GIWH:22

The comparison of the results under different scenarios can be seen in Table 8G.5.2.

Table 8G.5.2 Comparison of the Results from Different Lifetime Scenarios

Product Class	EL	Average LCC Savings** 2023$			Simple Payback Period* *years*			Net Cost** %		
		Low	High	Ref.	Low	High	Ref.	Low	High	Ref.
GIWH	1	(19)	16	(1)	12.6	12.6	12.6	18.0	17.0	17.5
	2	88	135	112	8.9	8.9	8.9	15.9	14.5	15.2
	3	75	104	90	8.3	8.3	8.3	26.7	23.3	25.0
	4	21	56	39	10.3	10.3	1.3	58.9	54.0	56.2

* The results for each EL are calculated assuming that all consumers use products with that efficiency level. The PBP is measured relative to the baseline product.
** The calculation includes impacted consumers. The LCC savings are relative to the no-new-standards case distribution.

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APPENDIX 8H. DISTRIBUTIONS USED FOR DISCOUNT RATLES

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APPENDIX 8H. DISTRIBUTIONS USED FOR DISCOUNT RATES

8H.1 INTRODUCTION: DISTRIBUTIONS USED FOR RESIDENTIAL CONSUMER DISCOUNT RATES

The Department of Energy (DOE) derived consumer discount rates for the life-cycle cost (LCC) analysis using data on interest or return rates for various types of debt and equity to calculate a real effective discount rate for each household in the Federal Reserve Board's *Survey of Consumer Finances* (*SCF*) in 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019.[1] To account for variation among households in rates for each of the types, DOE sampled a rate for each household in its building sample from a distribution of discount rates for each of six income groups. This appendix describes the distributions used.

8H.1.1 Distribution of Rates for Equity Classes

Figure 8H.1.1 through Figure 8H.1.6 show the distribution of real interest rates for different types of equity. Data for equity classes are not available from the Federal Reserve Board's *SCF*, so DOE derived data for these classes from national-level historical data (1993-2022). The rates for stocks are the annual returns on the Standard and Poor's 500 for 1993-2022.[2] The interest rates associated with AAA corporate bonds were collected from Moody's time-series data for 1993-2022.[3] Rates on Certificates of Deposit (CDs) accounts came from Cost of Savings Index (COSI) data covering 1993-2022.[4,a] The interest rates associated with state and local bonds (20-bond municipal bonds) were collected from Federal Reserve Board economic data time-series for 1993-2016, Bartel Associates for 2017-2021, and WM Financial Strategies for 2022.[10,11,12,b] The interest rates associated with treasury bills (30-Year treasury constant maturity rate) were collected from Federal Reserve Board economic data time-series for 1993–2022.[13] Rates for money market accounts are based on three-month money market account rates reported by Organization for Economic Cooperation and Development (OECD) from 1993–2022.[14] Rates for savings accounts are assumed to be half the average real money market rate. Rates for mutual funds are a weighted average of the stock rates and the bond rates.[c] The 30-year average nominal interest rates are shown in Table 8H.1.1. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year (see Figure 8H.1.7). In addition, DOE adjusted the nominal rates to real effective rates by accounting for the fact that interest on such equity types is taxable. The capital gains marginal tax rate varies for each household based on income as shown in chapter 8 (the impact of this is not shown in Figure 8H.1.1 through Figure 8H.1.6, which are only adjusted for inflation).

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[a] The Wells COSI is based on the interest rates that the depository subsidiaries of Wells Fargo & Company pay to individuals on certificates of deposit (CDs), also known as personal time deposits. Wells Fargo COSI started in November 2009.[5,6] From July 2007 to October 2009 the index was known as Wachovia COSI[7] and from January 1984 to July 2007 the index was known as GDW (or World Savings) COSI.[8,9]

[b] This index was discontinued in 2016. To calculate the 2017 and after values, DOE used data collected by Bartel Associates and WM Financial Strategies.

[c] SCF reports what type of mutual funds the household has (e.g., stock mutual fund, savings bond mutual fund, etc.). For mutual funds with a mixture of stocks and bonds, the mutual fund interest rate is a weighted average of the stock rates (two-thirds weight) and the savings bond rates (one-third weight).

Table 8H.1.1 30-Year Average Nominal Interest Rates for Household Equity Type

Type of Equity	30 Year Average Nominal Rate (%)
Savings accounts	2.54
Money market accounts	2.60
Certificate of deposit	2.76
Treasury Bills (T-bills)	4.47
State/Local bonds	4.46
AAA Corporate Bonds	5.34
Stocks (S&P 500)	11.13
Mutual funds	8.91

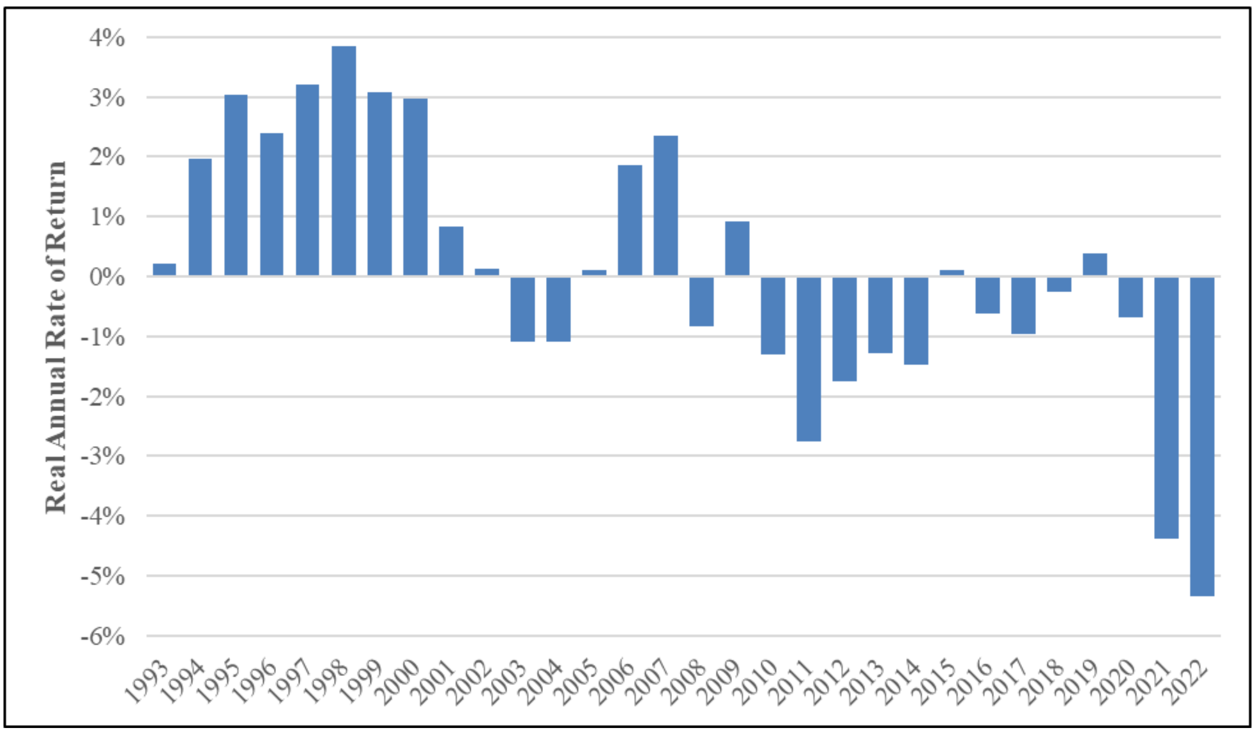

Figure 8H.1.1 Distribution of Annual Rate of Money Market Accounts

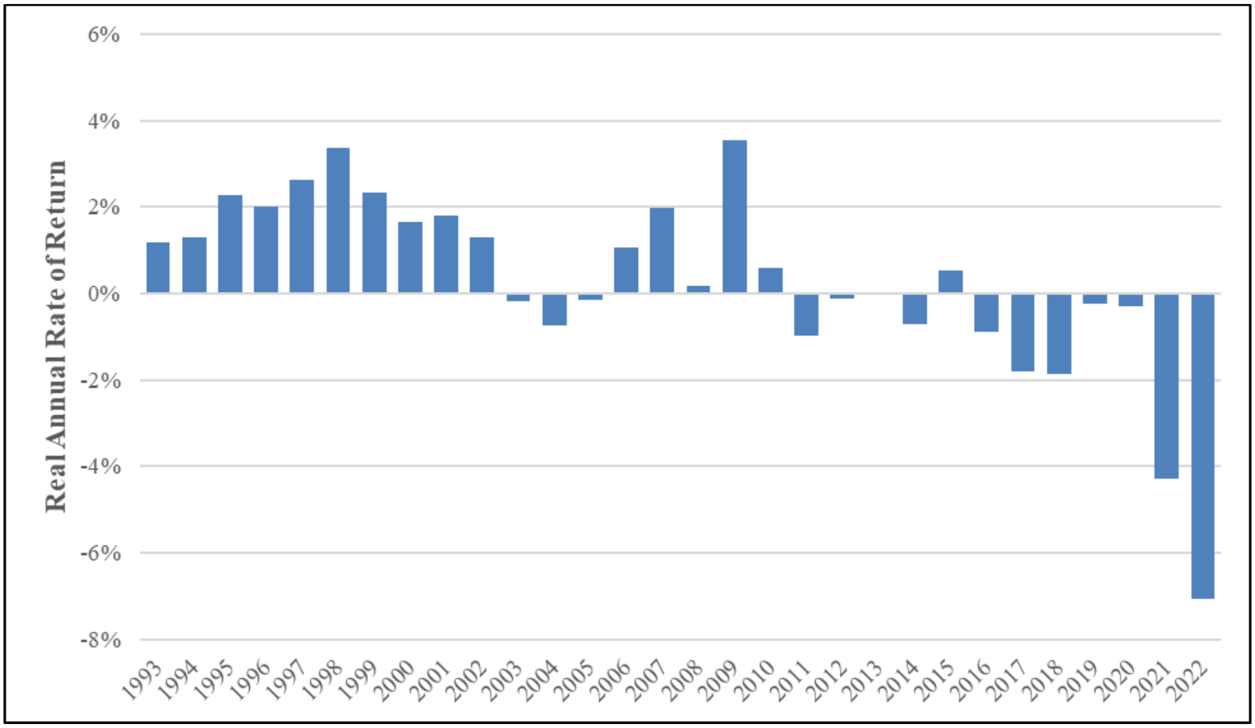

Figure 8H.1.2 Distribution of Annual Rate of Return on CDs

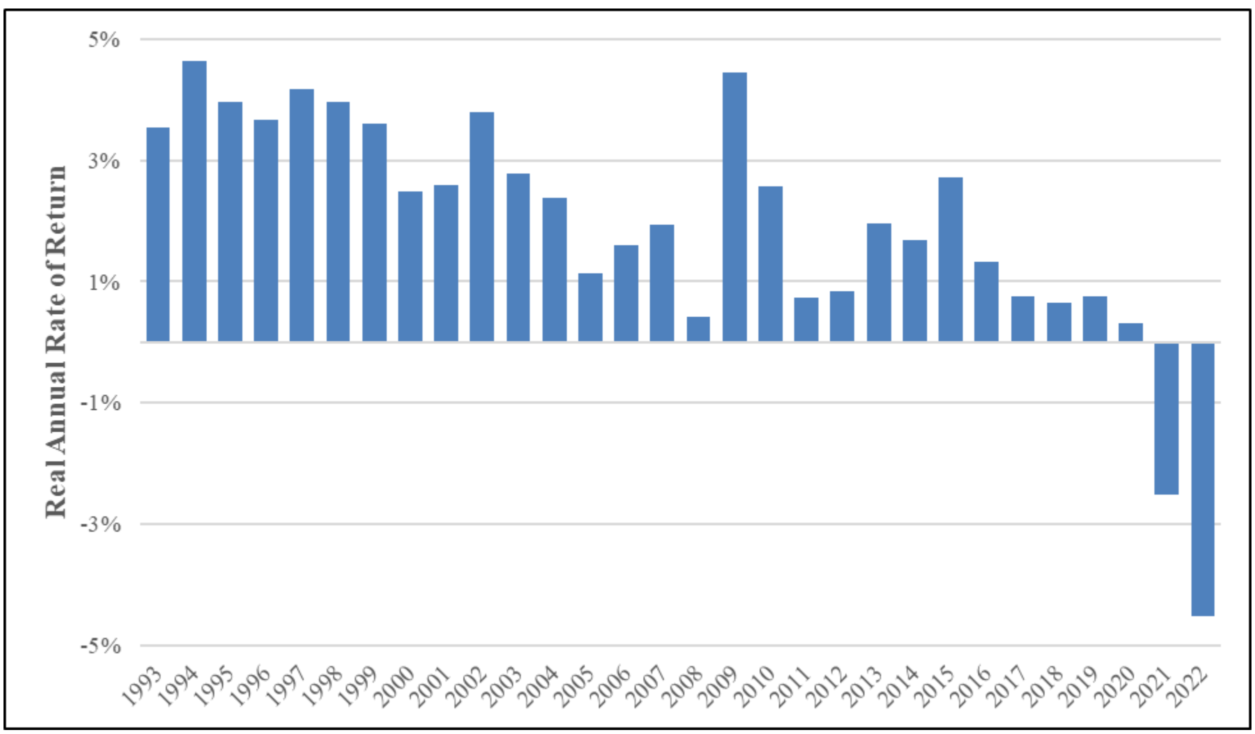

Figure 8H.1.3 Distribution of Annual Rate of Return on Savings Bonds (30 Year Treasury Bills)

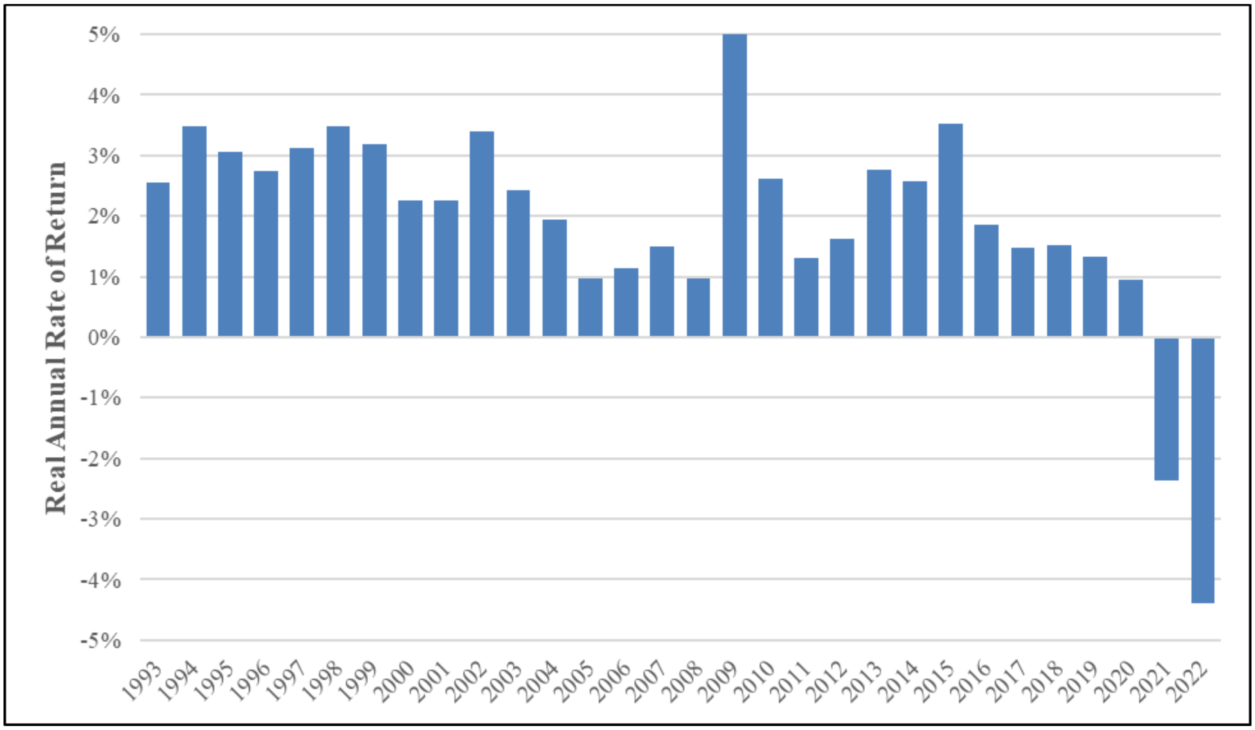

Figure 8H.1.4 Distribution of Annual Rate of State and Local Bonds

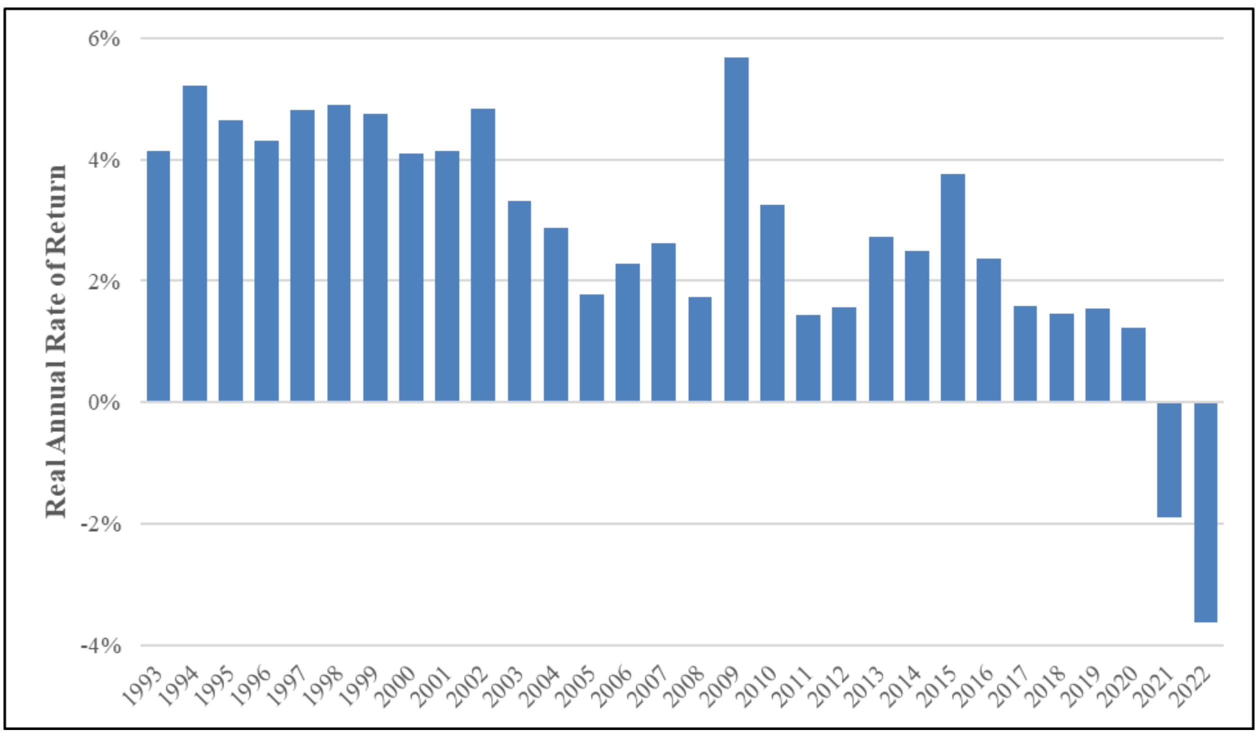

Figure 8H.1.5 Distribution of Annual Rate of Return on Corporate AAA Bonds

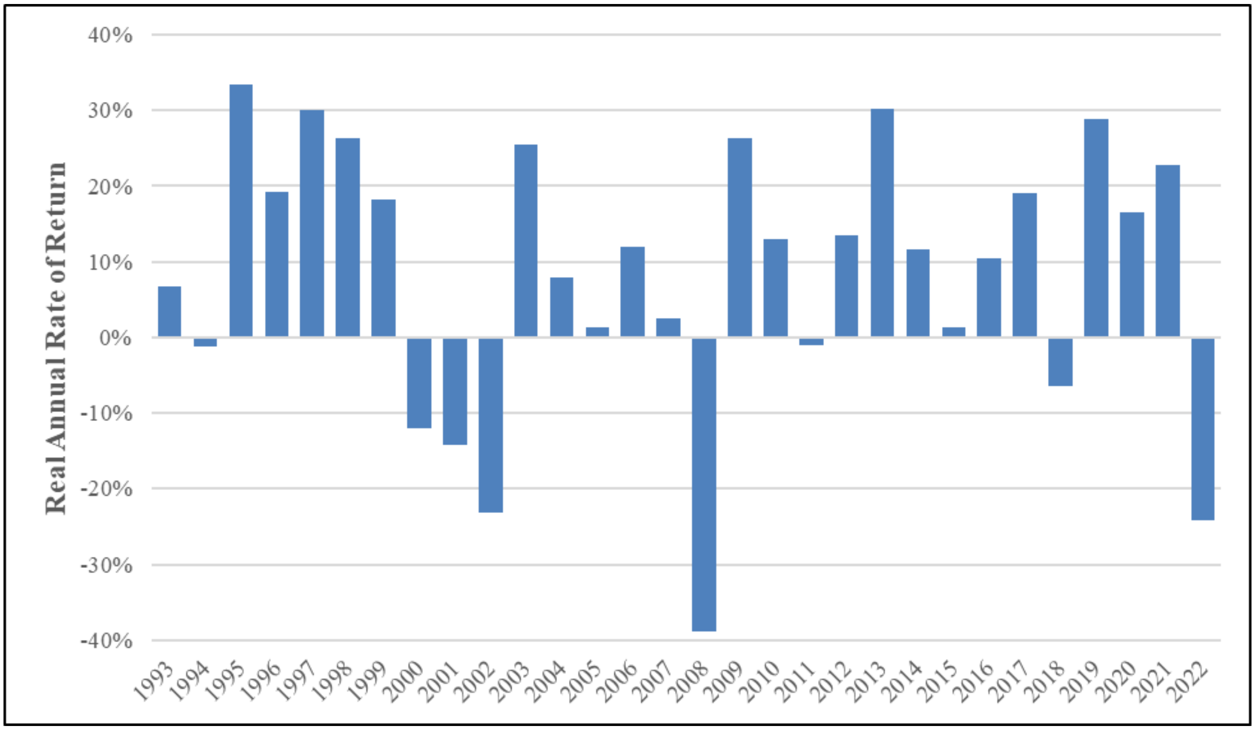

Figure 8H.1.6 Distribution of Annual Rate of Return on S&P 500

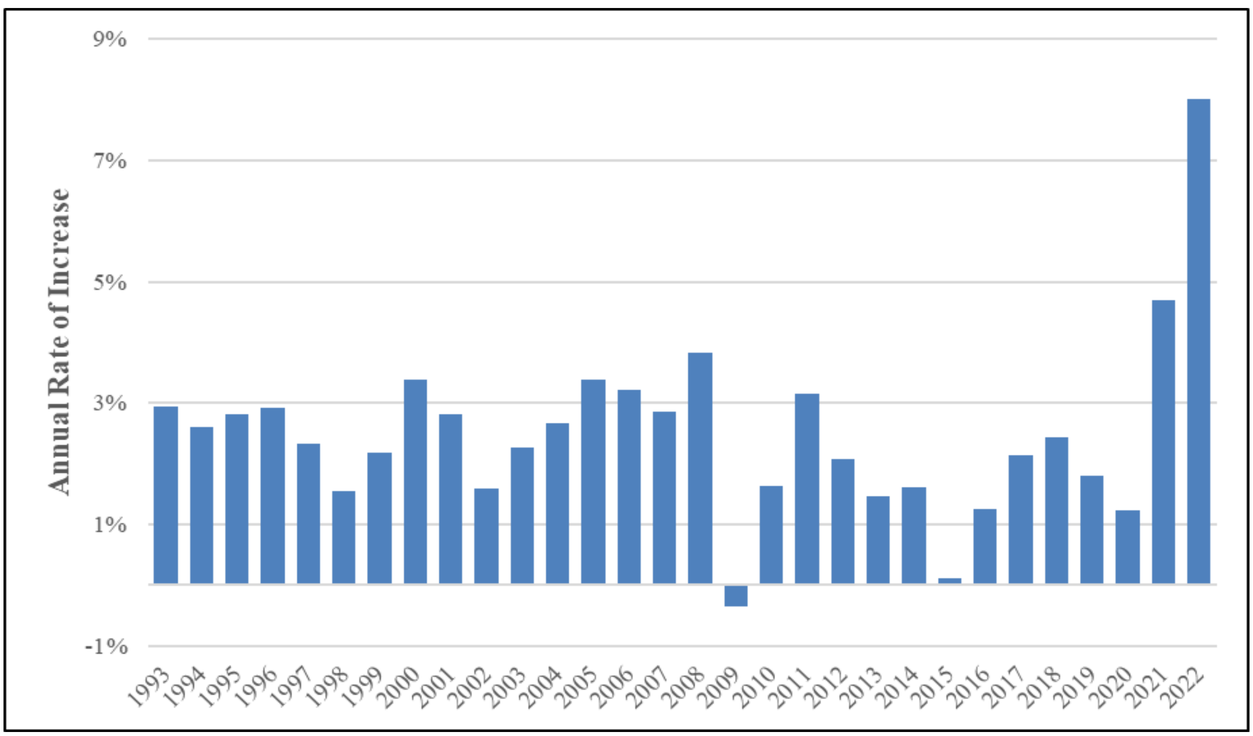

Figure 8H.1.7 Annual Consumer Price Index (CPI) Rate

8H.2 DISTRIBUTION OF REAL EFFECTIVE DISCOUNT RATES BY INCOME GROUP

Real effective discount rates were calculated for each household of the SCF using the method described in chapter 8. Interest rates for asset types were as described in 8H.1.1. The data source for the interest rates for mortgages, home equity loans, credit cards, installment loans, other residence loans, and other lines of credit is the Federal Reserve Board's *SCF* in 1995, 1998, 2001, 2004, 2007, 2010, 2013, 2016, and 2019. DOE adjusted the nominal rates to real rates using the annual inflation rate in each year.

Using the appropriate *SCF* data for each year, DOE adjusted the nominal mortgage interest rate and the nominal home equity loan interest rate for each relevant household in the *SCF* for mortgage tax deduction and inflation. In cases where the effective interest rate is equal to or below the inflation rate (resulting in a negative real interest rate), DOE set the real effective interest rate to zero. Figure 8H.2.1 provides a graphical representation of the real effective discount rate distributions by income group, while Table 8H.2.1 provides the full distributions as used in the LCC analysis.

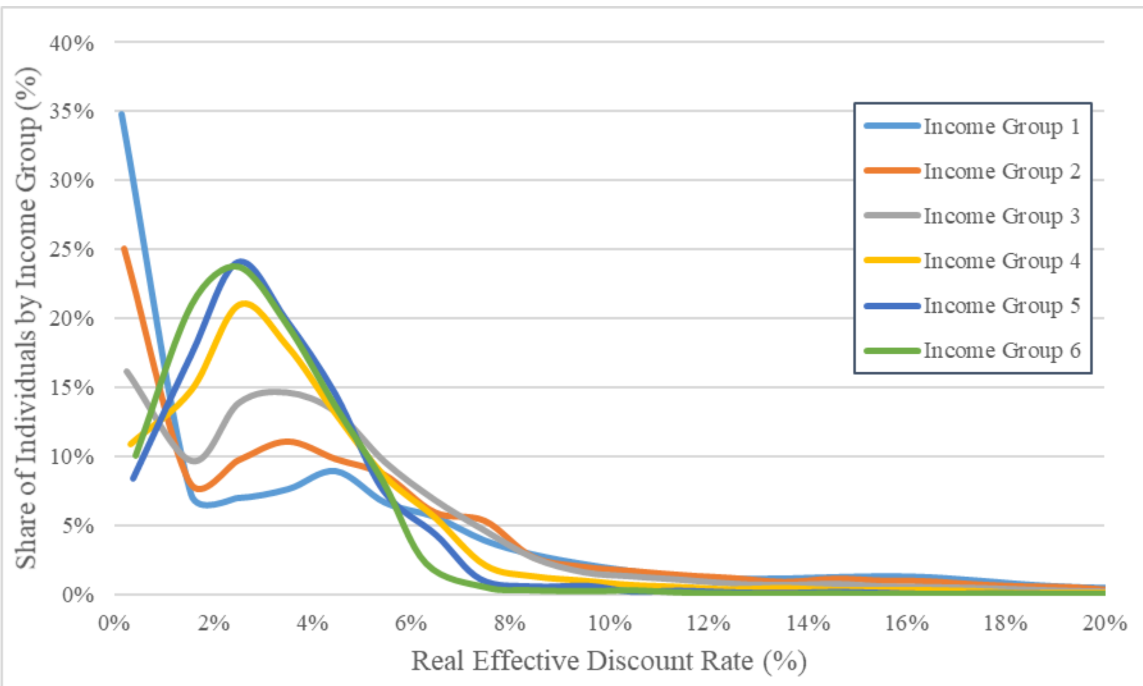

Figure 8H.2.1 Distribution of Real Discount Rates by Income Group

Table 8H.2.1 Distribution of Real Discount Rates by Income Group

DR Bin (%)	Income Group 1 (0-19.9 percentile)		Income Group 2 (20-39.9 percentile)		Income Group 3 (40-59.9 percentile)		Income Group 4 (60-79.9 percentile)		Income Group 5 (80-89.9 percentile)		Income Group 6 (90-100 percentile)	
	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %	Rate %	Weight %
0-1	0.14	34.80	0.20	25.09	0.25	16.13	0.32	10.88	0.39	8.43	0.44	10.04
1-2	1.55	7.25	1.52	8.17	1.56	9.65	1.55	14.81	1.55	17.35	1.57	20.96
2-3	2.48	6.97	2.51	9.73	2.52	13.86	2.52	21.01	2.50	24.12	2.51	23.72
3-4	3.51	7.62	3.49	11.09	3.48	14.61	3.49	18.02	3.48	19.92	3.48	19.61
4-5	4.47	8.92	4.48	9.82	4.48	13.20	4.46	13.13	4.47	14.56	4.47	13.66
5-6	5.47	6.63	5.45	8.69	5.47	9.57	5.46	8.57	5.44	7.55	5.44	8.16
6-7	6.48	5.59	6.47	5.95	6.48	6.81	6.47	5.61	6.51	4.31	6.31	2.22
7-8	7.48	3.89	7.48	5.33	7.43	4.72	7.49	2.11	7.40	1.12	7.51	0.49
8-9	8.44	2.89	8.45	2.71	8.47	2.63	8.49	1.29	8.44	0.59	8.40	0.28
9-10	9.53	2.15	9.49	1.99	9.49	1.58	9.48	0.99	9.58	0.62	9.62	0.22
10-11	10.51	1.64	10.45	1.69	10.44	1.29	10.43	0.68	10.44	0.22	10.47	0.28
11-12	11.49	1.17	11.52	1.38	11.52	1.03	11.56	0.51	11.40	0.28	11.56	0.11
12-13	12.52	1.12	12.47	1.18	12.54	0.75	12.47	0.35	12.47	0.16	12.34	0.06
13-14	13.54	1.13	13.53	0.90	13.50	0.66	13.52	0.44	13.48	0.12	13.50	0.02
14-15	14.51	1.23	14.56	1.13	14.59	0.73	14.50	0.31	14.54	0.18	14.44	0.06
15-16	15.55	1.29	15.55	0.98	15.53	0.56	15.47	0.31	15.42	0.13	15.52	0.02
16-17	16.49	1.22	16.41	0.95	16.46	0.51	16.43	0.30	16.17	0.06	16.39	0.01
17-18	17.58	0.95	17.51	0.70	17.52	0.44	17.48	0.21	17.53	0.06	17.93	0.03
18-19	18.42	0.70	18.47	0.56	18.41	0.33	18.35	0.09	18.47	0.06	18.49	0.01
19-20	19.45	0.51	19.40	0.50	19.45	0.22	19.60	0.09	19.39	0.05	19.16	0.01
20-21	20.56	0.44	20.41	0.26	20.38	0.18	20.45	0.09	20.47	0.04	20.13	0.02
21-22	21.43	0.54	21.43	0.34	21.34	0.16	21.47	0.07	21.38	0.06	0.00	0.00
22-23	22.49	0.39	22.48	0.23	22.58	0.08	22.72	0.03	0.00	0.00	0.00	0.00
23-24	23.41	0.17	23.52	0.13	23.40	0.10	23.44	0.02	0.00	0.00	23.89	0.03
24-25	24.65	0.18	24.46	0.10	24.55	0.04	24.07	0.01	0.00	0.00	0.00	0.00
25-26	25.35	0.16	25.40	0.10	25.47	0.06	25.33	0.03	25.79	0.00	0.00	0.00
26-27	26.52	0.13	26.46	0.03	26.50	0.05	0.00	0.00	0.00	0.00	0.00	0.00
27-28	27.49	0.07	27.40	0.02	27.41	0.03	27.27	0.03	27.14	0.00	0.00	0.00
28-29	28.14	0.09	28.29	0.05	28.38	0.01	0.00	0.00	0.00	0.00	0.00	0.00
29-30	29.87	0.01	29.37	0.01	29.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
>30	68.17	0.14	125.34	0.19	135.27	0.02	53.80	0.00	0.00	0.00	0.00	0.00
Total	4.63	100.00	4.86	100.00	4.41	100.00	3.71	100.00	3.34	100.00	3.01	100.00

8H.3 DISTRIBUTIONS USED FOR COMMERCIAL/INDUSTRIAL DISCOUNT RATES

Table 8H.3.1 Education Sector Discount Rate Distribution

Bin	Bin Range	Rates (%)	Weight (% of companies)	# of Companies
1	<0%			
2	≥0 to <1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	5.35	16.2	141
8	6-7%	6.62	36.8	320
9	7-8%	7.39	15.4	134
10	8-9%	8.40	19.1	166
11	9-10%	9.36	12.4	108
12	10-11%			
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**7.21**		

Table 8H.3.2 Food Sales Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%	3.91	6.0	55
6	4-5%	4.64	36.4	336
7	5-6%	5.48	29.5	272
8	6-7%	6.34	14.0	129
9	7-8%	7.59	3.6	33
10	8-9%	8.79	5.4	50
11	9-10%	9.53	3.6	33
12	10-11%	10.30	1.6	15
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**5.68**		

Table 8H.3.3 Food Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.80	4.8	95
7	5-6%	5.51	36.4	720
8	6-7%	6.61	31.0	614
9	7-8%	7.24	16.8	332
10	8-9%	8.30	3.5	70
11	9-10%	9.80	4.0	79
12	10-11%			
13	11-12%	11.10	3.5	70
14	12-13%			
15	≥13%			
Weighted Average		**6.58**		

Table 8H.3.4 Health Care Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5			
7	5-6	5.61	29.6	1782
8	6-7	6.47	23.1	1390
9	7-8	7.45	22.5	1353
10	8-9	8.25	13.4	808
11	9-10	9.17	11.5	690
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**6.99**		

Table 8H.3.5 Lodging Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5	4.74	19.2	337
7	5-6	5.40	18.6	326
8	6-7	6.48	21.9	385
9	7-8	7.25	27.7	485
10	8-9	8.40	5.1	89
11	9-10			
12	10-11	10.00	3.8	66
13	11-12	11.30	3.8	66
14	12-13			
15	≥13			
Weighted Average		**6.57**		

Table 8H.3.6 Mercantile Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5	4.55	0.5	29
7	5-6	5.66	19.3	1145
8	6-7	6.53	28.7	1703
9	7-8	7.45	36.6	2170
10	8-9	8.23	8.9	525
11	9-10	9.45	3.9	231
12	10-11	10.28	1.8	106
13	11-12	11.50	0.3	16
14	12-13			
15	≥13			
Weighted Average		**7.03**		

Table 8H.3.7 Office Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4	3.81	6.1	3068
6	4-5	4.53	14.9	7496
7	5-6	5.46	23.3	11698
8	6-7	6.46	12.8	6399
9	7-8	7.43	10.3	5148
10	8-9	8.55	13.3	6695
11	9-10	9.35	11.9	5965
12	10-11	10.41	3.5	1745
13	11-12	11.40	1.7	828
14	12-13	12.88	1.6	786
15	≥13	14.33	0.7	342
Weighted Average		**6.87**		

Table 8H.3.8 Public Assembly Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5			
7	5-6	5.66	11.0	442
8	6-7	6.54	34.8	1403
9	7-8	7.44	27.0	1088
10	8-9	8.49	15.7	635
11	9-10	9.25	11.5	465
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**7.31**		

Table 8H.3.9 Service Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3	2.30	1.3	223
5	3-4	3.87	4.9	818
6	4-5	4.45	13.0	2151
7	5-6	5.58	32.9	5438
8	6-7	6.45	20.2	3332
9	7-8	7.54	11.9	1968
10	8-9	8.50	9.1	1496
11	9-10	9.15	5.6	925
12	10-11	10.23	1.1	179
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**6.23**		

Table 8H.3.10 All Commercial Sectors Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3	2.30	0.3	223
5	3-4	3.83	4.5	3941
6	4-5	4.53	11.9	10523
7	5-6	5.52	24.9	22021
8	6-7	6.48	17.7	15676
9	7-8	7.44	14.4	12732
10	8-9	8.50	11.9	10534
11	9-10	9.31	9.6	8496
12	10-11	10.38	2.4	2111
13	11-12	11.37	1.1	980
14	12-13	12.88	0.9	786
15	≥13	14.33	0.4	342
Weighted Average		**6.76**		

Table 8H.3.11 Industrial Sectors Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2	1.60	0.0	13
4	2-3	2.73	0.1	76
5	3-4	3.71	1.7	1411
6	4-5	4.60	5.8	4889
7	5-6	5.56	19.2	16305
8	6-7	6.49	18.5	15686
9	7-8	7.53	16.8	14236
10	8-9	8.48	22.0	18674
11	9-10	9.37	11.1	9383
12	10-11	10.44	3.9	3338
13	11-12	11.69	0.4	306
14	12-13	12.52	0.3	285
15	≥13	13.10	0.1	121
Weighted Average		**7.29**		

Table 8H.3.12 Agriculture Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5			
7	5-6			
8	6-7	6.68	60.0	207
9	7-8	7.34	20.3	70
10	8-9	8.42	19.7	68
11	9-10			
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**7.16**		

Table 8H.3.13 R.E.I.T./Property Management Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2			
4	2-3			
5	3-4			
6	4-5	4.77	3.6	179
7	5-6	5.46	33.1	1636
8	6-7	6.38	34.2	1690
9	7-8	7.48	13.2	651
10	8-9	8.52	9.7	480
11	9-10	9.41	6.2	308
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**6.56**		

Table 8H.3.14 Investor-Owned Utility Sector Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of companies)	# of Companies
1	<0			
2	0-1			
3	1-2	1.60	0.6	13
4	2-3	2.76	1.5	33
5	3-4	3.69	50.2	1101
6	4-5	4.33	36.2	793
7	5-6	5.43	4.1	91
8	6-7	6.54	4.5	99
9	7-8	7.37	2.9	63
10	8-9			
11	9-10			
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**4.20**		

Table 8H.3.15 State/Local Government Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of years)	# of Quarters
1	<0	-2.4	5.8	8
2	0-1	0.9	2.2	3
3	1-2	1.6	22.6	31
4	2-3	2.5	24.8	34
5	3-4	3.5	34.3	47
6	4-5	4.2	10.2	14
7	5-6			
8	6-7			
9	7-8			
10	8-9			
11	9-10			
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**2.51**		

Table 8H.3.16 Federal Government Discount Rate Distribution

Bin	Bin Range (%)	Bin Average Discount Rate (%)	Weight (% of months)	# of Months
1	<0	-0.6	11.0	45
2	0-1	0.5	22.8	93
3	1-2	1.6	16.2	66
4	2-3	2.5	17.6	72
5	3-4	3.5	17.6	72
6	4-5	4.3	11.8	48
7	5-6	5.8	2.9	12
8	6-7			
9	7-8			
10	8-9			
11	9-10			
12	10-11			
13	11-12			
14	12-13			
15	≥13			
Weighted Average		**2.03**		

8H.4 ASSIGNMENT OF DETAILED DATA TO AGGREGATE SECTORS FOR DISCOUNT RATE ANALYSIS

Table 8H.4.1 Detailed Industries Assigned to Each Aggregate CBECS PBA Sector

Aggregate Sector for CBECS Mapping	Detailed Sector Names as Provided in Damodaran Online Data Sets (1998-2018)
Education	Education; Educational Services
Food Sales	Food Wholesalers; Grocery; Retail (Grocery and Food); Retail/Wholesale Food
Food Service	Restaurant; Restaurant/Dining
Health Care	Healthcare Facilities; Healthcare Information; Healthcare Services; Healthcare Support Services; Healthcare Information and Technology; Hospitals/Healthcare Facilities; Medical Services
Lodging	Hotel/Gaming
Mercantile	Drugstore; Retail (Automotive); Retail (Building Supply); Retail (Distributors); Retail (General); Retail (Hardlines); Retail (Softlines); Retail (Special Lines); Retail Automotive; Retail Building Supply; Retail Store
Office	Advertising; Bank; Bank (Canadian); Bank (Midwest); Bank (Money Center); Banks (Regional); Broadcasting; Brokerage & Investment Banking; Business & Consumer Services; Cable TV; Computer Services; Computer Software; Computer Software/Svcs; Diversified; Diversified Co.; E-Commerce; Human Resources; Insurance (General); Insurance (Life); Insurance (Prop/Cas.); Internet; Investment Co.; Investment Co.(Foreign); Investment Companies; Investments & Asset Management; Property Management; Public/Private Equity; R.E.I.T.; Real Estate (Development); Real Estate (General/Diversified); Real Estate (Operations & Services); Reinsurance; Retail (Internet); Retail (Online); Securities Brokerage; Software (Entertainment); Software (Internet); Software (System & Application); Telecom. Utility; Thrift
Public Assembly	Entertainment; Recreation
Service	Financial Svcs.; Financial Svcs. (Div.); Financial Svcs. (Non-bank & Insurance); Foreign Telecom.; Funeral Services; Industrial Services; Information Services; Internet software and services; IT Services; Office Equip/Supplies; Office Equipment & Services; Oilfield Svcs/Equip.; Pharmacy Services; Telecom. Services
All Commercial	All detailed sectors included in: Education, Food Sales, Food Service, Health Care, Mercantile, Office, Public Assembly, Service
Industrial	Aerospace/Defense; Air Transport; Aluminum; Apparel; Auto & Truck; Auto Parts; Auto Parts (OEM); Auto Parts (Replacement); Automotive; Beverage; Beverage (Alcoholic); Beverage (Soft); Biotechnology; Building Materials; Cement & Aggregates; Chemical (Basic); Chemical (Diversified); Chemical (Specialty); Coal; Coal & Related Energy; Computers/Peripherals; Construction; Construction Supplies; Copper; Drug; Drugs (Biotechnology); Drugs (Pharmaceutical); Electric Util. (Central); Electric Utility (East); Electric Utility (West); Electrical Equipment; Electronics; Electronics (Consumer & Office); Electronics (General); Engineering; Engineering & Const; Engineering/Construction; Entertainment Tech; Environmental; Environmental & Waste Services; Food Processing; Foreign Electronics; Furn/Home Furnishings; Gold/Silver Mining; Green & Renewable

Aggregate Sector for CBECS Mapping	Detailed Sector Names as Provided in Damodaran Online Data Sets (1998-2018)
	Energy; Healthcare Equipment; Healthcare Products; Heavy Construction; Heavy Truck & Equip; Heavy Truck/Equip Makers; Home Appliance; Homebuilding; Household Products; Machinery; Manuf. Housing/RV; Maritime; Med Supp Invasive; Med Supp Non-Invasive; Medical Supplies; Metal Fabricating; Metals & Mining; Metals & Mining (Div.); Natural Gas (Div.); Natural Gas Utility; Newspaper; Oil/Gas (Integrated); Oil/Gas (Production and Exploration); Oil/Gas Distribution; Packaging & Container; Paper/Forest Products; Petroleum (Integrated); Petroleum (Producing); Pharma & Drugs; Pipeline MLPs; Power; Precious Metals; Precision Instrument; Publishing; Publishing & Newspapers; Railroad; Rubber& Tires; Semiconductor; Semiconductor Equip; Shipbuilding & Marine; Shoe; Steel; Steel (General); Steel (Integrated); Telecom (Wireless); Telecom. Equipment; Textile; Tire & Rubber; Tobacco; Toiletries/Cosmetics; Transportation; Transportation (Railroads); Trucking; Utility (Foreign); Utility (General); Utility (Water); Water Utility; Wireless Networking
Agriculture	Farming/Agriculture
Utilities	Natural Gas Utility; Utility (Foreign); Utility (General); Utility (Water); Water Utility
R.E.I.T. / Property	Property Management; R.E.I.T.; Real Estate (Development); Real Estate (General/Diversified); Real Estate (Operations & Services)

8H.5 SMALL BUSINESS DISCOUNT RATE DISTRIBUTIONS BY SECTOR

Table 8H.5.1 Education Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	≥0 to <1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.70%	3.9%	34
11	9-10%	9.22%	26.2%	228
12	10-11%	10.54%	44.9%	390
13	11-12%	11.62%	21.1%	183
14	12-13%	12.20%	3.9%	34
15	≥13%			
Weighted Average		**10.41%**		

Table 8H.5.2 Food Sales Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	6.00%	2.7%	25
8	6-7%	6.64%	8.6%	79
9	7-8%	7.49%	51.4%	474
10	8-9%	8.38%	18.3%	169
11	9-10%	9.21%	5.2%	48
12	10-11%	10.46%	5.2%	48
13	11-12%	11.84%	7.0%	65
14	12-13%	0.00%	0.0%	0
15	≥13%	14.20%	1.6%	15
Weighted Average		**8.20%**		

Table 8H.5.3 Food Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%	8.00%	4.8%	95
10	8-9%	8.51%	34.3%	679
11	9-10%	9.45%	38.2%	757
12	10-11%	10.10%	7.5%	149
13	11-12%	11.68%	7.6%	151
14	12-13%	12.20%	4.0%	79
15	≥13%	13.50%	3.5%	70
Weighted Average		**9.53%**		

Table 8H.5.4 Health Care Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%	7.62%	3.6%	218
10	8-9%	8.57%	33.3%	2007
11	9-10%	9.38%	19.6%	1183
12	10-11%	10.45%	21.6%	1302
13	11-12%	11.67%	17.6%	1063
14	12-13%	12.70%	1.9%	112
15	≥13%	13.80%	2.3%	138
Weighted Average		**9.84%**		

Table 8H.5.5 Lodging Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.56%	16.5%	290
9	7-8%	7.53%	16.0%	280
10	8-9%	8.49%	16.2%	284
11	9-10%	9.40%	30.8%	540
12	10-11%	10.51%	9.0%	158
13	11-12%	11.64%	7.8%	136
14	12-13%			
15	≥13%	13.40%	3.8%	66
Weighted Average		**8.91%**		

Table 8H.5.6 Mercantile Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%	6.90%	0.3%	15
9	7-8%	7.74%	0.7%	43
10	8-9%	8.74%	13.0%	769
11	9-10%	9.53%	45.8%	2711
12	10-11%	10.32%	29.4%	1741
13	11-12%	11.56%	7.6%	453
14	12-13%	12.33%	2.5%	147
15	≥13%	13.97%	0.8%	46
Weighted Average		**9.90%**		

Table 8H.5.7 Office Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%	4.25%	0.9%	433
7	5-6%	5.72%	4.6%	2297
8	6-7%	6.39%	9.8%	4940
9	7-8%	7.51%	17.8%	8947
10	8-9%	8.57%	14.4%	7201
11	9-10%	9.41%	11.1%	5569
12	10-11%	10.39%	10.5%	5280
13	11-12%	11.57%	11.1%	5544
14	12-13%	12.50%	10.1%	5070
15	≥13%	14.72%	9.7%	4889
Weighted Average		**9.61%**		

Table 8H.5.8 Public Assembly Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.56%	21.0%	847
11	9-10%	9.52%	30.9%	1245
12	10-11%	10.48%	24.9%	1003
13	11-12%	11.85%	19.3%	778
14	12-13%	12.33%	4.0%	160
15	≥13%			
Weighted Average		**10.12%**		

Table 8H.5.9 Service Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%	2.70%	1.3%	223
5	3-4%			
6	4-5%	4.36%	8.1%	1341
7	5-6%	5.68%	6.0%	993
8	6-7%	6.33%	12.5%	2074
9	7-8%	7.11%	6.0%	993
10	8-9%	8.51%	20.3%	3355
11	9-10%	9.43%	23.8%	3933
12	10-11%	10.50%	9.9%	1643
13	11-12%	11.57%	6.3%	1039
14	12-13%	12.34%	4.0%	654
15	≥13%	13.26%	1.7%	282
Weighted Average		**8.41%**		

Table 8H.5.10 All Commercial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%	2.70%	0.3%	223
5	3-4%			
6	4-5%	4.33%	2.0%	1774
7	5-6%	5.71%	3.8%	3315
8	6-7%	6.39%	8.4%	7431
9	7-8%	7.48%	12.6%	11107
10	8-9%	8.56%	17.4%	15412
11	9-10%	9.44%	18.3%	16214
12	10-11%	10.41%	13.3%	11715
13	11-12%	11.61%	10.7%	9412
14	12-13%	12.47%	7.1%	6256
15	≥13%	14.59%	6.2%	5506
Weighted Average		**9.42%**		

Table 8H.5.11 Industrial Sectors Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%	3.00%	0.0%	13
5	3-4%	3.80%	0.0%	16
6	4-5%	4.66%	0.3%	281
7	5-6%	5.60%	1.8%	1500
8	6-7%	6.55%	2.9%	2472
9	7-8%	7.59%	9.5%	8062
10	8-9%	8.50%	12.3%	10426
11	9-10%	9.47%	17.1%	14473
12	10-11%	10.49%	20.3%	17233
13	11-12%	11.47%	18.1%	15354
14	12-13%	12.53%	12.2%	10317
15	≥13%	14.20%	5.4%	4576
Weighted Average		**10.20%**		

Table 8H.5.12 Agriculture Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%			
8	6-7%			
9	7-8%			
10	8-9%	8.64%	31.0%	107
11	9-10%	9.31%	28.1%	97
12	10-11%	10.64%	40.9%	141
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**9.65%**		

Table 8H.5.13 R.E.I.T./Property Management Sector Discount Rate Distribution

Bin	Bin Range	Bin Average Discount Rate	Weight (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%			
5	3-4%			
6	4-5%			
7	5-6%	5.80%	0.3%	16
8	6-7%	6.49%	2.3%	114
9	7-8%	7.70%	20.4%	1011
10	8-9%	8.35%	34.9%	1724
11	9-10%	9.44%	21.7%	1075
12	10-11%	10.38%	12.0%	593
13	11-12%	11.44%	8.1%	400
14	12-13%	12.60%	0.2%	11
15	≥13%			
Weighted Average		**8.91%**		

Table 8H.5.14 Investor-Owned Utility Sector Discount Rate Distribution

Bin	Bin Range	Rates	Distribution (% of companies)	# of Companies
1	<0%			
2	0-1%			
3	1-2%			
4	2-3%	3.00%	0.6%	13
5	3-4%	3.80%	0.7%	16
6	4-5%	4.72%	9.8%	216
7	5-6%	5.62%	37.8%	830
8	6-7%	6.43%	34.3%	753
9	7-8%	7.35%	8.2%	180
10	8-9%	8.72%	2.6%	58
11	9-10%	9.44%	5.1%	111
12	10-11%	10.30%	0.7%	16
13	11-12%			
14	12-13%			
15	≥13%			
Weighted Average		**6.23%**		

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APPENDIX 8I. NO-NEW-STANDARDS CASE DISTRIBUTION OF EFFICIENCY LEVELS

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APPENDIX 8I. NO-NEW-STANDARDS CASE DISTRIBUTION OF EFFICIENCY LEVELS

8I.1 INTRODUCTION

To estimate the share of consumers affected by a potential standard at a particular efficiency level, the Department of Energy's (DOE) LCC and PBP analysis considers the projected distribution (i.e., market shares) of product efficiencies that consumers will purchase in the first compliance year, without amended energy conservation standards (no-new-standards case). DOE derived no-new-standards case efficiency distributions of efficiency levels, recognizing that consumer's already purchasing products at efficiencies greater than or equal to a prospective standard level are not impacted by the standard. This appendix describes the distributions used.

DOE did not have access to sales data describing the actual distribution of efficiencies in current sales, nor was such information provided by industry for this rulemaking. As a consequence, DOE developed estimates of the distribution of efficiency levels for gas-fired instantaneous water heaters (GIWHs). The development of these distributions was based on the following key data inputs:

- Air-conditioning, Heating, and Refrigeration Institute (AHRI) [a] submitted historical shipment data by efficiency,[1]
- ENERGY STAR unit shipments data,[2]
- 2023 BRG Building Solutions report.[3]
- Consumer water heater models database based on AHRI certification directory[4] and DOE's public Certification Compliance Database (CCD)[5] with other publicly available data from manufacturers' catalogs.

8I.2 HISTORICAL EFFICIENCY DISTRIBUTIONS BASED ON SHIPMENTS

DOE used historical shipment data for consumer water heaters provided by AHRI, ENERGY STAR, and BRG Building Solutions. Data from both AHRI and BRG Building Solutions is confidential data, but ENERGY STAR unit shipments data is publicly available. BRG Building Solutions data shows a less than 1 percent market share for condensing gas-fired storage water heaters, 15-20 percent market share for power vented gas-fired storage water heaters, and more than 50 percent market share for condensing gas-fired instantaneous water heaters. The ENERGY STAR unit shipment data and specifications for consumer water heaters is summarized in the Figure 8I.2.1 and Table 8I.2.1, respectively.

[a] Previously known as Gas Appliance Manufacturers Association (GAMA).

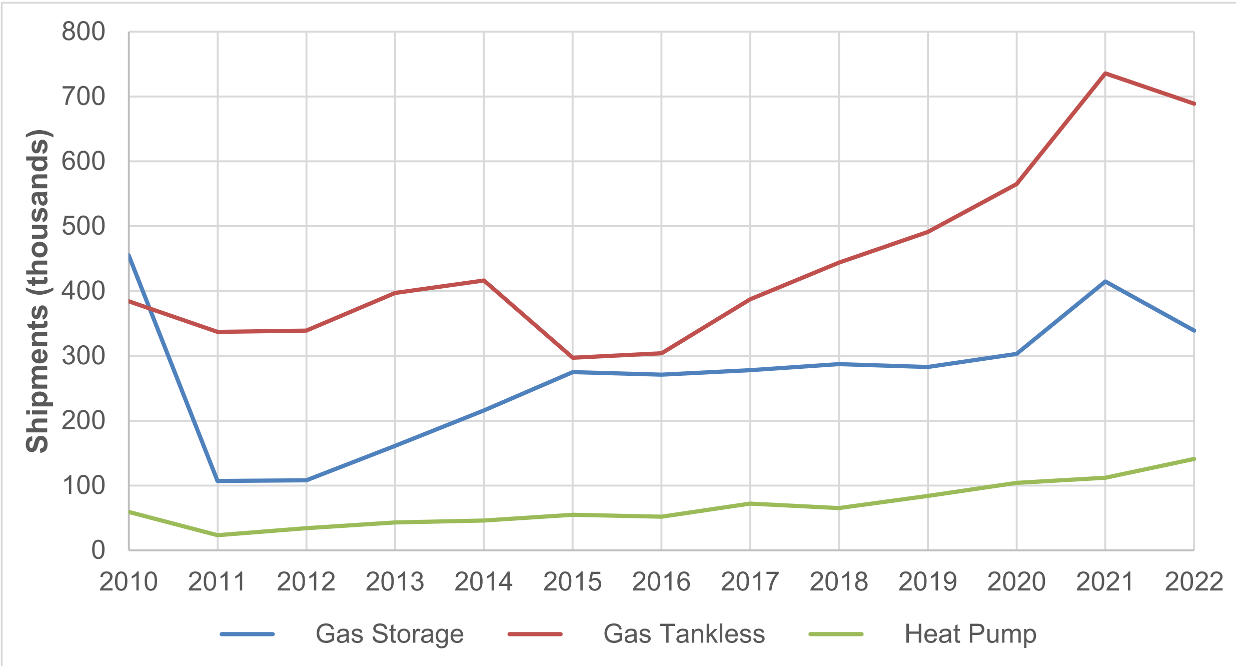

Figure 8I.2.1 ENERGY STAR Consumer Water Heater Unit Shipment Data, 2010-2022

Table 8I.2.1 ENERGY STAR Consumer Water Heater Specifications

Specification Version	Effective Date	Water Heater Type	Efficiency Requirement	First Hour Rating	Warranty
Version 1.0	1/1/2009	Gas-fired Storage (Non-condensing)	EF ≥ 0.62	≥ 67 gal	≥ 6 yrs on sealed system
	9/1/2010		EF ≥ 0.67	≥ 67 gal	≥ 6 yrs on sealed system
	1/1/2009	Gas-fired Storage (Condensing)	EF ≥ 0.80	≥ 67 gal	≥ 8 yrs on sealed system
		Whole Home Gas-fired Tankless	EF ≥ 0.82	≥ 2.5 GPM	≥ 10 yrs HX; ≥ 5 yrs on parts
		Electric Water Heaters	EF > 2.0	≥ 50 gal	≥ 6 yrs on sealed system
Version 2.0	7/1/2013	Gas-fired Storage	EF ≥ 0.67	≥ 67 gal	≥ 6 yrs on sealed system
		No other major changes to specifications for other WH types.			
Version 3.2	4/16/2015	Gas-fired Storage (⩽ 55 gal)	UEF ⩾ 0.64 (med draw); UEF ⩾ 0.68 (high draw)	≥ 67 gal	≥ 6 yrs on sealed system
		Gas-fired Storage (> 55 gal)	UEF ⩾ 0.78 (med draw); UEF ⩾ 0.80 (high draw)	≥ 67 gal	≥ 6 yrs on sealed system
		Whole Home Gas-fired Tankless	UEF ⩾ 0.87	≥ 2.9 GPM	≥ 6 yrs HX; ≥ 5 yrs on parts
		Electric Water Heaters	UEF ⩾ 2.00 (⩽ 55 gal); UEF ⩾ 2.20 (> 55 gal)	≥ 45 gal	≥ 6 yrs on sealed system
Version 4.0	1/5/2022	Gas-fired Storage (⩽ 55 gal)	UEF ⩾ 0.64 (med draw); UEF ⩾ 0.68 (high draw)	≥ 51 gal	≥ 6 yrs on sealed system
		Gas-fired Storage (> 55 gal)	UEF ⩾ 0.78 (med draw); UEF ⩾ 0.80 (high draw)	≥ 51 gal	≥ 6 yrs on sealed system
		Whole Home Gas-fired Tankless	UEF ⩾ 0.87	≥ 2.8 GPM	≥ 6 yrs HX; ≥ 5 yrs on parts
		Electric Water Heaters	UEF ⩾ 3.3 (Integratedl); UEF ⩾ 2.2 (Split or 120V unit)	≥ 45 gal	≥ 6 yrs on sealed system

8I.3 EFFICIENCY DISTRIBUTIONS BY MODELS IN 2023

DOE used data on the distribution of models from the AHRI and CCD of models to disaggregate the shipments by efficiency level and draw pattern (shown in Table 8I.3.1).

Table 8I.3.1 Gas-fired Instantaneous Water Heaters in 2023 by Efficiency Level

EL	Low		Medium		High		All Draw Patterns
	UEF*	Market Share	UEF*	Market Share	UEF*	Market Share	
Gas-fired Instantaneous Water Heaters, <2 gal and >50,000 Btu/h							
0			0.81	57%	0.81	33%	37%
1			0.87	14%	0.89	8%	9%
2			0.91	19%	0.93	22%	22%
3			0.92	5%	0.95	24%	21%
4			0.93	5%	0.96	13%	12%

* UEF values based on representative rated volume (see chapter 5).

8I.4 EFFICIENCY DISTRIBUTIONS TRENDS AFTER 2023

DOE used historical shipment data for consumer water heaters provided by AHRI, ENERGY STAR, and BRG Building Solutions, along with stakeholder input, to derive historical trends for higher efficiency options (condensing GIWHs) after 2022 as shown in Figure 8I.4.1. Trends for 2030 are used in the life-cycle cost (LCC) analysis, while the trends from 2030-2059 are used in the shipments analysis and national impact analysis (NIA).

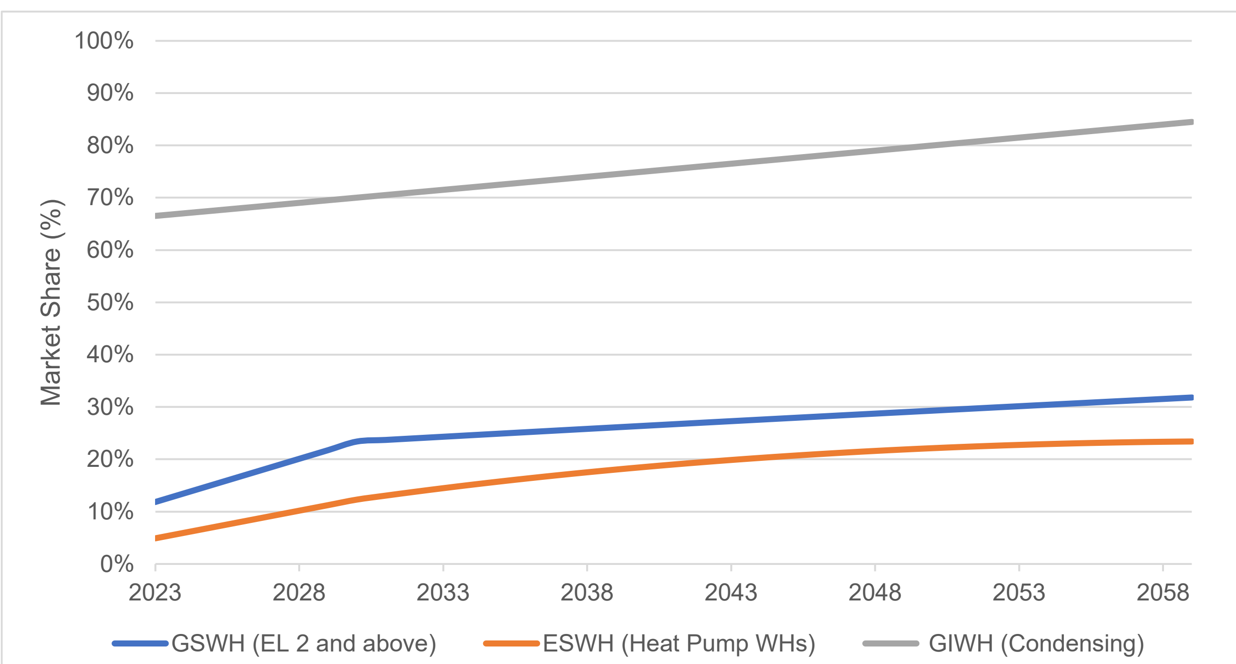

Figure 8I.4.1 Higher Efficiency Water Heater Design Option Market Share, 2023-2059

8I.5 EFFICIENCY DISTRIBUTIONS TRENDS FOR 2030

DOE used historical shipment data, stakeholder input, consultant input, as well as model data to derive the final fractions by efficiency level and draw pattern, as shown in Table 8I.5.1. Efficiency distributions after 2030 are shown in chapter 10.

Table 8I.5.1 Gas-fired Instantaneous Water Heaters in 2030 by Efficiency Level

EL	Low		Medium		High		All Draw Patterns
	UEF*	Market Share	UEF*	Market Share	UEF*	Market Share	
Gas-fired Instantaneous Water Heaters, <2 gal and >50,000 Btu/h							
0			0.81	30%	0.81	30%	30%
1			0.87	8%	0.89	8%	8%
2			0.91	48%	0.93	47%	47%
3			0.92	6%	0.95	7%	7%
4			0.93	8%	0.96	8%	8%

* UEF values based on representative rated volume (see Chapter 5).

8I.6 EFFICIENCY DISTRIBUTION SCENARIO

In the LCC, there are a handful of outcomes with large benefits as a consequence of the assignment methodology. Nevertheless, the median results (instead of the average results) from the LCC continue to show positive LCC savings at the adopted standard levels. However, DOE also considered a sensitivity analysis that eliminated these outcomes with large benefits. Under certain combinations of parameters, particularly in new construction, the total installed cost of a condensing, higher efficiency gas-fired instantaneous water heater can be lower than a non-condensing baseline gas-fired instantaneous water heater (due to the differing vent lengths and material costs). With assignment methodology used by DOE (and the constraints of the market data by efficiency level), there are a handful of individual gas-fired instantaneous water heater LCC consumers assigned a baseline non-condensing gas-fired instantaneous water heater even though a higher efficiency product would cost less. This is a rare outcome and only occurs for approximately 2.5 percent of the sample. In the sensitivity analysis, DOE removed these outlier consumers from the analysis in case they may be overly biasing the overall results. This sensitivity scenario therefore eliminates any instance of a consumer assigned EL 0 even though EL 2 would cost less to install. The resulting average LCC savings are reduced to $87 across the rest of the entire gas-fired instantaneous water heater consumer sample, with 15 percent of consumers experiencing a net cost, 20 percent experiencing a net savings, and 65 percent of consumers not impacted by the rule. Although the average LCC savings are reduced in this sensitivity analysis, and slightly more consumers are negatively impacted by the adopted standards, the average (and median) LCC savings remain positive and there continue to be significant energy and environment savings.[b]

[b] These sensitivity results can be found in the LCC Results spreadsheet.

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APPENDIX 8J. LIFE-CYCLE COST ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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8J.1 INTRODUCTION

This appendix presents life-cycle cost (LCC) results using energy price projections from alternative economic growth scenarios. The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration (EIA)'s *Annual Energy Outlook 2023* (*AEO 2023*).[1]

This appendix describes the High and Low Economic Growth scenarios in further detail. See appendix 8A for details about how to generate LCC results for High Economic Growth and Low Economic Growth scenarios using the LCC spreadsheet.

8J.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate LCC results reported in chapter 8, DOE uses the Reference case energy price projections from *AEO 2023*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. For *AEO 2023*, EIA explored the impacts of alternative assumptions in other scenarios with different macroeconomic growth rates, world oil prices, rates of technology progress, and policy changes.

To reflect uncertainty in the projection of U.S. economic growth, EIA's *AEO 2023* uses High and Low Economic Growth scenarios to project the possible impacts of alternative economic growth assumptions on energy markets. The High Economic Growth scenario incorporates population, labor force and productivity growth rates that are higher than the Reference scenario, while these values are lower for the Low Economic Growth scenario. Economic output as measured by real GDP increases by 1.9 percent per year from 2022 through 2050, in the Reference case, 1.4 percent per year in the Low Economic Growth case, and 2.4 percent per year in the High Economic Growth case.[2]

In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario than they are in the Reference Case. The energy price forecasts affect the operating cost savings at different efficiency levels. Figure 8J.2.1 through Figure 8J.2.3 show the national residential energy price trends for the Reference, High Economic Growth, and Low Economic Growth scenarios. Note that data after 2050 uses a 5-year growth AEO data from 2046 to 2050.

Because *AEO 2023* provides the price trends by census division, each sampled household is matched to the appropriate census division price trend. See appendix 8E for details about how energy price trends by census division are applied in the LCC analysis.

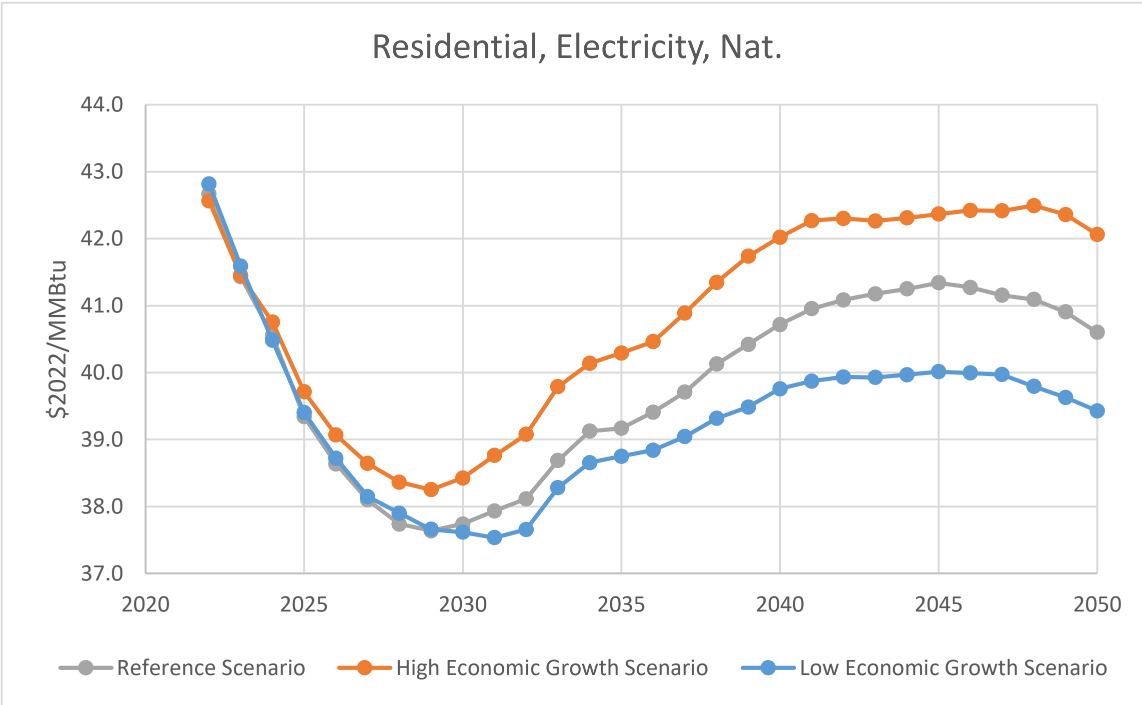

Figure 8J.2.1 Electricity Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

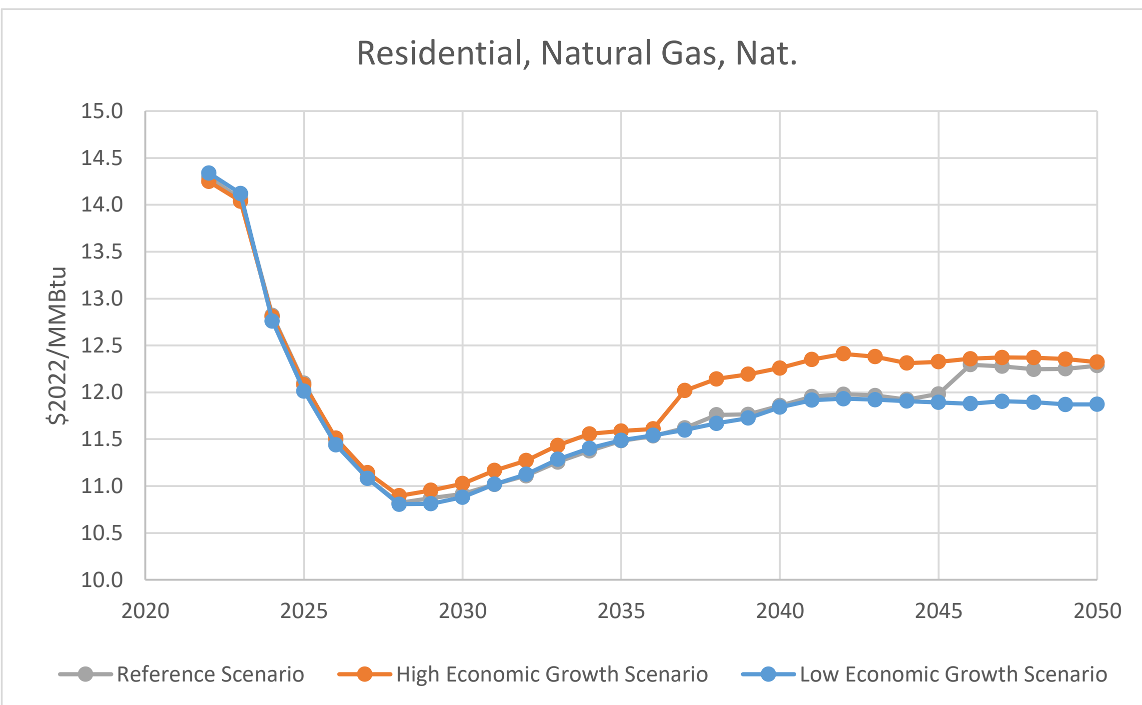

Figure 8J.2.2 Natural Gas Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

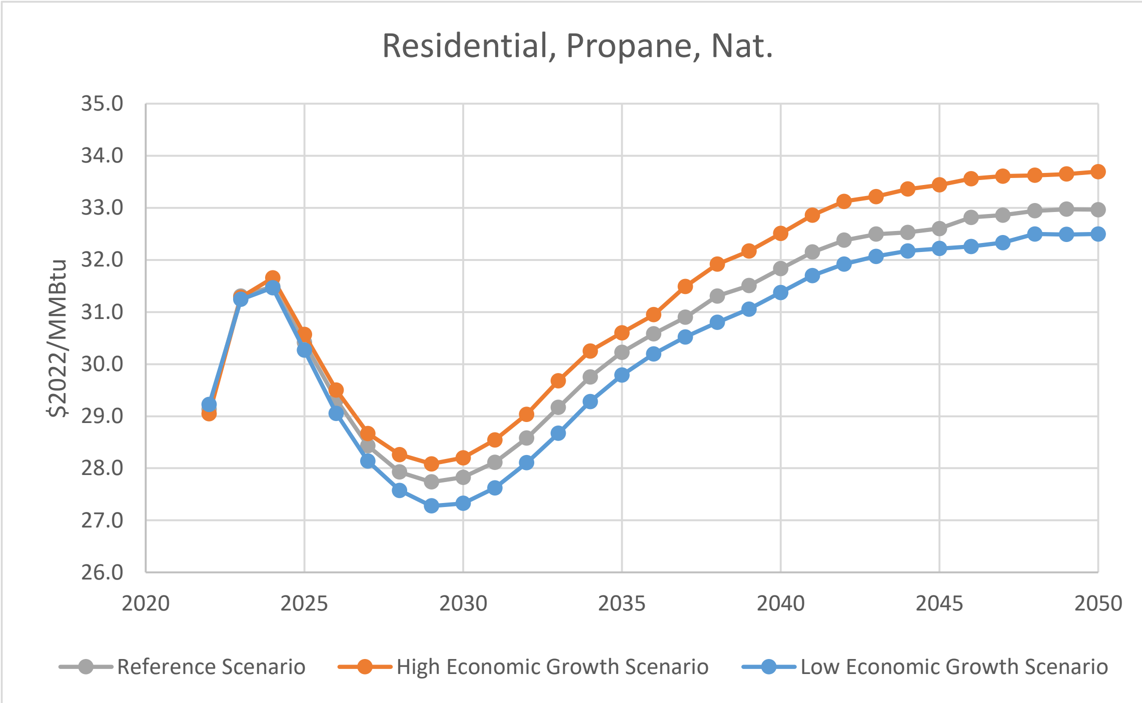

Figure 8J.2.3 LPG Price Forecasts for Reference Case and High and Low Economic Growth Scenarios (National)

8J.3 RESULTS

Table 8J.3.1 to Table 8J.3.4 present and compares the LCC and PBP results for the reference and high and low economic growth scenarios and efficiency level (EL) for gas-fired instantaneous water heaters.

Table 8J.3.1 Reference Case (Default) Scenario LCC Results and Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,087	303	4,571	6,659	NA	NA	NA
	1	2,304	285	4,339	6,644	12.6	(1)	17%
	2	2,318	277	4,210	6,528	8.9	112	15%
	3	2,334	273	4,154	6,487	8.3	90	25%
	4	2,424	270	4,107	6,531	10.3	39	56%

Table 8J.3.2 High Economic Growth Scenario LCC Results and Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,087	306	4,637	6,725	NA	NA	NA
	1	2,304	289	4,400	6,705	12.4	3	17%
	2	2,318	280	4,269	6,587	8.8	117	15%
	3	2,334	276	4,212	6,545	8.2	93	24%
	4	2,424	273	4,164	6,588	10.1	43	55%

Table 8J.3.3 Low Economic Growth Scenario LCC Results and Efficiency Level for Gas-fired Instantaneous Water Heaters

Product Class	EL	All Consumers*					Impacted Consumers**	
		Installed Cost	First Year Oper. Cost	Lifetime Oper. Cost*	LCC	Simple PBP	LCC Savings	Net Cost
Gas-fired Instantaneous Water Heaters	0	2,087	299	4,459	6,546	NA	NA	NA
	1	2,304	282	4,236	6,540	12.7	(11)	18%
	2	2,318	274	4,110	6,429	9.0	100	15%
	3	2,334	270	4,056	6,390	8.4	83	25%
	4	2,424	267	4,011	6,435	10.4	31	57%

Table 8J.3.4 Results Comparison of Average LCC Savings, PBP and Percentage of Consumers Experiencing Net Cost for Economic Growth Scenarios for AFUE Standards for Gas-fired Instantaneous Water Heaters

Product Class	EL	Average LCC Savings 2023$			Simple Payback Period *years*			Net Cost *%*		
		High AEO	Ref. Case	Low AEO	High AEO	Ref. Case	Low AEO	High AEO	Ref. Case	Low AEO
GIWH	1	3	(1)	(11)	12.4	12.6	12.7	17	17	18
	2	117	112	100	8.8	8.9	9.0	15	15	15
	3	93	90	83	8.2	8.3	8.4	24	25	25
	4	43	39	31	10.1	10.3	10.4	55	56	57

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APPENDIX 9A. HISTORICAL SHIPMENTS AND SATURATIONS DATA

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APPENDIX 9A. HISTORICAL SHIPMENTS AND SATURATIONS DATA

9A.1 INTRODUCTION

DOE used historical shipments data for domestic shipments and imports to populate its shipments model for consumer water heaters. DOE also obtained historical stock and new construction saturation to help supplement its shipments model. Using this data DOE was able to assess historical trends that helped develop the consumer gas-fired instantaneous water heater (GIWH) shipments model.

DOE first used the data to project shipments in its no-new-standards case. DOE also used this data for the consumer choice modeling in the standards cases.

9A.2 SATURATIONS

The historical data on the market saturation of GIWHs based on Energy Information Administration (EIA)'s 1990–2020 Residential Energy Consumption Survey (RECS),[1] EIA's 2018 Commercial Building Energy Consumption Survey (CBECS),[2] U.S. Census American Housing Survey,[3] U.S. Census Characteristics of New Housing,[4] Decision Analyst's American Home Comfort Study,[5] and Home Innovations Research Labs Annual Builder Practices Survey.[6] DOE used a 10-year historical average from 2013-2022 to project the saturation in future years. For GIWHs, after 2023 DOE estimated a negative 1 percent decreasing growth rate for gas-fired storage water heaters (GSWHs) that goes towards GIWH saturations. For commercial applications, DOE assumed that a consumer water heater was installed on average every 15,800 sq.ft. of the new additions to commercial floor space. Figure 9A.2.1 through Figure 9A.2.3 present the saturations for each market segment starting from 2015-2022 based on historical data and the 2023-2059 estimated projections.

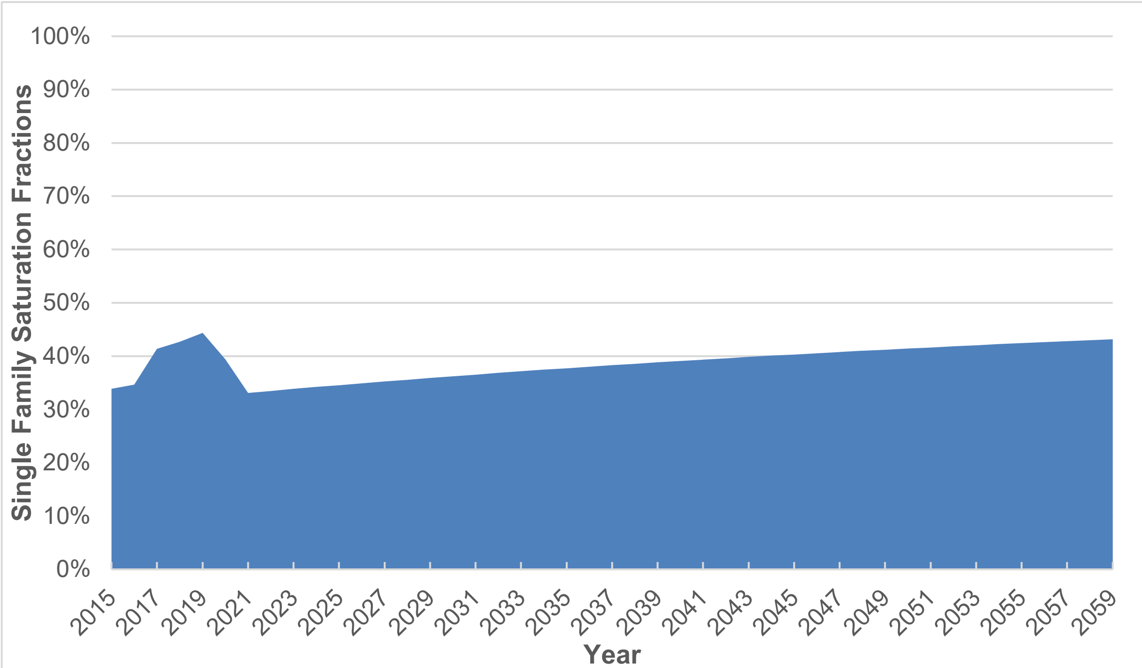

Figure 9A.2.1 Gas-fired Instantaneous water heaters Water Heaters Saturations for Single-Family Housing Starts, 2015-2059

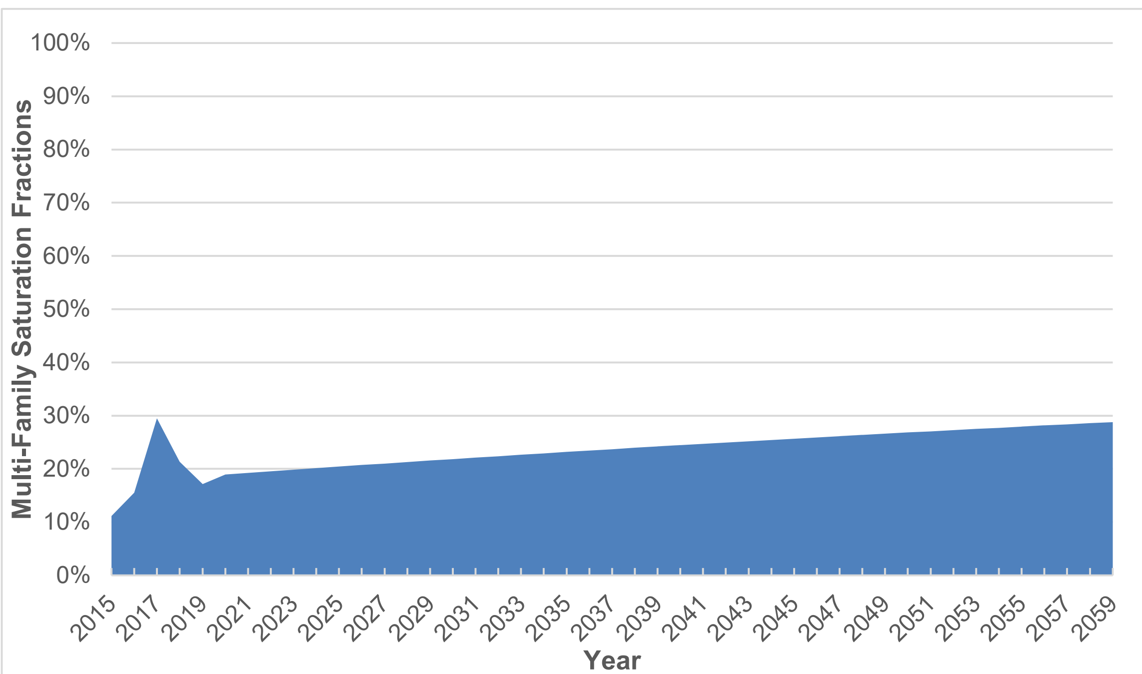

Figure 9A.2.2 Gas-fired Instantaneous Water Heaters Saturations for Multi-Family Housing Starts, 2015-2059

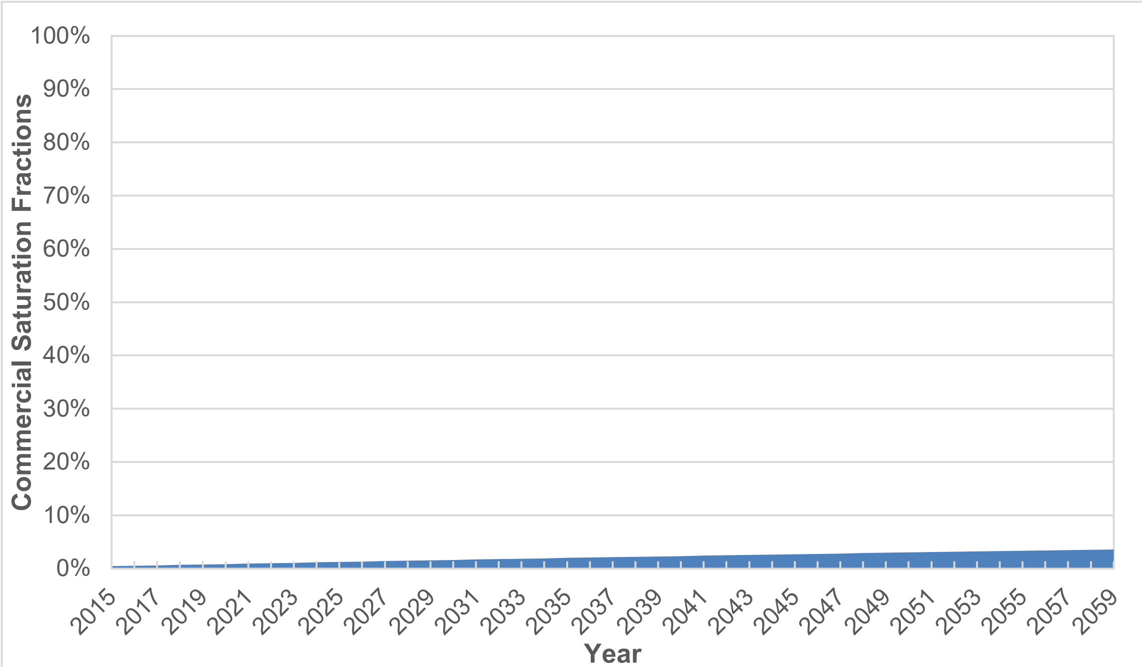

Figure 9A.2.3 Gas-fired Instantaneous Water Heaters Saturations for New Additions to the Commercial Floor Space, 2015-2059

9A.3 WATER HEATING ELECTRIFICATION: POLICIES AND INCENTIVES

DOE researched ongoing electrification policies at the Federal, State, and local levels that are likely to encourage installation of electric water heaters in new homes and adoption of electric water heaters in homes that currently use gas-fired water heaters. However, there are many uncertainties about the timing and impact of these policies that make it difficult to reliably account for their likely impact on gas and electric water heater market shares in the time frame for this analysis (i.e., 2030 through 2059). Nonetheless, DOE has adjusted shipments projections in the no-new-standards case from the preliminary analysis (taking into account policy changes and incentives highlighted below, especially in the new construction market) to attempt to account for impacts that seem most likely in the relevant time frame. Shipments model adjustments result in a decrease in GIWH shipments market share (relative to the consumer water heater market) in 2059 from approximately 25 percent in the preliminary analysis to 18 percent in this final rule analysis (as well as the July 2023 NOPR and July 2023 NODA). The changes result in a minimal impact on the GIWH shipments market share of the total consumer water heater market in 2030.

DOE acknowledges that electrification policies may potentially result in a larger decrease in shipments of GIWHs than projected in this final rule analysis, especially if stronger policies are adopted in coming years and barriers to electrification can be overcome. However, this would occur in the no-new-standards case and thus would only reduce the impacts estimated (including energy savings and emissions) in this adopted rule. DOE notes that the economic justification for the adopted rule would not change if DOE included a lower market share of GIWHs in the no-new-standards case, even if the absolute magnitude of the savings were to decline.

9A.3.1 Policies

9A.3.1.1 New Homes

Building Codes

California: The 2022 Energy Code includes elements that encourage electric heat pump technology for space and water heating, and adopts electric-ready requirements for single-family homes to facilitate future electrification.[a] The CEC is planning to prioritize multi-family buildings for the 2025 code update.

Colorado: Requires jurisdictions to adopt the 2021 IECC along with PV-ready, EV-ready, and electric-ready requirements when adopting or updating any other building codes after July 1, 2023. Then, it requires jurisdictions to adopt a "low energy and carbon code" when adopting or updating any other building codes after July 1, 2026. A new Energy Code Board will identify the minimum EV-ready, PV-ready, and electric-ready provisions and determine the "low energy and carbon code" language.

New York: Passed bill that authorizes the NYS Codes Council to incorporate greenhouse gas emissions reduction standards into building codes, and enables building code changes to phase out fossil fuels from existing buildings.

Washington: New homes and apartments built in Washington state beginning in July 2023 must use electric heat pump systems.

Bans on Natural Bas in New Buildings

New York: Starting in 2026, new buildings under seven stories won't be allowed to include furnaces, water heaters or stoves that burn gas and other fossil fuels.

As of Oct. 2022, approx. 70 U.S. cities had adopted all-electric requirements for residential new construction. Large cities with such requirements include: Chicago, New York, Oakland, Sacramento, Salt Lake City, San Francisco, Seattle area, Washington, DC.[b]

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[a] The update adopted by the CEC would include heat pumps as a performance standard baseline for water or space heating in single-family homes, and space heating in multi-family homes. In addition, "electric-ready" requirements for single-family homes mean they would need to have dedicated circuits and other infrastructure that would easily enable higher wattage electric appliances to be installed in the future.

[b] In April 2023, the Ninth Circuit struck down Berkeley's ban on natural gas in new construction. The impact on related policies in other cities is uncertain. Legal challenges from natural gas producers, distributors, and users will likely emerge, especially as the 2030 state ban on the sale of natural gas appliances approaches. (National Law Review, April 26, 2023; https://www.natlawreview.com/article/ninth-circuit-strikes-down-berkeley-s-ban-natural-gas-new-construction-dealing-blow)

9A.3.1.2 Existing Homes

As part of a statewide plan for attaining the federal standard for ozone, the California Air Resources Board (CARB) is planning to adopt a statewide zero-emission standard which would have criteria pollutant benefits along with GHG reductions. Beginning in 2030, 100 percent of sales of new space heaters and water heaters would need to comply with the emission standard.[c] A proposed rule will be considered by CARB by 2025.

The (San Francisco) Bay Area Air Quality Management District has adopted rules to phase out the sale and installation of natural-gas water heaters and furnaces. The rules would require zero-NOx models for water heaters smaller than 75,000 BTU/hour starting in 2027, and for water heaters larger than 75,000 BTU/hour and smaller than 2 million BTU/hour starting in 2031.[d]

Denver adopted an ordinance that requires partial or full electrification of certain types of space and water heating equipment at the time of replacement. These requirements take effect in 2025 or 2027, depending on the equipment type.

9A.3.1.3 Other

The California PUC voted to entirely eliminate ratepayer subsidies for the extension of new gas lines beginning in July 2023.[e] This is expected to incentivize home builders to install electric appliances.

9A.3.2 Incentives for Consumers

9A.3.2.1 Federal

The Inflation Reduction Act of 2022 (IRA) contains provisions for a number of programs that provides financial incentives to install electrical equipment.

The High-Efficiency Electric Home Rebate program will provide point-of-sale consumer rebates to enable low- and moderate-income households to electrify their homes. Covers 100 percent of electrification project costs (up to item-specific caps) for low-income households and 50 percent of costs (up to item-specific caps) for moderate-income households.[f] Qualified electrification projects include heat pump HVAC systems, heat pump water heaters, electric stoves and cooktops, heat pump clothes dryers, and enabling measures such as upgrading circuit

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[c] https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf; p. 101
[d] https://www.baaqmd.gov/rules-and-compliance/rule-development/building-appliances?mc_cid=4b543e338d&mc_eid=6c98946805
[e] California builders and developers previously had access to a variety of ratepayer-funded subsidies to help pay for new connections to the gas utility system.
[f] Compared to the "Area Median Income" (AMI) for a region, any household making less than 80 percent of AMI is considered low income, and any household making between 80 percent and 150 percent of AMI is considered moderate income.

panels, insulation, air sealing, ventilation, and wiring.[g] Project costs include both purchase and installation costs. Household could receive up to $1,750 for a heat pump water heater, up to $2,500 for electrical wiring, and up to $4,000 for an electrical panel (if under 100 amps). The rebates only apply if replacing a non-electric appliance. Runs through 2032.

The Energy Efficient Home Improvement credit, or 25C, allows households to deduct from their taxes up to 30 percent of the cost of upgrades to their homes, including installing heat pumps, insulation and, importantly, upgrading their breaker boxes to accommodate additional electric load. Upgrade costs include both equipment and installation/labor costs. Tax credit cap for buying and installing a heat pump water heater or heat pump is $2,000.[h] Runs through 2032.

The New Energy Efficient Home credit, or 45L, provides up to $5,000 to developers to build homes that qualify for the Department of Energy's Zero Energy Ready Homes standard.

The IRA provides $1 billion for a HUD-led grant program to improve energy and water efficiency -- including electrification of systems and appliances -- of eligible affordable rental housing.

9A.3.2.2 State

California. TECH Clean California is a $120 million initiative designed to drive the market adoption of low-emissions space and water heating technologies for existing single and multi-family homes. Provides comprehensive guidance on product incentives, pilots, workforce development and training opportunities, and local and state policies that impact the market.

9A.3.3 Incentives for Manufacturers

The Enhanced Use of the Defense Production Act 2022 includes $500 million to bolster the domestic manufacturing of heat pumps and the processing of critical. The magnitude of incentives for heat pump manufacturing, and the resulting impact on manufacturer selling prices, are as yet uncertain.

[g] The rebates are applicable only to ENERGY STAR-certified appliances.
[h] The 25C tax credit is applicable only to heat pumps and heat pump water heaters in the Consortium for Energy Efficiency's highest tier.

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALYSIS SPREADSHEET MODEL

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APPENDIX 10A. USER INSTRUCTIONS FOR NATIONAL IMPACT ANALSIS SPREADSHEET MODEL

10A.1 USER INSTRUCTIONS

The results obtained in this analysis can be examined and reproduced using the Microsoft Excel® spreadsheets accessible on the Internet from the Department of Energy's (DOE)'s consumer water heaters rulemaking page: https://www.energy.gov/eere/buildings/consumer-water-heaters. From that page, follow the links to the Final Rule (FR) phase of the rulemaking and then to the analytical tools.

10A.2 STARTUP

The NIA spreadsheets enable the user to perform a National Impact Analysis (NIA) for consumer gas-fired instantaneous water heaters (GIWHs). To utilize the spreadsheet, the Department assumed that the user would have access to a personal computer (PC) with a hardware configuration capable of running Windows 10 or later. To use the NIA spreadsheets, the user requires Microsoft Excel® 2013 or later installed under the Windows operating system.

10A.3 DESCRIPTION OF NATIONAL IMPACT ANALYSIS WORKSHEETS

The NIA spreadsheets perform calculations to project the change in national energy use and net present value of financial impacts due to revised energy efficiency standards. The energy use and associated costs for a given standard level are determined by calculating the shipments and then calculating the energy use and costs for all GIWHs shipped under that standard. The differences between the standards and no-new-standards case can then be compared and the overall energy savings and net present values (NPV) determined. The NIA spreadsheets consist of the following major worksheets as shown in Table 10A.3.1.

Table 10A.3.1 Description of NIA Spreadsheet Worksheets

Worksheet	Description
Introduction	Contains an introduction to the NIA analysis and related spreadsheets.
Summary Result	Contains a summary of disaggregated NIA results by Trial Standard Levels (TSLs).
GIWH	Contains gas-fired instantaneous water heater NIA calculations.
PC Inputs	Contains energy use, electricity use, retail price, installation cost, and annual repair and maintenance costs for each efficiency level.
Shipments	Contains historical and projected shipments data for gas-fried instantaneous water heaters.
Hist Shipments	Contains historical shipments data for gas-fried instantaneous water heaters.
Price Indices	Contains the learning multipliers to adjust the manufacturer's cost over the entire analysis period.
Lifetime	Includes the lifetime and the retirement function for gas-fired instantaneous water heaters.
Energy Factors	Contains energy conversion factors for NIA calculations.
Energy Price	Contains energy prices by year.
Supplementary Worksheets	Worksheets used for documentation and downstream analysis.

10A.4 BASIC INSTRUCTIONS FOR OPERATING THE NATIONAL IMPACT ANALYSIS SPREADSHEETS

Basic instructions for operating the NIA spreadsheets are as follows:

1. Once the NIA spreadsheet file has been downloaded from the Department's web site, open the file using MS Excel. Click "Enable Editing" when prompted and then click on the tab for the worksheet User Inputs.

2. Use MS Excel's View/Zoom commands at the top menu bar to change the size of the display to make it fit your monitor.

3. The user can change the parameters in the sheet "Summary Result". The default parameters (shown in Figure 10A.4.1) are:

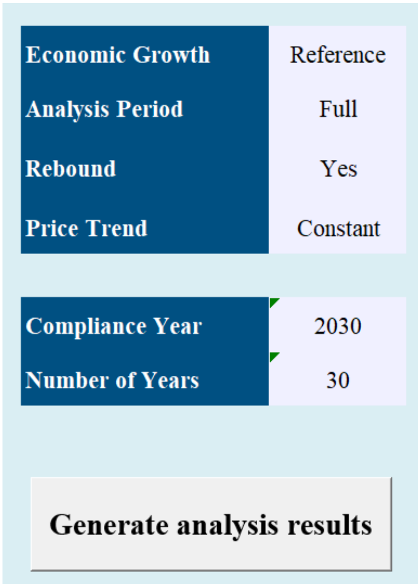

Figure 10A.4.1 Default User Input Parameters (Summary) for NIA Spreadsheets

a) Economic Growth: Set to “Reference”. To change value, click on the drop down menu next to cell “Economic Growth” and change to desired scenario (“Reference”, “High”, or “Low”).

b) Analysis Period: Set to “Full”. To change value, click on the drop down menu next to the cell “Analysis Period” and change to desired analysis period (“Full” (30 years) or “Short” (9 years)).

c) Rebound: Set to “Yes”. To change value, click on the drop down menu next to the cell “Rebound” and change to desired value (“Yes” or “No”).

d) Price Trend: Set to “Constant”. To change value, click on the drop down menu next to cell “Price Trend” and change to desired scenario (“Constant”, “Decreasing”, or “Increasing”).

4. The user can click the “Generate analysis results” button to generate summarized analysis results.

5. The user can view the summarized results (energy savings and NPV) in the “Summary Result” sheet (one example is shown in Figure 10A.4.2).

Cumulative National Energy Savings for Gas-fired Instantaneous Water Heaters
30 Years of Shipments, 2030-2059 (Quads)

Cumulative Site National Energy Savings (Quads)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (<2 gal and >50,000 Btu/h)	0.32	0.53	0.77	0.91

Cumulative Primary National Energy Savings (Quads)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (<2 gal and >50,000 Btu/h)	0.32	0.52	0.76	0.97

Cumulative Full-Fuel-Cycle National Energy Savings (Quads)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (<2 gal and >50,000 Btu/h)	0.35	0.58	0.85	1.07

Cumulative Consumer Net Present Value for Gas-fired Instantaneous Water Heaters
30 Years of Shipments, 2030-2059 (Billion 2023$)

Cumulative Consumer Net Present Value, Discounted at 3 Percent (Billion 2023$)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (<2 gal and >50,000 Btu/h)	1.26	3.06	4.89	4.50

Cumulative Consumer Net Present Value, Discounted at 7 Percent (Billion 2023$)

Product Class	TSL 1	TSL 2	TSL 3	TSL 4
Gas-fired Instantaneous Water Heaters (<2 gal and >50,000 Btu/h)	0.24	0.87	1.45	0.98

Figure 10A.4.2 NIA Result for Gas-fired Instantaneous Water Heaters Final Rule

Make sure that the spreadsheet is in automatic calculation mode. The calculation mode could be changed by (shown in Figure 10A.4.3):

1. In Excel 2013 and later, go to the tab "Formulas" in the Office ribbon.
2. Click on the button "Calculation Options" and select "Automatic".

The results are updated each time after clicking the "Generate analysis results" button and are reported in the "Summary Result" sheet.

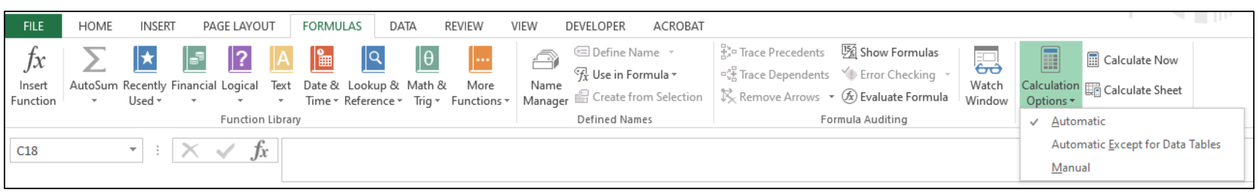

Figure 10A.4.3 Set the Spreadsheet to Automatic Calculation Mode

APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

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APPENDIX 10B. FULL-FUEL-CYCLE ANALYSIS

10B.1 INTRODUCTION

This appendix summarizes the methods the U.S. Department of Energy (DOE) used to calculate the estimated full-fuel-cycle (FFC) energy savings from potential energy conservation standards. The FFC measure includes point-of-use (site) energy; the energy losses associated with generation, transmission, and distribution of electricity; and the energy consumed in extracting, processing, and transporting or distributing primary fuels. DOE's method of analysis previously encompassed only site energy and the energy lost through generation, transmission, and distribution of electricity. In 2011 DOE announced its intention, based on recommendations from the National Academy of Sciences, to use FFC measures of energy use and emissions when analyzing proposed energy conservation standards.[1] This appendix summarizes the methods DOE used to incorporate impacts of the full fuel cycle into the analysis.

In the national energy savings calculation, DOE estimates the site, primary and full-fuel-cycle (FFC) energy consumption for each standard level, for each year in the analysis period. DOE defines these quantities as follows:

- Site energy consumption is the physical quantity of fossil fuels or electricity consumed at the site where the end-use service is provided.[a] The site energy consumption is used to calculate the energy cost input to the net present value (NPV) calculation.
- Primary energy consumption is defined by converting the site fuel use from physical units, for example cubic feet for natural gas, or kWh for electricity, to common energy units (million Btu or MMBtu). For electricity the conversion factor is a marginal heat rate that incorporates losses in generation, transmission and distribution, and depends on the sector, end use and year.
- The full-fuel-cycle (FFC) energy use is equal to the primary energy use plus the energy consumed "upstream" of the site in the extraction, processing and distribution of fuels. The FFC energy use was calculated by applying a fuel-specific FFC energy multiplier to the primary energy use.

For electricity from the grid, site energy is measured in terawatt-hours (TWh). The primary energy of a unit of grid electricity is equal to the heat content of the fuels used to generate that electricity, including transmission and distribution losses.[b] DOE typically measures the primary energy associated with the power sector in quads (quadrillion Btu). Both primary fuels and electricity are used in upstream activities. The treatment of electricity in full-fuel-cycle analysis must distinguish between electricity generated by fossil fuels and electricity generated from renewable sources (wind, solar, and hydro). For the former, the upstream fuel cycle relates

[a] For fossil fuels, this is the site of combustion of the fuel.
[b] For electricity sources like nuclear energy and renewable energy, the primary energy is calculated using the EIA convention as described below.

to the fuel consumed at the power plant. There is no upstream component for the latter, because no fuel *per se* is used.

10B.2 SITE-TO-PRIMARY ENERGY FACTORS

DOE uses heat rates to convert site electricity savings in TWh to primary energy savings in quads. The heat rates are developed as a function of the sector, end-use and year of the analysis period. For this analysis DOE uses output of the DOE/Energy Information Administration (EIA)'s National Energy Modeling System (NEMS).[2] EIA uses the NEMS model to produce the *Annual Energy Outlook* (*AEO*). DOE's approach uses the most recently available edition, in this case *AEO 2023*.[3] The *AEO* publication includes a reference case and a series of side cases incorporating different economic and policy scenarios. DOE calculates marginal heat rates as the ratio of the change in fuel consumption to the change in generation for each fossil fuel type, where the change is defined as the difference between the reference case and the side case. DOE calculates a marginal heat rate for each of the principal fuel types: coal, natural gas and oil. DOE uses the EIA convention of assigning a heat rate of 10.5 Btu/Wh to nuclear power and 9.5 Btu/Wh to electricity from renewable sources.

DOE multiplied the fuel share weights for sector and end-use, described in appendix 15A of this TSD, by the fuel specific marginal heat rates, and summed over all fuel types, to define a heat rate for each sector/end-use. This step incorporates the transmission and distribution losses. In equation form:

$$h(u,y) = (1 + TDLoss) * \sum_{r,f} g(r,f,y)\, H(f,y)$$

Where:

TDLoss = the fraction of total generation that is lost in transmission and distribution, equal to 0.07037
u = an index representing the sector/end-use (e.g., commercial cooling)
y = the analysis year
f = the fuel type
H(f,y) = the fuel-specific heat rate
g(r,f,y) = the fraction of generation provided by fuel type *f* for end-use *u* in year *y*
h(u,y) = the end-use specific marginal heat rate

The sector/end-use specific heat rates are shown in Table 10B.2.1. These heat rates convert site electricity to primary energy in quads; i.e., the units used in the table are quads per TWh.

Table 10B.2.1 Electric Power Heat Rates (MMBtu/MWh) by Sector and End-Use

	2025	2030	2035	2040	2045	2050+
Residential						
Clothes Dryers	9.640	9.309	9.455	9.451	9.449	9.443
Cooking	9.623	9.298	9.444	9.440	9.440	9.433
Freezers	9.660	9.311	9.456	9.451	9.449	9.441
Lighting	9.675	9.346	9.495	9.489	9.486	9.480
Refrigeration	9.659	9.312	9.457	9.452	9.450	9.443
Space Cooling	9.529	9.162	9.292	9.295	9.300	9.289
Space Heating	9.696	9.365	9.516	9.509	9.504	9.498
Water Heating	9.650	9.327	9.476	9.471	9.469	9.463
Other Uses	9.639	9.311	9.457	9.453	9.452	9.445
Commercial						
Cooking	9.528	9.244	9.390	9.391	9.395	9.390
Lighting	9.553	9.257	9.403	9.403	9.406	9.400
Office Equipment (Non-Pc)	9.478	9.203	9.347	9.350	9.357	9.352
Office Equipment (Pc)	9.478	9.203	9.347	9.350	9.357	9.352
Refrigeration	9.626	9.303	9.449	9.446	9.445	9.439
Space Cooling	9.502	9.140	9.269	9.273	9.279	9.268
Space Heating	9.706	9.370	9.521	9.513	9.508	9.502
Ventilation	9.629	9.306	9.453	9.449	9.448	9.442
Water Heating	9.526	9.246	9.393	9.394	9.398	9.394
Other Uses	9.499	9.219	9.364	9.366	9.372	9.367
Industrial						
All Uses	9.499	9.219	9.364	9.366	9.372	9.367

10B.3 FFC METHODOLOGY

The methods used to calculate FFC energy use are summarized here. The mathematical approach to determining FCC is discussed in Coughlin (2012).[4] Details related to the modeling of the fuel production chain are presented in Coughlin (2013).[5]

When all energy quantities are normalized to the same units, FFC energy use can be represented as the product of the primary energy use and an FFC multiplier. Mathematically the FFC multiplier is a function of a set of parameters that represent the energy intensity and material losses at each stage of energy production. Those parameters depend only on physical data, so the calculations require no assumptions about prices or other economic factors. Although the parameter values may differ by geographic region, this analysis utilizes national averages.

The fuel cycle parameters are defined as follows.

- a_x is the quantity of fuel x burned per unit of electricity produced for grid electricity. The calculation of a_x includes a factor to account for losses incurred through the transmission and distribution systems.

- b_y is the amount of grid electricity used in producing fuel *y*, in MWh per physical unit of fuel *y*.
- c_{xy} is the amount of fuel *x* consumed in producing one unit of fuel *y*.
- q_x is the heat content of fuel *x* (MBtu/physical unit).

All the parameters are calculated as functions of an annual time step; hence, when evaluating the effects of potential new standards, a time series of annual values is used to estimate the FFC energy and emissions savings in each year of the analysis period and cumulatively.

The FFC multiplier is denoted μ (mu). A separate multiplier is calculated for each fuel used on site. Also calculated is a multiplier for electricity that reflects the fuel mix used in its generation. The multipliers are dimensionless numbers applied to primary energy savings to obtain the FFC energy savings. The upstream component of the energy savings is proportional to (μ-1). The fuel type is denoted by a subscript on the multiplier μ.

The method for performing the full-fuel-cycle analysis utilizes data and projections published in the *AEO 2023*. Table 10B.3.1 summarizes the data used as inputs to the calculation of various parameters. The column titled "*AEO* Table" gives the name of the table that provided the reference data.

Table 10B.3.1 Dependence of FFC Parameters on *AEO* Inputs

Parameter(s)	Fuel(s)	*AEO* Table	Variables
q_x	All	Conversion factors	MMBtu per physical unit
a_x	All	Electricity supply, disposition, prices, and emissions Energy consumption by sector and source	Generation by fuel type Electric energy consumption by the power sector
b_c, c_{nc}, c_{pc}	Coal	Coal production by region and type	Coal production by type and sulfur content
b_p, c_{np}, c_{pp}	Petroleum	Refining industry energy consumption Liquid fuels supply and disposition International liquids supply and disposition Oil and gas supply	Refining-only energy use Crude supply by source Crude oil imports Domestic crude oil production
c_{nn}	Natural gas	Oil and gas supply Natural gas supply, disposition, and prices	U.S. dry gas production Pipeline, lease, and plant fuel
z_x	All	Electricity supply, disposition, prices, and emissions	Power sector emissions

The *AEO 2023* does not provide all the information needed to estimate total energy use in the fuel production chain. Coughlin (2013) describes the additional data sources needed to complete the analysis. The time dependence in the FFC multipliers, however, arises exclusively from variables taken from the *AEO*.

10B.4 ENERGY MULTIPLIERS FOR THE FULL FUEL CYCLE

FFC energy multipliers for selected years are presented in Table 10B.4.1. The 2050 value was held constant for the analysis period beyond 2050, which is the last year in the *AEO 2023* projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

Table 10B.4.1 Energy Multipliers for the Full Fuel Cycle (Based on *AEO 2023*)

	2025	2030	2035	2040	2045	2050+
Electricity (grid)	1.045	1.032	1.028	1.028	1.027	1.027
Natural Gas	1.115	1.112	1.114	1.114	1.115	1.117

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APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

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APPENDIX 10C. NATIONAL NET PRESENT VALUE OF CONSUMER BENEFITS USING ALTERNATIVE PRODUCT PRICE FORECASTS

10C.1 INTRODUCTION

DOE investigated the impact of different product price trends on the net present value (NPV) for the considered trial standard levels (TSLs) for consumer gas-fired instantaneous water heaters (GIWHs). The NPV results presented in chapter 10 are based on a default constant product price trend.

DOE considered two price trend sensitivities: (1) a decreasing price trend scenario and (2) an increasing price trend scenario. The derivation of these two alternative price trend scenarios are explained in appendix 8C, and the results of the estimated learning rate in each price trend scenario are summarized in Table 10C.1.1.

Table 10C.1.1 Price Trend Sensitivities

Sensitivity	Price Trend	Average Annual Price Change Rate (%)	Learning Rate Factor in 2030 (2023=1)
Default	Constant price projection	0.00	1.000
Decreasing Price Trend Scenario	Power-law fit to the non-electric water heater PPI from 1977 to 1991	-0.33	0.973
Increasing Price Trend Scenario	Symmetric to the Decreasing Price Trend Scenario	0.33	1.028

10C.2 NET PRESENT VALUE RESULTS USING ALTERNATIVE PRODUCT PRICE TRENDS

Table 10C.2.1 compares the NPV using the default product price forecast with the NPV using the alternative product price forecasts. With the decreasing price trend scenario, the NPV for the highest TSLs rises compared with the reference case; in contrast, it declines with the increasing price trend scenario.

Table 10C.2.1 Comparison of NPV for Alternative Product Price Trends

Discount Rate	Price Trend Scenario	Trial Standard Level			
		1	2	3	4
		billion 2023$			
3-Percent	Reference Case (Constant Trend)	1.26	3.06	4.89	4.50
	Decreasing Price Trend	1.39	3.20	5.05	4.83
	Increasing Price Trend	1.12	2.91	4.71	4.14
7-Percent	Reference Case (Constant Trend)	0.24	0.87	1.45	0.98
	Decreasing Price Trend	0.30	0.94	1.53	1.13
	Increasing Price Trend	0.17	0.80	1.37	0.82

APPENDIX 10D. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

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APPENDIX 10D. NATIONAL IMPACT ANALYSIS USING ALTERNATIVE ECONOMIC GROWTH SCENARIOS FOR CONSUMER GAS-FIRED INSTANTANEOUS WATER HEATERS

10D.1 INTRODUCTION

This appendix presents National Impact Analysis (NIA) results using energy price forecasts from alternative economic growth scenarios for the considered TSLs for consumer gas-fired Instantaneous Water Heaters (GIWHs). The scenarios are based on the High Economic Growth case and the Low Economic Growth case from Energy Information Administration's (EIA's) *Annual Energy Outlook 2023* (*AEO 2023*).[1] To estimate energy prices after 2050 in the high and low scenarios, DOE used the average growth rate between 2045 and 2050. See appendix 8J for details about alternative economic growth scenarios.

This appendix also describes the High and Low Economic Growth scenarios in further detail. See appendix 10A for details about how to generate NIA results for High Economic Growth and Low Economic Growth scenarios using the NIA spreadsheet.

10D.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

To generate NIA results reported in chapter 10, DOE uses the Reference case energy price and housing projections from *AEO 2023*. The reference case is a business-as-usual estimate, given known market, demographic, and technological trends. To reflect uncertainty in the future of U.S. economic growth, *AEO 2023* uses High and Low Economic Growth scenarios to project the possible impacts on energy markets of alternative assumptions for macroeconomic growth rates.[2] In general, energy prices are higher in the High Economic Growth scenario and lower in the Low Economic Growth scenario. See appendix 8J for details about the effect of these alternative economic scenarios on energy prices.

Because *AEO 2023* provides the price trends by census division, each sampled household is matched to the appropriate census division price trend. See chapter 10 for details about how energy price trends are applied in the NIA analysis.

In addition, the High and Low Economic Growth scenarios provide different housing starts and new commercial square footage projections that affect the GIWH shipments projections (see Figure 10D.2.1 and Figure 10D.2.2).

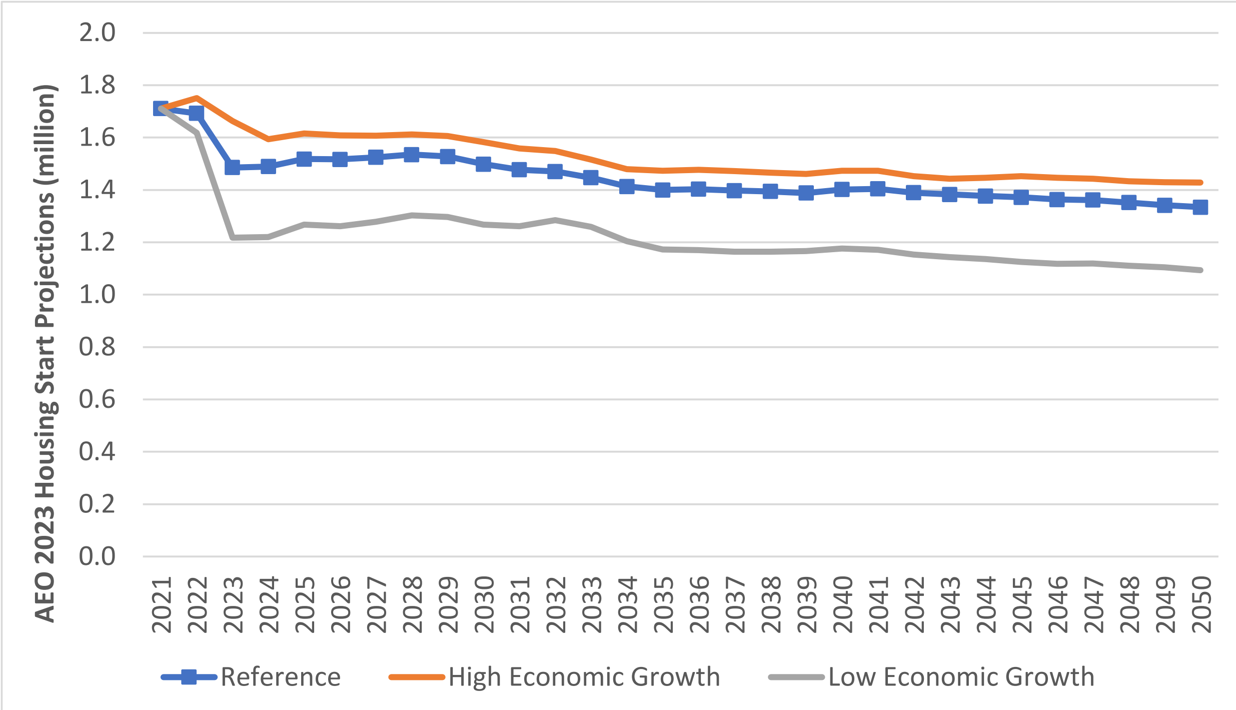

Figure 10D.2.1 AEO Housing Starts Projections for Reference Case and High and Low Economic Growth Scenarios

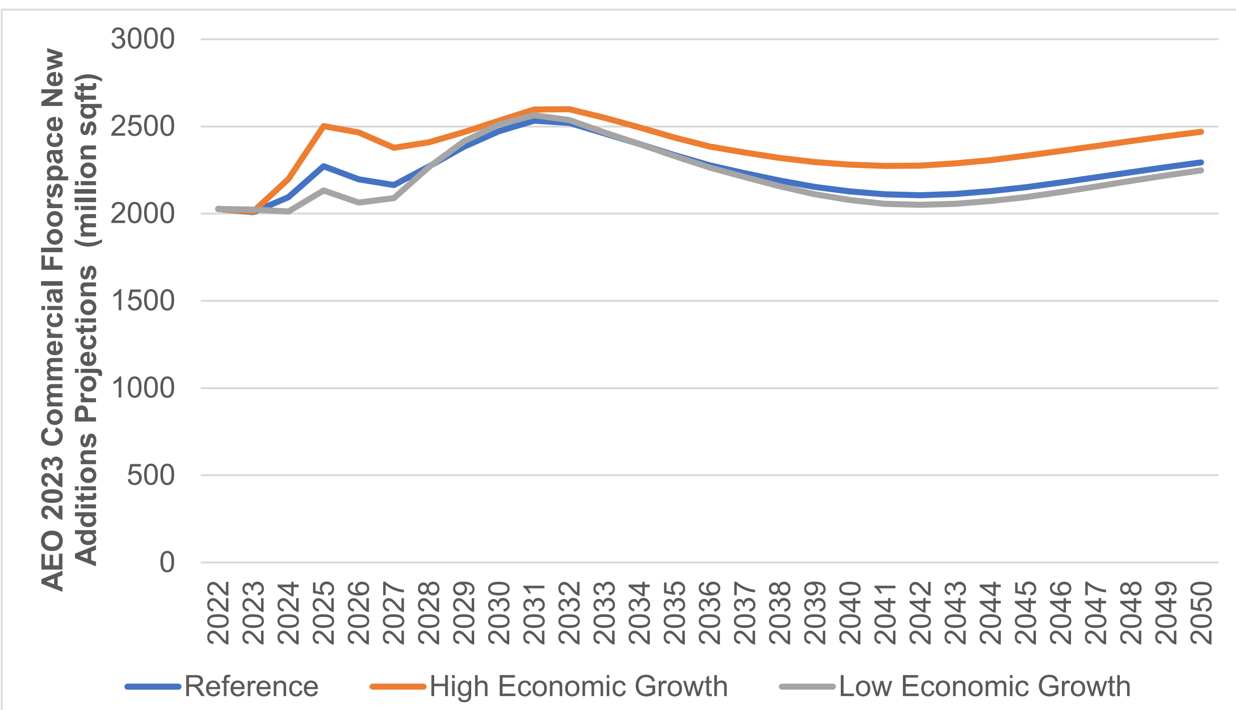

Figure 10D.2.2 AEO Housing Starts Projections for Reference Case and High and Low Economic Growth Scenarios

10D.3 RESULTS

This section presents the national energy savings (NES) and national present value (NPV) results for the considered trial standard levels (TSLs) for GIWHs using the Reference Case, High Economic Growth, and Low Economic Growth scenarios.

Table 10D.3.1 shows the NES results for each TSL analyzed for GIWHs under different economic growth scenarios.

Table 10D.3.1 Comparison of National Energy Savings (Full Fuel Cycle) Under Alternative Growth Scenarios; 30 Years of Shipments (2030-2059)

Scenarios	Trial Standard Level			
	1	2	3	4
	quads			
Reference Case	0.35	0.58	0.85	1.07
High Economic Growth	0.36	0.59	0.86	1.09
Low Economic Growth	0.35	0.57	0.83	1.05

Table 10D.3.2 shows the NPV results for each of the TSLs analyzed for GIWHs under different economic growth scenarios. A negative NPV indicates that the costs of a standard at a given efficiency level exceed the savings.

Table 10D.3.2 Comparison of Net Present Value of Consumer Benefits for Gas-fired Instantaneous Water Heaters Under Alternative Growth Scenarios; 30 Years of Shipments (2030–2059)

Discount Rate	Scenario	Trial Standard Level			
		1	2	3	4
		billion 2023$			
3-Percent	Reference Case	1.26	3.06	4.89	4.50
	High Economic Growth	1.43	3.36	5.33	5.03
	Low Economic Growth	1.10	2.77	4.46	3.99
7-Percent	Reference Case	0.24	0.87	1.45	0.98
	High Economic Growth	0.30	0.98	1.61	1.16
	Low Economic Growth	0.18	0.77	1.31	0.81

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APPENDIX 10E. REBOUND EFFECT ANALYSIS

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APPENDIX 10E. REBOUND EFFECT ANALYSIS

10E.1 INTRODUCTION

As the energy efficiency of a product improves following an amended energy conservation standard, the cost of operating the unit, for the same amount of energy service, will decrease. The rebound effect describes a phenomenon where consumers increase their demand for the energy service as a result of this reduction in operating cost, leading to a decrease in potential energy savings. At the same time, consumers benefit from increased utilization of products due to rebound. Overall consumer welfare (taking into account additional costs and benefits) is generally understood to increase from rebound.

There are two main types of rebound effects in consumer theory: direct and indirect rebound effect.[1,2,3] The direct rebound effect measures the behavioral response directly attributed to the energy efficiency improvement. This approach treats an energy efficiency improvement as an exogenous effect while holding other product attributes constant (no change in the quality of the energy service). The indirect rebound effect, on the other hand, has a much broader scope which considers the substitution and income effect on other goods induced by the decline in price of a given energy service.

In monetizing the impact of the rebound effect, DOE focuses on the impact of the *direct* rebound effect in the net present value (NPV) calculation in the National Impact Analysis (NIA). In this appendix, DOE describes the conceptual theory and implementation of the calculation used to monetize the consumer welfare benefit from the rebound effect in the NIA.

This appendix also presents National Impact Analysis (NIA) results using the rebound and without rebound scenarios for the considered TSLs for consumer gas-fired instantaneous water heaters (GIWHs). See appendix 10A for details about how to generate NIA results for the scenarios using the NIA spreadsheet.

10E.2 DESCRIPTION OF HIGH AND LOW ECONOMIC SCENARIOS

The direct rebound effect can be measured by the elasticity of demand for energy service (S), with respect to energy efficiency (ε), denoted as $\eta_{S,\varepsilon}$, or alternatively, the elasticity of demand for energy (E) with respect to energy efficiency (ε), denoted as $\eta_{E,\varepsilon}$.[2,4] Given the relationship between energy demand and energy service demand, $S = \varepsilon E$, it can be shown that:

$$\eta_{E,\varepsilon} = \frac{\partial E}{\partial \varepsilon}\frac{\varepsilon}{E} = \frac{\varepsilon}{E}\left(\frac{1}{\varepsilon}\frac{\partial S(\varepsilon)}{\partial \varepsilon} - \frac{1}{\varepsilon^2}S\right) = \frac{\partial S}{\partial \varepsilon}\frac{\varepsilon}{S} - 1 \equiv \eta_{S,\varepsilon} - 1$$

Eq. 10E.1

For example, a direct rebound effect of 20% implies that that a 10 percent increase in energy efficiency would result in a 2 percent increase in demand for energy service and also an 8 percent reduction in energy consumption. Alternatively speaking, a 20 percent of energy savings would be taken back compared to the expected 10 percent reduction in energy consumption if there was no increased demand in energy service following the improvement in energy efficiency (zero rebound).

Based on the framework proposed by Sorrell and Dimitropoulos (2008), the implicit price of energy service can be expressed as $P_S = {P_E}/{\varepsilon}$. From this it follows[5]:

$$\eta_{E,\varepsilon} = \frac{\partial E}{\partial \varepsilon}\frac{\varepsilon}{E} = \frac{\varepsilon}{E}\left(\frac{1}{\varepsilon}\frac{\partial S}{\partial P_S}\frac{\partial P_S}{\partial \varepsilon} - \frac{1}{\varepsilon^2}S\right) = \frac{\varepsilon}{E}\left(-\frac{\partial S}{\partial P_S}\frac{P_E}{\varepsilon^3} - \frac{1}{\varepsilon^2}S\right) = -\frac{\partial S}{\partial P_S}\frac{P_S}{S} - 1 \equiv -\eta_{S,P_S} - 1$$

Eq. 10E.2

Thus, the direct rebound effect, $\eta_{S,\varepsilon}$, can be approximated by $-\eta_{S,P_S}$, or the negative of the elasticity of demand for energy service (S) with respect to the price of energy service (P_S).

While the rebound effect may likely reduce the energy savings, the presence of rebound effect also has welfare implications on energy efficiency policies. Understanding the magnitude of the rebound effect and its energy savings and economic welfare implications helps evaluate the welfare effect of the energy efficiency policies on consumers.[6,7]

As energy efficiency improves, the price of energy service moves from P_S to P_S', and the change in consumer surplus can be illustrated as below:

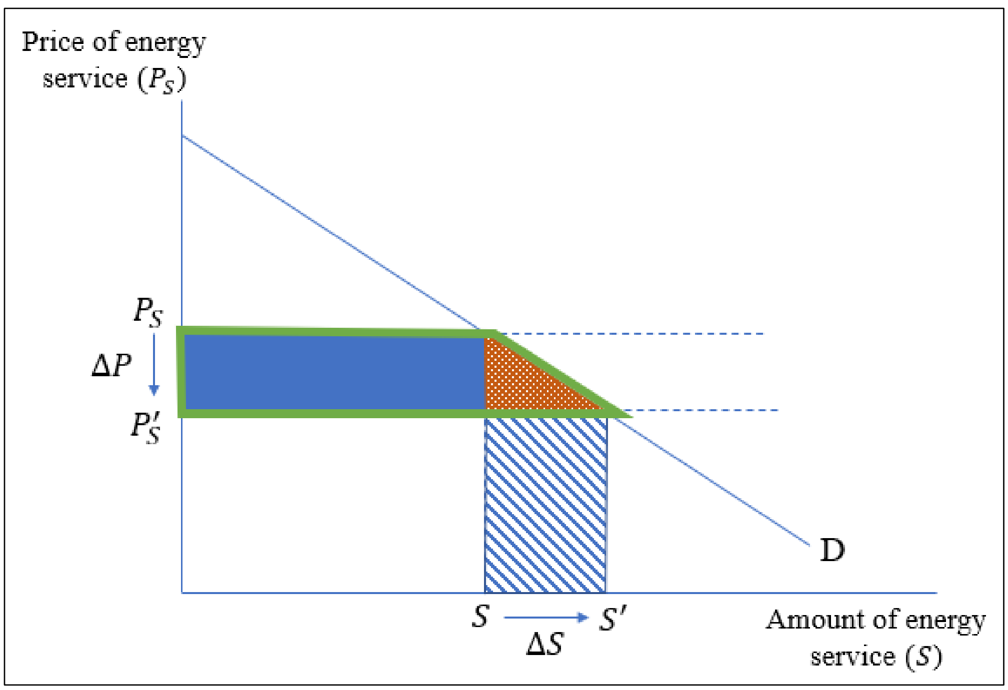

Figure 10E.2.1 The Consumer Surplus Illustration with Rebound Effect

The trapezoidal area outlined in green depicts the change in consumer surplus from improved energy efficiency (P_S to P_S') with rebound effect (S to S'). The solid blue rectangular area reflects the monetary savings from the decrease in energy service price while holding the level of energy service constant. The difference of the two areas, the orange triangle, represents the welfare gained from consuming additional energy service at the lower energy service price. All these areas are expressed in the unit of dollar.

In the context of water heaters, the energy service (S) being provided is heating in terms of British Thermal Units (*Btus)* and the energy efficiency (ε) is approximated as the shipment-weighted uniform energy factor efficiency (UEF).

The change in the price of energy service, ΔP_S, expressed in units of *$/Btu* can be written as:

$$\Delta P_S = \frac{P_E}{1{,}000{,}000} \times \left(\frac{1}{SWUEF_{NNS}(v)} - \frac{1}{SWUEF_{STD}(v)}\right)$$

Eq. 10E.3

where,

P_E = weighted-average marginal natural gas price (*$/MMBtu*),
v = shipments vintage,
$SWAFUE_{NNS}$ = shipment-weighted AFUE in the no new standard case, and
$SWAFUE_{STD}$ = shipment-weighted AFUE in the standards case.

The change in the amount of water heating service, ΔS, expressed in units of *Btu* can be written as:

$$\Delta S = \eta_{S,P_S} S_{NNS} \frac{\Delta P_S}{P_{s,NNS}}$$

Eq. 10E.4

where,

η_{S,P_S} = the price elasticity of energy service,
S_{NNS} = annual demand in water heating energy service in the no-new-standards case *(Btu),*
ΔP_S = the change in the price of energy service *($/Btu),*
$P_{S,NNS}$ = the price of energy service in the no-new-standards case *($/Btu).*

To calculate the average consumer welfare benefit ($CW_{rebound}$) of the rebound (i.e., the orange triangle) in a given year for each unit shipped after the standard takes effect, DOE employs the following equation:

$$\begin{aligned} CW_{Rebound}(v) &= \frac{1}{2}\Delta P_S \Delta S \\ &= \frac{1}{2}\frac{P_E}{1{,}000{,}000} SWAFUE_{NNS}(v) \\ &\times \left(\frac{1}{SWAFUE_{NNS}(v)} - \frac{1}{SWAFUE_{STD}(v)}\right)^2 \eta_{S,P_S} S_{NNS} \end{aligned}$$

Eq. 10E.5

where,

$CW_{Rebound}(v)$ = the average consumer welfare benefit from the rebound effect for shipments vintage *v ($),*
P_E = weighted-average marginal natural gas price (*$/MMBtu*),
$v =$ shipments vintage,
$SWAFUE_{NNS}$ = shipment-weighted AFUE in the no new standard case,
$SWAFUE_{STD}$ = shipment-weighted AFUE in the standards case,
η_{S,P_S} = the price elasticity of energy service, and
S_{NNS} = annual demand in water heating energy service in the no-new-standards case *(Btu)*.

10E.3 WATER HEATER DATA SOURCES

In order to calculate the triangular area shown in Figure 10E.2.1, one must first derive the slope of the energy service demand curve, or the price elasticity of energy service. DOE examined a 2009 review of empirical estimates of the rebound effect for various energy-using products.[4] This review concluded that the econometric and quasi-experimental studies suggest a mean value for the direct rebound effect for household heating of around 20 percent. DOE also examined a 2012 ACEEE paper[3] and a 2013 paper by Thomas and Azevedo.[2] Both of these publications examined the same studies that were reviewed by Sorrell, as well as Greening *et al.*,[8] and identified methodological problems with some of the studies. The studies believed to be most reliable by Thomas and Azevedo show a direct rebound effect for water heating products in the 1-percent to 15-percent range, while Nadel concludes that a more likely range is 1 to 12 percent, with rebound effects sometimes higher for low-income households who could not afford to adequately provide for hot water needs and lower rebound effect for occupants (primarily renters) that do not pay for their utility bills. Based on DOE's review of these recent assessments, DOE used a 10-percent rebound effect for GIWHs in the residential applications for standards. However, for commercial applications, DOE applied no rebound effect, consistent with other recent energy conservation standards rulemakings.[9,10,11]

10E.4 RESULTS

This section presents the national energy savings (NES) and national present value (NPV) results for the considered trial standard levels (TSLs) for GIWHs using the with rebound (reference case) and without rebound scenarios.

Table 10E.4.1 and Table 10E.4.2 show the NES and NPV results for GIWH standards for each of the TSL with and without rebound. NES results without rebound are larger compared to the Reference Case (with rebound), while NPV results without rebound are smaller compared to the Reference Case (with rebound).

Table 10E.4.1 Comparison of National Energy Savings (Full Fuel Cycle) Results with and without Rebound

Scenarios	Trial Standard Level			
	1	**2**	**3**	**4**
	quads			
With Rebound (Reference Case)	0.35	0.58	0.85	1.07
Without Rebound	0.38	0.63	0.92	1.16

Table 10E.4.2 Comparison of Net Present Value Results with and without Rebound

Discount Rate	Scenario	Trial Standard Level			
		1	**2**	**3**	**4**
		billion 2023$			
3-Percent	With Rebound (Reference Case)	1.26	3.06	4.89	4.50
	Without Rebound	1.26	3.05	4.87	4.48
7-Percent	With Rebound (Reference Case)	0.24	0.87	1.45	0.98
	Without Rebound	0.24	0.87	1.45	0.98

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APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

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APPENDIX 12A. MANUFACTURER IMPACT ANALYSIS INTERVIEW GUIDE

12A.1 INTRODUCTION

Thank you for expressing interest in the U.S. Department of Energy (DOE) manufacturer interviews for the Consumer Water Heaters energy conservation standards rulemaking. As part of the rulemaking process, DOE retained Guidehouse to meet with manufacturers to discuss the potential impact of this rulemaking on manufacturers. All information provided in response to this interview guide will be maintained as confidential under the signed NDA with Guidehouse. Guidehouse provides industry averages and results of aggregated analysis to DOE, but Guidehouse does not disclose values supplied by individual manufacturers.

For consumer water heaters, the current energy conservation standards specified in 10 CFR 430.32 are based on the Uniform Energy Factor (UEF) metric, which is determined in accordance with 10 CFR part 430, subpart B, appendix E ("Appendix E"). EPCA defines a consumer "water heater" as a product which utilizes oil, gas, or electricity to heat potable water for use outside the heater upon demand, including storage-type units, instantaneous type units, and heat pump type units. (42 U.S.C. 6291(27)(A)-(C))

Table 12A.1.1 lists the current consumer water heater products covered at 10 CFR 430.32(d). Table 12A.1.2 specifies the consumer water heater products being analyzed for higher UEF levels. Table 12A.1.3 specifies the consumer water heater product types for which DOE is analyzing to convert EF standards to UEF standards.

Table 12A.1.1 Currently Covered Consumer Water Heater Products

Product	Rated Storage Volume and Input Rating (if applicable)
Gas-fired Storage	≥20 gal and ≤55 gal
	>55 gal and ≤100 gal
Oil-fired Storage	≤50 gal
Electric Storage	≥20 gal and ≤55 gal
	>55 gal and ≤100 gal
Tabletop	≥20 gal and ≤120 gal
Instantaneous Gas-Fired	<2 gal and >50,000 Btu/h
Instantaneous Electronic	<2 gal
Grid-Enabled	>75 gal

Table 12A.1.2 Consumer Water Heaters Analyzed for Higher UEF Levels

Product	Rated Storage Volume and Input Rating (if applicable)
Gas-fired Storage	≥20 gal and ≤55 gal
Oil-fired Storage	≤50 gal
Electric Storage	≥20 gal and ≤55 gal
	>55 gal and ≤100 gal
Instantaneous Gas-Fired	<2 gal and >50,000 Btu/h
Grid-Enabled	>75 gal

Table 12A.1.3 Consumer Water Heaters Analyzed for Conversion of EF Standards to UEF Standards

Product	Nominal Input	Rated Storage Volume
Gas-fired Storage Water Heater	≤ 75,000 Btu/h	< 20 gal
		> 100 gal
Oil-fired Storage Water Heater	≤ 105,000 Btu/h	> 50 gal
Electric Storage Water Heaters	≤ 12 kW	< 20 gal
		> 120 gal
Tabletop Water Heater	≤ 12 kW	< 20 gal
		> 120 gal
Instantaneous Gas-fired Water Heater	≤ 50,000 Btu/h	< 2 gal
	≤ 200,000 Btu/h	≥ 2 gal
Instantaneous Oil-fired Water Heater	≤ 210,000 Btu/h	< 2 gal
		≥ 2 gal
Instantaneous Electric Water Heater	≤ 12 kW	≥ 2 gal
Gas-fired Circulating Water Heater*	≤ 200,000 Btu/h	All
Oil-fired Circulating Water Heater*	≤ 210,000 Btu/h	All
Electric Circulating Water Heater*	≤ 12 kW	All
Low Temperature Water Heater*	≤ 12 kW	All

*Newly proposed product class

12A.2 KEY ISSUES

DOE is interested in understanding the impact of amended energy conservation standards on manufacturers. This section provides an opportunity for manufacturers to identify high priority issues that DOE should take into consideration.

2.1 In general, what are the key concerns for your company regarding this consumer water heater rulemaking?

2.2 Are there specific product classes or efficiency levels for which your concerns are particularly acute or exacerbated?

12A.3 TECHNOLOGIES

3.1 For gas-fired water heaters, both storage and instantaneous type, how does your company determine whether to require category III venting, category IV venting, or to not specify a venting category?

3.2 What design factors influence the type or thickness of the insulation chosen for consumer storage water heaters? Is there a limit to the amount of insulation that can be added to tanks (e.g., due to constraints on overall tank dimensions or diameter)?

3.3 Through review of available product databases, spec sheets, and physical examination during teardowns, DOE has seen several types of insulating materials used including polystyrene foam, polyurethane foam, and fiberglass insulation. Polyurethane foam insulation appears to be the most common type of insulation and is used to insulate most of the tank, while polystyrene foam and fiberglass insulation are used in small amounts and in hard to insulate areas. Are there reasons to exclude any of these technologies from DOE's analyses? Are there other insulation technologies that DOE should consider in its analyses? Are there other insulating materials not mentioned above that you have considered for use, but rejected (and if so, why were these materials rejected)?

3.4 Please describe the processes for insulating consumer storage water heaters. Are all surfaces (including top and bottom) typically insulated, and if so, are they insulated in the same way and/or with the same type and amount of insulation? How are ports insulated?

3.5 Through review of product literature, DOE has identified several materials that are used for lining the inner walls of a consumer storage water heater, including cement or enamel. What are the most commonly used lining materials? Are there any other lining materials used in consumer storage water heaters? Are there any significant performance differences for each of the coatings (e.g., from either from an efficiency or reliability standpoint)?

3.6 Do you plan to convert products using R-134a refrigerant to a low-GWP alternative in the near future? If so, which refrigerant? Are all heat pump water heaters affected?

3.7 Do you produce or plan to produce any water heaters that can switch between two or more types of fuel (e.g., a heat pump water heater with gas back-up)? If so, what determines when the fuel source changes (i.e., is the operation user-initiated or automatic)?

3.8 Do you produce or plan to produce any water heaters that store water at a temperature higher than the delivery temperature and use a mixing valve (either built-in or required to be installed by the installer) to reduce the stored water temperature to the required delivery temperature? Are there any performance or safety differences between a unit with a built-in mixing valve and a separately installed mixing valve? What temperatures can these products store water at? For consumers who have a water heater with this capability, what fraction of the time do you estimate consumers will utilize the overheating capability to get more delivery capacity from their water heaters?

12A.4 COST-EFFICIENCY CURVES

DOE has preliminarily chosen several efficiency levels (in terms of UEF values) to analyze for product classes which already have UEF-based standards at 10 CFR 430.32(d). These levels from the March 2022 Preliminary Analysis (found online at https://www.regulations.gov/document/EERE-2017-BT-STD-0019-0018) are shown in the tables below. Please provide comments on the assumed technology options as well as the efficiency levels, including any levels that should not be included or any additional levels (and their associated technologies and costs) that should be included. Please also provide comment on the preliminary manufacturer production cost (MPC) and shipping estimates.

Table 12A.4.1 Gas-fired Storage: 20 gal ≤ V_R ≤ 55 gal, Standard and Low NO_X

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	0.54	0.58	0.63**	Standing Pilot, Foam Insulation - Side: 1 in., Top: 1 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue	Low Draw: 171.82 Med: 184.41 High: 212.55	Low Draw: 45.21 Med: 49.51 High: 77.02	
1	N/A	0.57	0.60	0.64	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue	Low Draw: 187.07 Med: 201.04 High: 221.62	Low Draw: 49.51 Med: 72.97 High: 77.02	
2	N/A	0.59	0.64	0.68	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Thermopile Flue Damper, Heat Exchanger: Straight Flue	Low Draw: 214.20 Med: 228.00 High: 248.43	Low Draw: 49.51 Med: 72.97 High: 77.02	
	N/A	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in.,	Low Draw: 252.85 Med: 266.30	Low Draw: 49.51 Med: 72.97	

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
					Venting Category: I, Outlet Venting: Electric Flue Damper, Heat Exchanger: Straight Flue	High: 286.40	High: 77.02	
	N/A	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Fan Assist, Heat Exchanger: Straight Flue, Increased Baffling	Low Draw: 263.81 Med: 277.20 High: 297.39	Low Draw: 49.51 Med: 72.97 High: 77.02	
3	N/A	0.60	0.65	0.69	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: III, Outlet Venting: Power Vent, Heat Exchanger: Straight Flue, Increased Baffling	Low Draw: 233.04 Med: 246.94 High: 267.14	Low Draw: 49.51 Med: 72.97 High: 77.02	
4	N/A	0.71	0.75	0.80	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue	Low Draw: 356.77 Med: 379.99 High: 406.27	Low Draw: 49.51 Med: 72.97 High: 77.02	
5	N/A	0.77	0.81	0.86	Electronic Ignition, Foam Insulation - Side: 3 in., Top: 3 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue, Increased Surface Area	Low Draw: 424.69 Med: 454.46 High: 488.87	Low Draw: 72.97 Med: 77.02 High: 86.65	

*There are no gas-fired storage water heaters with standard or low NOX burners on the market within the very small draw pattern.
**The side and top insulation thicknesses are 1.5 in and 1.5 in, respectively.

Table 12A.4.2 Gas-fired Storage: 20 gal ≤ V_R ≤ 55 gal, Ultra Low NO_X

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	0.54	0.58	0.63**	Standing Pilot, Foam Insulation - Side: 1 in., Top: 1 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue	Low Draw: 258.43 Med: 274.48 High: 307.99	Low Draw: 45.21 Med: 49.51 High: 77.02	
1	N/A	0.57	0.60	0.64	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue	Low Draw: 273.80 Med: 291.76 High: 317.12	Low Draw: 49.51 Med: 72.97 High: 77.02	
2	N/A	0.59	0.64	0.68	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Thermopile Flue Damper, Heat Exchanger: Straight Flue	Low Draw: 299.32 Med: 317.04 High: 342.24	Low Draw: 49.51 Med: 72.97 High: 77.02	
	N/A	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Electric Flue Damper, Heat Exchanger: Straight Flue	Low Draw: 347.68 Med: 365.40 High: 390.60	Low Draw: 49.51 Med: 72.97 High: 77.02	
	N/A	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Fan Assist, Heat Exchanger: Straight Flue, Increased Baffling	Low Draw: 358.63 Med: 376.29 High: 401.59	Low Draw: 49.51 Med: 72.97 High: 77.02	
3	N/A	0.60	0.65	0.69	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: III, Outlet Venting: Power Vent, Heat Exchanger: Straight Flue, Increased Baffling	Low Draw: 327.99 Med: 346.26 High: 371.56	Low Draw: 49.51 Med: 72.97 High: 77.02	
4	N/A	0.71	0.75	0.80	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue	Low Draw: 434.93 Med: 461.66 High: 491.85	Low Draw: 49.51 Med: 72.97 High: 77.02	

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
5	N/A	0.77	0.81	0.86	Electronic Ignition, Foam Insulation - Side: 3 in., Top: 3 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue, Increased Surface Area	Low Draw: 503.51 Med: 535.89 High: 574.18	Low Draw: 72.97 Med: 77.02 High: 86.65	

*There are no gas-fired storage water heaters with ultra-low NO_X burners on the market within the very small draw pattern.
**The side and top insulation thicknesses are 1.5 in and 1.5 in, respectively.

Table 12A.4.3 Oil-fired Storage: $V_R \leq 50$ gal

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	N/A	N/A	0.64	Heat Exchanger: Single Flue, Foam Insulation - Side: 1 in., Top: 1.5 in.	866.41	72.97	
1	N/A	N/A	N/A	0.66	Heat Exchanger: Single Flue, Foam Insulation - Side: 2 in., Top: 2.5 in.	893.19	77.02	
2	N/A	N/A	N/A	0.68	Heat Exchanger: Multi-Flue, Foam Insulation - Side: 2 in., Top: 2.5 in.	969.99	77.02	

*There are no oil-fired storage water heaters on the market within the very small, low, or medium draw patterns.

Table 12A.4.4 Electric Storage: 20 gal $\leq V_R \leq$ 55 gal, Short and Tall Aspect Ratios

EL	UEF*				Technology Options	MPC: Short, Tall (2020$)	Shipping: Short, Tall (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	0.92**	0.92	0.93	Primary Heating Type: Electric Resistance, Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 3 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 3 in.	Low Draw: 143.91, 144.37 Med: 170.32, 171.07 High: 176.41, 176.52	Low Draw: 38.51, 49.51 Med: 77.02, 77.97 High: 77.02, 77.97	
1	N/A	0.93†	0.93	0.94	Primary Heating Type: Electric Resistance, Tall Aspect Ratio, Foam Insulation - Side: 4 in., Top: 4 in., Short Aspect Ratio, Foam Insulation - Side: 4 in., Top: 4 in.	Low Draw: 153.55, 165.28 Med: 195.75, 197.38 High: 203.16, 204.03	Low Draw: 40.77, 77.02 Med: 92.42, 86.65 High: 92.42, 86.65	
2	N/A	3.30	3.35	3.47	Primary Heating Type: Heat Pump, Evaporator: Tube and Fin, Condenser: Aluminum tubing around tank, Refrigerant: R-134a Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in.	Low Draw: 441.68, 427.56 Med: 457.66, 456.83 High: 464.34, 463.10	Low Draw: 69.32, 49.51 Med: 86.65, 72.97 High: 86.65, 72.97	
3	N/A	3.70	3.75	3.87	Primary Heating Type: Heat Pump,	Low Draw:	Low Draw:	

EL	UEF*				Technology Options	MPC: Short, Tall (2020$)	Shipping: Short, Tall (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
					Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in.	551.61, 529.08 Med: 560.74, 559.62 High: 567.59, 566.42	79.98, 49.51 Med: 86.65, 72.97 High: 86.65, 72.97	

*There are no electric storage water heaters on the market within the very small draw pattern.
**The top insulation thickness for the tall and short aspect ratios is 2 in.

Table 12A.4.5 Electric Storage: 55 gal < $V_R \leq$ 120 gal

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	N/A	2.05	2.15	Primary Heating Type: Heat Pump, Evaporator: Tube and Fin, Condenser: Aluminum tubing around tank, Refrigerant: R-134a Foam Insulation - Side: 2 in., Top: 2 in.,	Med Draw: 440.81 High: 474.76	Med Draw: 77.02 High: 86.65	
1	N/A	N/A	3.35	3.45	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Foam Insulation - Side: 2 in., Top: 2 in.,	Med Draw: 475.39 High: 510.02	Med Draw: 77.02 High: 86.65	
2	N/A	N/A	3.90	4.00	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Foam Insulation - Side: 2 in., Top: 2 in.,	Med Draw: 579.42 High: 610.38	Med Draw: 77.02 High: 86.65	
3	N/A	3.70	3.75	3.87	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in.	Low Draw: 551.61, 529.08 Med: 560.74, 559.62 High: 567.59, 566.42	Low Draw: 79.98, 49.51 Med: 86.65, 72.97 High: 86.65, 72.97	

*There is only one electric storage water heater over 55 gallons on the market within the low draw pattern, and none in the very small draw pattern.

Table 12A.4.6 Grid-Enabled

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	N/A	N/A	0.92	Foam Insulation - Side: 2 in., Top: 2 in.	230.94	86.65	
1	N/A	N/A	N/A	0.93	Foam Insulation - Side: 4 in., Top: 3 in.	264.24	148.54	

*There are no grid-enabled water heaters on the market within the very small, low, or medium draw patterns.

Table 12A.4.7 Tabletop

Due to the low market share and lack of viable technology options for substantively improving energy efficiency, DOE has tentatively determined not to analyze amended energy conservation standards for tabletop water heaters further. Please provide feedback on this tentative determination.

Table 12A.4.8 Gas-fired Instantaneous: V_R < 2 gal, Q_{in} > 50,000 Btu/h

EL	UEF*				Technology Options	MPC (2020$)	Shipping (2020$)	Manufacturer Feedback
	Very Small	Low	Medium	High				
0	N/A	0.81**	0.81	0.81	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: N/A	Med Draw: 250.35 High: 260.39	Med Draw: 6.25 High: 6.67	
1	N/A	N/A	0.87	0.89	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube	Med Draw: 358.52 High: 379.50	Med Draw: 9.37 High: 9.37	
2	N/A	N/A	0.91	0.93	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube, Increased Heat Exchange Area	Med Draw: 364.23 High: 386.60	Med Draw: 10.19 High: 10.89	
3	N/A	0.86†	0.96	0.97	Burner: Fully Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Flat Plate, Increased Heat Exchange Area	Med Draw: 375.19 High: 403.38	Med Draw: 19.80 High: 19.80	

*As of the preliminary analysis, DOE has not confirmed there are any gas-fired instantaneous water heaters on the market within the very small draw pattern.
**No models available on the market. Efficiency level is the energy conservation standard.
†One model on the market that uses a step modulating burner and a tube and fin condensing HX. This model does not have a non-condensing HX.

Table 12A.4.9 Electric Instantaneous

With regards to electric instantaneous water heaters which are capable of delivering water at the set point temperature specified in appendix E (125 °F ± 5 °F), DOE reviewed product literature regarding electric instantaneous water heaters and completed multiple product teardowns and was unable to determine technologies that would increase the efficiency of these products. Please comment on whether there are technologies that can improve the UEF of these products and, if so, which technologies and how much improvement in UEF is achievable.

12A.4.1 Manufacturing Production Cost Breakdown and Component Costs

Guidehouse estimated the MPCs of consumer water heaters. Guidehouse defines MPC as all direct costs associated with manufacturing a product. It includes direct labor, direct materials, and overhead (including depreciation costs). The breakdown of MPC has implications for the quantitative impacts on manufacturers of consumer water heater product in the manufacturer impact analysis.

4.1 Please compare your MPC percentages to the estimates tabulated below. Are the percentages of each cost representative of your company or the consumer water heater industry? Please explain any differences.

Table 12A.4.10 Breakdown of Manufacturer Production Costs for Baseline Consumer Water Heaters

Cost	DOE's Estimated Percentage of MPC							Manufacturer Feedback
	Gas-Fired Storage		Oil-fired Storage	Electric Storage		Gas-Fired Instantaneous	Grid-Enabled	
	Standard NO_X	Ultra-Low NO_X		Electric Resistance	Heat Pump			
Material	81.7%	83.7%	59.9%	64.7%	80.5%	58.9%	72.7%	
Labor	10.4%	9.0%	6.9%	25.1%	13.0%	25.5%	18.4%	
Depreciation	3.7%	3.1%	15.7%	5.3%	2.8%	9.0%	4.2%	
Overhead	4.2%	4.1%	17.6%	4.9%	3.6%	6.6%	4.6%	

4.2 Do these percentages change at larger volumes (or input rates, as applicable) or at higher efficiency levels for any of the product classes? Do they change significantly for any particular technology options?

4.3 Table 12A.4.11 below contains cost estimates for various consumer water heater components that have a significant impact on our MPCs and overall engineering analysis. Please provide feedback on our costs as compared to the cost estimates below. Given that some of these components vary depending on the application, feel free to provide either a range of costs or the cost for an average component.

Table 12A.4.11 Estimated Costs for Various Consumer Water Heater Components

Type of Unit	Associated Tech Option	Part/ Subassembly Description	Estimated Cost	Manufacturer Feedback
Heat Pump ESWH	Heat Pump	EEV	[redacted]	
		SPM Fan Motor for 5.7 kBTU/hr Heat Pump	[redacted]	
		Rotary Compressor, R134a, 5.7 kBTU/hr, 12.5 EER	[redacted]	
		Rotary Compressor, R134a, 5.7 kBTU/hr, 14.5 EER	[redacted]	
		ECM Fan Motor, 115V, 6.3 A, 1550 RPM	[redacted]	
	Controls	Dedicated Control PCB w/ WiFi	[redacted]	
		Dedicated Control PCB w/ UI Display and WiFi	[redacted]	
GSWH/ESWH		Stainless Steel Mixing Valve	[redacted]	
GSWH	Blower	SPM Inducer Blower Assembly for 40 Gallon Tank, 120V, 3.1 FLA	[redacted]	
		SPM Inducer Blower Assembly for 70 Gallon Tank, 120V	[redacted]	
		Blower Assembly w/ Premixer for 75kBTU/hr Power Burner	[redacted]	
		Non-Condensing PSC Inducer Assembly	[redacted]	
	Burner Assembly	Gas Valve w/ Standing Pilot and Igniter	[redacted]	
		Transformer for Ignition Control	[redacted]	
		115V Gas Valve Assembly	[redacted]	
		24V Digital Gas Valve Assembly	[redacted]	
		Thermopile Gas Valve Assembly w/ Digital Thermostat	[redacted]	
		Standing Pilot Gas Valve Assembly w/ Analog Thermostat	[redacted]	
	Gas Venting	Flue Damper Assembly	[redacted]	
ESWH	Grid Enabled	CTA 2045 Port	[redacted]	
		Activation Lock, 120/277VAC 30A	[redacted]	
	Controls	Electronic ESWH Control PCB w/ WiFi	[redacted]	
		Electronic ESWH Control PCB w/ UI Display and WiFi	[redacted]	
		Basic Electronic Thermostat	[redacted]	
OSWH	Controls	High Limit Controller for Oil Burner	[redacted]	
	Burner Assembly	150 kBTU Oil Burner Assembly	[redacted]	
GIWH	Controls	Spark Ignition Controller, 1pos, 120VV	[redacted]	
		24V Gas Valve Solenoid Coil	[redacted]	
		12V Single Stage Gas Valve Solenoid Header	[redacted]	
	Blower	BLDC Motor, 30VDC, 1.4A	[redacted]	
		BLDC Motor, 140VDC, 125W	[redacted]	
		BLDC Motor, 47.5VDC, 75W	[redacted]	

12A.5 NEW PRODUCT CLASSES

For consumer water heaters currently without UEF-based standards (including not only the volumes/input ranges which are not covered at 10 CFR 430.32(d), but also new product classes such as circulating water heaters and low temperature water heaters), DOE performed a crosswalk of the EF-based standards initially prescribed in EPCA (see 42 U.S.C. 6295(e)(1)) to determine new baseline standards in terms of UEF. DOE used the conversion equations from the December 2016 Conversion Factor Final Rule, along with preliminary assumptions for input parameters to the conversion equations to develop the converted UEF standards.

5.1 Do you manufacture any water heaters which fall in the product categories shown in Table 12A.5.1? If yes, which product categories?

5.2 Please provide feedback on the recovery efficiency assumptions used to convert EF-based standards to UEF-based standards for the following product categories which currently do not have UEF-based standards.

Table 12A.5.1 Recovery Efficiency by Product Category for the Derivation of Representative Baseline Models

Product Category	Nominal Input	Rated Storage Volume	Average Assumed Recovery Efficiency (%)	Manufacturer Feedback
Gas-fired Storage Water Heater	≤ 75,000 Btu/h	< 20 gal	79	
		> 100 gal	79	
Oil-fired Storage Water Heater	≤ 105,000 Btu/h	> 50 gal	70	
Electric Storage Water Heaters	≤ 12 kW	< 20 gal	98	
		> 120 gal	98	
Tabletop Water Heater	≤ 12 kW	< 20 gal	98	
Instantaneous Gas-fired Water Heater	≤ 50,000 Btu/h	< 2 gal	65	
	≤ 200,000 Btu/h	≥ 2 gal	79	
Instantaneous Oil-fired Water Heater	≤ 210,000 Btu/h	< 2 gal	62	
		≥ 2 gal	70	
Instantaneous Electric Water Heater	≤ 12 kW	≥ 2 gal	95	
Gas-fired Circulating Water Heater	≤ 200,000 Btu/h	All	65	
Oil-fired Circulating Water Heater	≤ 210,000 Btu/h	All	62	
Electric Circulating Water Heater	≤ 12 kW	All	95	

12A.6 CONVERSION COSTS

An increase in energy conservation standards may cause the industry to incur capital and product conversion costs to meet the amended energy conservation standards. The MIA considers three types of conversion-related impacts:

- **Capital conversion costs** – One-time investments in plant, property, and equipment (PPE) necessitated by amended energy conservation standards. These may be incremental changes to existing PPE or the replacement of existing PPE. Included are expenditures on buildings, equipment, and tooling.

- **Product conversion costs** – One-time investments in research, product development, testing, marketing, and other costs for redesigning products necessitated by amended energy conservation standards.

With a detailed understanding of the conversion costs necessitated by different standard levels, DOE can better model the impact on the consumer water heater industry resulting from amendments to the conservation standards.

6.1 How many consumer water heater basic models (covered by the scope of this rulemaking) does your company manufacturer?

6.2 What are the estimated conversion costs associated with transitioning from R-134a-based heat pump water heaters to low GWP alternatives?

6.3 Please provide an estimate of the capital conversion costs and product conversion costs that might result at the various efficiency levels for each equipment class in the tables below:

Table 12A.6.1 Gas-fired Storage: 20 gal ≤ V_R ≤ 55 gal, Standard and Low NO_X

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
0	0.54	0.58	0.63**	Standing Pilot, Foam Insulation - Side: 1 in., Top: 1 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue			
1	0.57	0.60	0.64	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue			
2	0.59	0.64	0.68	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Thermopile Flue Damper, Heat Exchanger: Straight Flue			

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Electric Flue Damper, Heat Exchanger: Straight Flue			
	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Fan Assist, Heat Exchanger: Straight Flue, Increased Baffling			
3	0.60	0.65	0.69	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: III, Outlet Venting: Power Vent, Heat Exchanger: Straight Flue, Increased Baffling			
4	0.71	0.75	0.80	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue			
5	0.77	0.81	0.86	Electronic Ignition, Foam Insulation - Side: 3 in., Top: 3 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue, Increased Surface Area			

*There are no gas-fired storage water heaters with standard or low NOX burners on the market within the very small draw pattern.
**The side and top insulation thicknesses are 1.5 in and 1.5 in, respectively.

Table 12A.6.2 Gas-fired Storage: 20 gal ≤ V_R ≤ 55 gal, Ultra Low NO_X

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
0	0.54	0.58	0.63**	Standing Pilot, Foam Insulation - Side: 1 in., Top: 1 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue			
1	0.57	0.60	0.64	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Atmospheric Vent, Heat Exchanger: Straight Flue			
2	0.59	0.64	0.68	Standing Pilot, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Thermopile Flue Damper, Heat Exchanger: Straight Flue			

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Electric Flue Damper, Heat Exchanger: Straight Flue			
	0.59	0.64	0.68	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: I, Outlet Venting: Fan Assist, Heat Exchanger: Straight Flue, Increased Baffling			
3	0.60	0.65	0.69	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: III, Outlet Venting: Power Vent, Heat Exchanger: Straight Flue, Increased Baffling			
4	0.71	0.75	0.80	Electronic Ignition, Foam Insulation - Side: 2 in., Top: 2 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue			
5	0.77	0.81	0.86	Electronic Ignition, Foam Insulation - Side: 3 in., Top: 3 in., Venting Category: IV, Outlet Venting: Power Vent, Condensing, Heat Exchanger: Helical Flue, Increased Surface Area			

Table 12A.6.3 Oil-fired Storage: $V_R \leq 50$ gal

EL	UEF*	Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	High				
0	0.64	Heat Exchanger: Single Flue, Foam Insulation - Side: 1 in., Top: 1.5 in.			
1	0.66	Heat Exchanger: Single Flue, Foam Insulation - Side: 2 in., Top: 2.5 in.			
2	0.68	Heat Exchanger: Multi-Flue, Foam Insulation - Side: 2 in., Top: 2.5 in.			

*There are no oil-fired storage water heaters on the market within the very small, low, or medium draw patterns.

Table 12A.6.4 Electric Storage: 20 gal $\leq V_R \leq$ 55 gal, Short and Tall Aspect Ratios

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
0	0.92**	0.92	0.93	Primary Heating Type: Electric Resistance, Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 3 in.,			

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
				Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 3 in.			
1	0.93 †	0.93	0.94	Primary Heating Type: Electric Resistance, Tall Aspect Ratio, Foam Insulation - Side: 4 in., Top: 4 in., Short Aspect Ratio, Foam Insulation - Side: 4 in., Top: 4 in.			
2	3.30	3.35	3.47	Primary Heating Type: Heat Pump, Evaporator: Tube and Fin, Condenser: Aluminum tubing around tank, Refrigerant: R-134a Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in.			
3	3.70	3.75	3.87	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Tall Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in., Short Aspect Ratio, Foam Insulation - Side: 2 in., Top: 2 in.			

*There are no electric storage water heaters on the market within the very small draw pattern.
**The top insulation thickness for the tall and short aspect ratios is 2 in.
†The tall aspect ratio top insulation thickness is 3 in. and the short aspect ratio side and top insulation thicknesses are 3 in. and 3 in., respectively.

Table 12A.6.5 Electric Storage: 55 gal < V_R ≤ 120 gal

EL	UEF*		Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Med.	High				
0	2.05	2.15	Primary Heating Type: Heat Pump, Evaporator: Tube and Fin, Condenser: Aluminum tubing around tank, Refrigerant: R-134a Foam Insulation - Side: 2 in., Top: 2 in.,			
1	3.35	3.45	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor Foam Insulation - Side: 2 in., Top: 2 in.,			
2	3.90	4.00	Primary Heating Type: Heat Pump, Increased Evaporator and Condenser Heat Exchange Area, Increased Capacity of Compressor			

EL	UEF*		Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Med.	High				
			Foam Insulation - Side: 2 in., Top: 2 in.,			

*There is only one electric storage water heater over 55 gallons on the market within the low draw pattern, and none in the very small draw pattern.

Table 12A.6.6 Grid-Enabled

EL	UEF*	Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	High				
0	0.92	Foam Insulation - Side: 2 in., Top: 2 in.			
1	0.93	Foam Insulation - Side: 4 in., Top: 3 in.			

*There are no grid-enabled water heaters on the market within the very small, low, or medium draw patterns

Table 12A.6.7 Gas-fired Instantaneous: V_R < 2 gal, Q_{in} > 50,000 Btu/h

EL	UEF*			Technology Options	Capital Conversion Costs	Product Conversion Costs	Manufacturer Feedback
	Low	Med.	High				
0	0.81**	0.81	0.81	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: N/A			
1	N/A	0.87	0.89	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube			
2	N/A	0.91	0.93	Burner: Step Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Tube, Increased Heat Exchange Area			
3	0.86†	0.96	0.97	Burner: Fully Modulating, Non-Condensing HX: Tube and Fin, Condensing HX: Flat Plate, Increased Heat Exchange Area			

*As of the preliminary analysis, DOE has not confirmed there are any gas-fired instantaneous water heaters on the market within the very small draw pattern.
**No models available on the market. Efficiency level is the energy conservation standard.
†One model on the market that uses a step modulating burner and a tube and fin condensing HX. This model does not have a non-condensing HX.

12A.7 COMPANY OVERVIEW AND ORGANIZATIONAL CHARACTERISTICS

Understanding how the manufacturing of consumer water heaters fits within your larger organization will help DOE better estimate the probable impacts of amended energy conservation standards.

7.1 Do you have a parent company and/or subsidiary? If so, please provide their name(s).

7.2 What are your product line niches and relative strengths in the consumer water heater market?

7.3 What percentage of your company's overall revenue is from consumer water heater sales covered by this rulemaking?

7.4 Where are your production facilities located, and what type of product is manufactured at each location? Please provide production figures for your company's manufacturing at each location by representative unit or equipment class grouping.

Table 12A.7.1 Manufacturing Locations

Location	Product Class	Employees (Production)	Employees (Non-production)	Units/Yr Produced
***Example*:** Jackson, TN	Gas-fired storage water heater (< 20 gal)	75	25	2,000

7.5 Is higher efficiency consumer water heater product built at separate production facilities than lower efficiency product? Are different product classes manufactured at separate production facilities?

7.6 Are other products besides consumer water heaters produced at each of the locations listed in the table above? If so, is any of the production equipment used to manufacture consumer water heaters shared to manufacture other products?

12A.8 FINANCIAL PARAMETERS

8.1 Please compare your company's consumer water heater financial parameters to the financial parameters tabulated below.

Table 12A.8.1 Financial Parameters for Consumer Water Heater Manufacturers

GRIM Input	Definition	Industry Estimated Value (%)	Manufacturer Feedback
Income Tax Rate	Corporate effective income tax paid (percentage of earnings before taxes)	24	
Discount Rate	Weighted average cost of capital (inflation-adjusted weighted average of corporate cost of debt and return on equity)	24.9	

GRIM Input	Definition		
		Industry Estimated Value (%)	Manufacturer Feedback
Working Capital	Current assets less current liabilities (percentage of revenues)	24.9	
Net PPE	Property, plant, and equipment used to manufacture the covered products. Net is the gross minus the book value depreciated (percentage of revenues)	16.3	
SG&A	Selling, general, and administrative expenses (percentage of revenues)	22.8	
R&D	Research and development expenses (percentage of revenues)	2.6	
Depreciation	Amortization of fixed assets (percentage of revenues)	2.3	
Capital Expenditures	Outlay of cash to acquire or improve capital assets (percentage of revenues, not including acquisition or sale of business units)	2.5	

12A.9 MARKET SHARE AND PRODUCT DISTRIBUTIONS

9.1 What is your company's annual shipments of covered products by product class? What is the approximate national market share for each of these product classes?

Table 12A.9.1 Annual Shipments and Market Share

Product Class	Rated Storage Volume and Input Rating (if applicable)	Annual Unit Shipments	Market Share (% of total industry shipments)
Gas-fired Storage	≥20 gal and ≤55 gal		
Oil-fired Storage	≤50 gal		
Electric Storage	≥20 gal and ≤55 gal		
	>55 gal and ≤100 gal		
Instantaneous Gas-Fired	<2 gal and >50,000 Btu/h		
Grid-Enabled	>75 gal		

9.2 Can you comment on the efficiency distributions (percentage of shipments at each EL listed in Table 12A.1.2) within each product class?

9.3 How would your company's product mix change with amended energy conservation standards?

9.4 Who are your primary competitors? Can you provide an estimate of their market shares in each product class?

9.5 Could amended standards result in disproportionate economic or performance penalties for particular consumer subgroups?

9.6 Beyond price and energy efficiency, could amended standards result in product that will be more or less desirable to consumers due to changes in product functionality, utility, or other features?

12A.10 MANUFACTURER MARKUP AND PROFITABILITY

DOE defines manufacturer selling price (MSP) as the average price manufacturers charge their first customer. MSP does not include the distribution chain markups made by intermediaries, such as distributors and installation contractors, between the manufacturer and the end customer.

DOE defines manufacturer markup as MSP/MPC, the manufacturer sales price divided by the manufacturer production cost. The manufacturer markup is a multiplier applied to the MPC to cover production costs, per unit research and development, selling, general, and administrative expenses, and profit.

10.1 DOE calculated the following manufacturer markups for consumer water heaters. How does this figure compare to your company's manufacturer markups for consumer water heaters? Do the manufacturer markups vary by product class?

Table 12A.10.1 Annual Shipments and Market Share

Product Type	Manufacturer Markup	Gross Margin (%)	Manufacturer Comment
Gas-fired storage	1.31	24	
Electric storage	1.28	22	
Oil-fired storage	1.30	23	
Gas-fired instantaneous	1.45	31	
Grid-enabled	1.28	22	

10.2 Within each product type, does the manufacturer markup vary by efficiency?

10.3 What other factors affect the manufacturer markup?

10.4 Would you expect amended energy conservation standards to affect your manufacturer markup? If so, please explain why.

12A.11 DISTRIBUTION CHANNELS

11.1 In the consumer water heater industry, which party in the supply chain typically pays for shipping product to the distributor warehouse?

11.2 What are the primary distribution channels for consumer water heaters?

Table 12A.11.1 Distribution Channels Market Share

Channel	% of Units Sold
Sold directly to customers	
Sold through a retailer	
Sold through a distributor	
Sold directly to a contractor	
Sold directly to a builder:	
Other:	

11.3 What percentage of your consumer water heater sales is for replacement versus new construction?

Table 12A.11.2 Market Share for Replacement Versus New Construction

Customer Type	% of Units Sold
Replacement	
New construction	

12A.12 SHIPMENT PROJECTIONS

Amended energy conservation standards can change overall shipments by altering product attributes, marketing approaches, product availability, and price. DOE's shipments model includes forecasts for the base case shipments (i.e., total industry shipments absent amended energy conservation standards) and the standards case shipments (i.e., total industry shipments with amended energy conservation standards).

12.1 In the absence of amended standards, is there a market trend toward more efficient products? Does this vary by product class?

12.2 How do you think amended energy conservation standards will impact the sales of more efficient product?

12.3 How will amended standards affect total unit sales for the industry? How sensitive do you think shipments will be to price changes? Will it vary with product class?

12A.13 INSTALLATION, MAINTENANCE, AND REPAIR

13.1 For your customer base, what is the typical replacement rate for consumer water heaters (e.g., 5 years, 10 years, 20 years)? Is there any variation in unit or component replacement based on product class? Is there any variation in replacement rate by application?

13.2 How active is the used consumer water heater market? Relative to the size of the new consumer water heater market, what would you estimate as the size of the used consumer water heater market (e.g., 2%, 10%)?

13.3 How do installation costs differ between a baseline and higher efficiency consumer water heaters?

13.4 How do maintenance costs and repair costs differ between baseline and higher efficiency consumer water heaters?

12A.14 CUMULATIVE REGULATORY BURDEN

Cumulative regulatory burden refers to the burden that industry faces from overlapping effects of new or revised DOE standards and/or other Federal regulatory actions affecting the same product or revenue streams.

14.1 Are there other Federal regulations that could result in cumulative regulatory burden?

14.2 Are there non-Federal regulations that will require redesign of consumer water heaters?

14.3 Under what circumstances would you be able to coordinate expenditures related to these other regulations with amended energy conservation standards, thereby lessening the cumulative burden?

14.4 Do you anticipate any industry-wide constraints that would delay the industry's ability to comply with potential amended energy conservation standards?

12A.15 CAPACITY, EXPORTS, FOREIGN COMPETITION, AND OUTSOURCING

15.1 How would amended energy conservation standards impact your company's manufacturing capacity, in either the short-term or the long-term?

15.2 Absent amended energy conservation standards, are production facilities being relocated to foreign countries?

15.3 Would amended energy conservation standards impact your domestic vs. foreign manufacturing decision?

15.4 What percentage of your U.S. production of consumer water heaters is exported?

15.5 What percentage of the U.S. market for consumer water heaters is imported? Would amended energy conservation standards have an impact on foreign competition?

12A.16 CONSOLIDATION

Amended energy conservation standards can alter the competitive dynamics of the market. This can include prompting companies to enter or exit the market, or to merge. DOE and the Department of Justice are both interested in any potential reduction in competition that could result from amended energy conservation standards.

16.1 Please comment on industry consolidation and related trends over the last several years.

16.2 In the absence of amended energy conservation standards, do you expect any further industry consolidation? Please describe your expectations.

16.3 How would industry competition change as result of amended energy conservation standards?

12A.17 IMPACTS ON SMALL BUSINESSES

17.1 The Small Business Association (SBA) denotes a small business in the consumer water heater industry as having less than 1,500 employees.[a] Below is a list of small business consumer water heater manufacturers compiled by DOE. Are there any small manufacturers that should be added to this list? Are there specific manufacturers on this list that may be more severely impacted by amended energy conservation standards than others?

[a] DOE uses the SBA small business size standards effective August 19, 2019 to determine whether a company is a small business. Consumer water heater manufacturing is classified under NAICS code 335220 ("Major Household Appliance Manufacturing"). To be categorized as a small business consumer water heater manufacturer, a company and its affiliates may employ a maximum of 1,500 employees. The 1,500 employee threshold includes all employees in a business's parent company and any other subsidiaries.

Table 12A.17.1 Small Business Manufacturers

Manufacturer	Feedback
Bock Water Heaters	
Hubbell Electric Heater Company	
King Electrical Manufacturing Company	
Marey Water Heaters	
Niagara Industries	
Nyle Water Heating Systems	
Other:	
Other:	
Other:	

17.2 Are there any reasons that a small business might be at a disadvantage relative to a larger business under amended energy conservation standards?

APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

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APPENDIX 12B. GOVERNMENT REGULATORY IMPACT MODEL OVERVIEW

12B.1 INTRODUCTION AND PURPOSE

The purpose of the Government Regulatory Impact Model (GRIM) is to help quantify the impacts of energy conservation standards on manufacturers in aggregate. The basic mode of analysis is to estimate the change in the value of the industry, or industry net present value (INPV), following new and/or amended energy conservation standard, as represented by trial standard levels (TSL).

Industry net present value is defined, for the purpose of this analysis, as the discounted sum of industry free cash flows plus a discounted terminal value. The model calculates the actual cash flows by year and then determines the present value of those cash flows both without an energy conservation standard (i.e., the no-standards case) and under different trial standard levels (i.e., the standards cases).

Outputs from the model consist of summary financial metrics, graphs of major variables, and access to the complete cash flow calculation.

12B.2 MODEL DESCRIPTION

The basic structure of the GRIM is a standard annual cash flow analysis that uses financial parameters, shipments from the national impact analysis, and manufacturing production costs as inputs and accepts a set of regulatory conditions as changes in costs and investments. The cash flow analysis is separated into two major blocks: an industry income statement and an industry cash flow statement. The income calculation determines net operating profit after taxes. The cash flow calculation converts net operating profit after taxes into an annual cash flow by including investment and non-cash items. Below are definitions of listed items on the output sheet ("No STDs Case DCF" tab) of the GRIM. Please refer to Figure 12B.2.1.

Industry Income Statement

(1) ***Revenues:*** The GRIM presents annual revenues for the industry. Revenues are calculated by multiplying unit sales at each efficiency level by the associated manufacturer sales price. Annual revenues are the sum of revenues from all efficiency levels in a given year.

(2) ***Total Shipments:*** Total annual shipments for the industry were obtained from the National Impact Analysis. Total shipments are the sum of shipments for all efficiency levels in a given year. Shipments by TSL, product class, and efficiency level can be found in the "Shipments" tab of the GRIM.

(3) ***MPC:*** The manufacturer production cost (MPC).

(4) ***Overhead:*** The portion of MPC that accounts for production facility overhead, including utilities, maintenance, property tax, and insurance. The annual overhead cost is the sum of the overhead component of MPC for all units shipped in a year.

(5) ***Standard SG&A:*** Selling, general, and administrative (SG&A) expenses are calculated by multiplying revenue by the SG&A percentage found on the "Financials" tab of the GRIM.

(6) ***R&D:*** Research and development (R&D) expenses are calculated by multiplying revenue by the R&D value found on the "Financials" tab of the GRIM.

(7) ***Product Conversion Costs:*** Product conversion costs are one-time investments in research, development, testing, marketing, and other costs focused on making equipment designs comply with new and/or amended energy conservation standards. The GRIM allocates these costs over the period between the standard's announcement year (i.e., publication of a final rule) and the compliance year. Product conversion cost details can be found in the "Conversion Costs" tab of the GRIM.

(8) ***Stranded Assets:*** In the compliance year of the standard, the GRIM can include a one-time write-off of assets that become obsolete or non-performing due to new and/or amended standards. Stranded asset details can be found in the "Conversion Costs" tab of the GRIM.

(9) ***Earnings Before Interest and Taxes (EBIT):*** Includes profits before deductions for interest paid and taxes.

(10) ***Taxes:*** Industry tax expenses calculated by multiplying EBIT by the tax rate contained in "Financials" tab of the GRIM.

(11) ***Net Operating Profits After Taxes (NOPAT):*** Computed by subtracting manufacturer production costs (Materials + Labor + Overhead + Depreciation), SG&A, R&D, Product Conversion Costs, and Taxes from Revenues.

Industry Cash Flow Statement

(1) ***NOPAT***: This is a repeat of NOPAT in the Industry Income Statement.

(2) ***Depreciation***: Industry depreciation is added back into the Statement of Cash Flows because it is a non-cash expense.

(3) ***Loss on Disposal of Stranded Assets:*** This is a repeat of Stranded Assets in the Industry Income Statement. This is added back into the Statement of Cash Flows because it is a non-cash expense.

(4) ***Change in Working Capital***: Change in cash tied up in accounts receivable, inventory, and other cash investments necessary to support operations is calculated by multiplying working capital (as a percentage of revenues) by the change in annual revenues. The Working Capital percentage can be found on the "Financials" tab of the GRIM.

(5) ***Cash Flow from Operations***: Calculated by taking NOPAT, adding back the non-cash items Depreciation and Loss on Disposal of Stranded Assets, and subtracting the Change in Working Capital.

(6) ***Ordinary Capital Expenditures:*** Ordinary investments in property, plant, and equipment to maintain and replace existing production assets, computed as a percentage of revenues based on the value on the "Financials" tab of the GRIM.

(7) ***Capital Conversion Costs:*** Capital conversion costs are one-time investments in property, plant, and equipment to adapt or change existing production facilities so that new equipment designs can be fabricated and assembled under the new regulation. The GRIM allocates these costs over the period between the standard's announcement and compliance dates. Capital conversion cost details can be found in the "Conversion Costs" tab of the GRIM.

(8) ***Free Cash Flow:*** Annual cash flow from operations and investments; computed by subtracting Ordinary Capital Expenditures and Capital Conversion Costs from Cash Flows from Operations.

(9) ***Free Cash Flow:*** This is a repeat of Free Cash Flow from the Industry Cash Flow Statement.

(10) ***Terminal Value:*** Estimate of the continuing value of the industry after the analysis period. Computed by growing the Free Cash Flow at a constant rate in perpetuity. The terminal growth rate can be found in the "Financials" tab of the GRIM.

(11) ***Present Value Factor:*** Factor used to calculate an estimate of the present value of an amount to be received in the future that is calculated using the industry's Weighted Average Cost of Capital, found on the "Financials" tab of the GRIM.

(12) ***Discounted Cash Flow:*** Free Cash Flows multiplied by the Present Value Factor. For the final year of the analysis, the discounted cash flow includes the discounted Terminal Value.

(13) ***Industry Net Present Value (INPV):*** The sum of Discounted Cash Flows from the reference year to the terminal year of the GRIM analysis.

Standard Case DCF | **Navigation**

Industry Income Statement (in 2020$ millions)	**2018**	**Ref Yr 2019**	**2020**	**Ancmt Yr 2021**	**2022**	**2023**	**2024**	**2025**	**Std Yr 2026**	**2027**	**2028**
Revenues	$ 8,529.7	$ 8,929.4	$ 9,308.1	$ 9,586.6	$ 9,786.7	$ 9,970.5	$ 10,207.6	$ 10,365.0	$ 10,549.2	$ 10,761.7	$ 10,977.4
Total Shipments *(million units)*	6.534	6.831	7.113	7.320	7.470	7.606	7.644	7.757	7.889	8.041	8.195
- MPC	$ 6,357.7	$ 6,655.4	$ 6,937.6	$ 7,145.0	$ 7,294.2	$ 7,431.1	$ 7,607.6	$ 7,724.8	$ 7,862.0	$ 8,020.3	$ 8,180.8
- Standard SG&A	$ 1,347.7	$ 1,410.8	$ 1,470.7	$ 1,514.7	$ 1,546.3	$ 1,575.3	$ 1,612.8	$ 1,637.7	$ 1,666.8	$ 1,700.4	$ 1,734.4
- R&D	$ 189.4	$ 198.2	$ 206.6	$ 212.8	$ 217.3	$ 221.3	$ 226.6	$ 230.1	$ 234.2	$ 238.9	$ 243.7
- Product Conversion Costs	$ -	$ -	$ 0.8	$ 6.8	$ 14.3	$ 17.9	$ 0.8	$ -	$ -	$ -	$ -
- Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9.2	$ -	$ -
Earnings Before Interest and Taxes (EBIT)	$ 635.0	$ 664.9	$ 692.4	$ 707.3	$ 714.6	$ 724.8	$ 759.8	$ 772.4	$ 777.0	$ 802.2	$ 818.4
Per Unit EBIT *($/unit)*	$ 97.18	$ 97.34	$ 97.35	$ 96.62	$ 95.67	$ 95.30	$ 99.40	$ 99.57	$ 98.49	$ 99.76	$ 99.87
EBIT/Revenues (%)	*7.4%*	*7.4%*	*7.4%*	*7.4%*	*7.3%*	*7.3%*	*7.4%*	*7.5%*	*7.4%*	*7.5%*	*7.5%*
- Taxes	$ 215.9	$ 226.1	$ 235.4	$ 240.5	$ 243.0	$ 246.4	$ 258.3	$ 262.6	$ 264.2	$ 272.8	$ 278.3
Net Operating Profit after Taxes (NOPAT)	**$ 419.1**	**$ 438.8**	**$ 457.0**	**$ 466.8**	**$ 471.7**	**$ 478.4**	**$ 501.4**	**$ 509.8**	**$ 512.8**	**$ 529.5**	**$ 540.2**

Industry Cash Flow Statement											
NOPAT	$ 419.1	$ 438.8	$ 457.0	$ 466.8	$ 471.7	$ 478.4	$ 501.4	$ 509.8	$ 512.8	$ 529.5	$ 540.2
+ Depreciation	$ 153.5	$ 160.7	$ 167.5	$ 172.6	$ 176.2	$ 179.5	$ 183.7	$ 186.6	$ 189.9	$ 193.7	$ 197.6
+ Loss on Disposal of Stranded Assets	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ 9.2	$ -	$ -
- Change in Working Capital	$ -	$ 39.6	$ 37.5	$ 27.6	$ 19.8	$ 18.2	$ 23.5	$ 15.6	$ 18.2	$ 21.0	$ 21.3
Cash Flows from Operations	$ 572.6	$ 560.0	$ 587.1	$ 611.8	$ 628.0	$ 639.6	$ 661.7	$ 680.8	$ 693.7	$ 702.1	$ 716.4
- Ordinary Capital Expenditures	$ 170.6	$ 178.6	$ 186.2	$ 191.7	$ 195.7	$ 199.4	$ 204.2	$ 207.3	$ 211.0	$ 215.2	$ 219.5
- Capital Conversion Costs	$ -	$ -	$ 1.2	$ 10.4	$ 22.0	$ 27.5	$ -	$ -	$ -	$ -	$ -
Free Cash Flow	**$ 402.0**	**$ 381.4**	**$ 399.7**	**$ 409.7**	**$ 410.3**	**$ 412.8**	**$ 457.5**	**$ 473.5**	**$ 482.7**	**$ 486.9**	**$ 496.9**

Discounted Industry Cash Flow											
Free Cash Flow	$ 402.0	$ 381.4	$ 399.7	$ 409.7	$ 410.3	$ 412.8	$ 457.5	$ 473.5	$ 482.7	$ 486.9	$ 496.9
Terminal Value	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Present Value Factor	*0.000*	*1.000*	*0.901*	*0.812*	*0.731*	*0.659*	*0.593*	*0.535*	*0.482*	*0.434*	*0.391*
Discounted Cash Flow	**$ -**	**$ 381.4**	**$ 360.1**	**$ 332.5**	**$ 300.0**	**$ 271.9**	**$ 271.5**	**$ 253.1**	**$ 232.5**	**$ 211.3**	**$ 194.2**

INPV at No STDs Case $ 4,652.2

Net PPE	$ -	$ 17.9	$ 37.7	$ 67.2	$ 108.8	$ 156.2	$ 176.6	$ 197.3	$ 209.2	$ 230.7	$ 252.7
Net PPE as % of Sales	0.0%	0.2%	0.4%	0.7%	1.1%	1.6%	1.7%	1.9%	2.0%	2.1%	2.3%
Net Working Capital	$ 844.4	$ 884.0	$ 921.5	$ 949.1	$ 968.9	$ 987.1	$ 1,010.6	$ 1,026.1	$ 1,044.4	$ 1,065.4	$ 1,086.8
Return on Invested Capital (ROIC)	49.63%	48.66%	47.64%	45.93%	43.77%	41.84%	42.24%	41.67%	40.91%	40.85%	40.33%
Weighted Average Cost of Capital (WACC)	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%
Return on Sales (EBIT/Sales)	7.44%	7.45%	7.44%	7.38%	7.30%	7.27%	7.44%	7.45%	7.37%	7.45%	7.46%

Figure 12B.2.1 Detailed Income Statement and Cash Flow Statement Example

APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

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APPENDIX 13A. EMISSIONS ANALYSIS METHODOLOGY

13A.1 INTRODUCTION

The emissions analysis consists of two components. The first component estimates the effect of potential energy conservation standards on power sector and site combustion emissions of carbon dioxide (CO_2), nitrogen oxides (NO_X), sulfur dioxide (SO_2), and mercury (Hg). The second component estimates the impacts of a potential standard on emissions of two additional greenhouse gases, methane (CH_4) and nitrous oxide (N_2O), as well as the reductions to emissions of all species due to "upstream" activities in the fuel production chain. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Together, these emissions account for the full-fuel-cycle (FFC), in accordance with DOE's FFC Statement of Policy. 76 FR 51282 (Aug. 18, 2011).

The analysis of power sector emissions uses marginal emissions intensity factors calculated by DOE. DOE's methodology is based on results published with the most recent edition of the *Annual Energy Outlook (AEO)* which is published by the Energy Information Agency (EIA). For this analysis DOE used *AEO 2023*.[1] DOE developed end-use specific emissions intensity coefficients, in units of mass of pollutant per kWh of site (grid) electricity, for each pollutant. The methodology is based on the more general approach used for all the utility sector impacts calculations, which is described in appendix 15A of this TSD and in the report "Utility Sector Impacts of Reduced Electricity Demand" (Coughlin, 2014; Coughlin, 2019).[2,3] This appendix describes the methodology used to estimate the upstream emissions factors, and presents the values used for all emissions factors.

13A.2 POWER SECTOR AND SITE EMISSIONS FACTORS

Power sector marginal emissions factors are calculated by looking at the difference, over the full analysis period, in fuel consumption and emissions across a variety of cases published with the AEO. The analysis produces a set of emissions intensity factors that quantify the reduction in emissions of a given pollutant per unit reduction of fuel used in (grid) electricity generation for each of the primary fossil fuel types (coal, natural gas and oil). These factors are combined with estimates of the fraction of generation allocated to each fuel type, also calculated from *AEO 2023* data, for each sector and end-use. The result is a set of end-use specific marginal emissions intensity factors, summarized in the tables below. Total emissions reductions are estimated by multiplying the intensity factors times the energy savings calculated in the national impact analysis (chapter 10). Power sector emissions factors are presented in Table 13A.4.2 through Table 13A.4.7.

Site combustion of fossil fuels in buildings (for example in water-heating, space-heating or cooking applications) also produces emissions of CO_2 and other pollutants. To quantify the reduction in these emissions from a considered standard level, DOE used emissions intensity factors from Environmental Protection Agency (EPA) publications.[4] These factors, presented in Table 13A.4.1, are constant in time. The EPA defines SO_2 emissions in terms of a formula that depends on the sulfur content of the fuel. The typical use of petroleum-based fuels in buildings if for heating, and a typical sulfur content for heating oils is a few hundred parts-per-million (ppm). The value provided in Table 13A.4.1 corresponds to a sulfur content of approximately 100 ppm.

13A.3 UPSTREAM FACTORS

The FFC upstream emissions are estimated based on the methodology developed by Coughlin (2013).[5] The upstream emissions include both emissions from fuel combustion during extraction, processing and transportation of fuel, and "fugitive" emissions (direct leakage to the atmosphere) of CH_4 and CO_2.

The FFC accounting approach is described briefly in appendix 10B and in Coughlin (2013).[5] When demand for a particular fuel is reduced, there is a corresponding reduction in the upstream activities associated with production of that fuel (mining, refining etc.) These upstream activities also consume energy and therefore produce combustion emissions. The FFC accounting estimates the total consumption of electricity, natural gas and petroleum-based fuels in these upstream activities. The relevant combustion emissions factors are then applied to this fuel use to determine the total upstream emissions intensities from combustion, per unit of fuel delivered to the consumer.

In addition to combustion emissions, extraction and processing of fossil fuels also produces fugitive emissions of CO_2 and CH_4. Fugitive emissions of CO_2 are small relative to combustion emissions, comprising about 2-3 percent of total CO_2 emissions for natural gas and 1-2 percent for petroleum fuels. In contrast, the fugitive emissions of methane from fossil fuel production are relatively large compared to combustion emissions of CH_4. Hence, fugitive emissions make up over 99 percent of total methane emissions for natural gas, about 95 percent for coal, and 93 percent for petroleum fuels.

Fugitive emissions factors for CO_2 and methane from coal mining and natural gas production were estimated based on a review of studies compiled by Burnham (2011).[6] This review includes estimates of the difference between fugitive emissions factors for conventional production of natural vs. unconventional (shale or tight gas). These estimates rely in turn on data gathered by EPA under new GHG reporting requirements for the petroleum and natural gas industries.[7,8] The value for methane, if it were translated to a leakage rate, would be equivalent to 1.3%. Actual leakage rates of methane at various stages of the production process are highly variable and the subject of ongoing research. In a comprehensive review of the literature, Brandt et al. (2014)[9] find that, while regional studies with very high emissions rates may not be representative of typical natural gas systems, it is also true that official inventories have most likely underestimated methane emissions. As more data are made available, DOE will continue to update these estimated emissions factors.

Upstream emissions factors account for both fugitive emissions and combustion emissions in extraction, processing, and transport of primary fuels. For ease of application in its analysis, DOE developed all of the emissions factors using site (point of use) energy savings in the denominator. Table 13A.4.1 presents the electricity upstream emissions factors for selected years. The caps that apply to power sector NO_X emissions do not apply to upstream combustion sources, so some components of the upstream fuel cycle (particularly off-road mobile engines) can contribute significantly to the upstream NO_X emissions factors.

13A.4 DATA TABLES

Summary tables of all the emissions factor data used by DOE for rules using *AEO 2023* are presented in the tables below. Table 13A.4.1 provides combustion emissions factors for fuels commonly used in buildings. Table 13A.4.2 to Table 13A.4.7 present the marginal power sector emissions factors as a function of sector and end use for a selected set of years.

Table 13A.4.8 to Table 13A.4.10 provide the upstream emissions factors for all pollutants, for site electricity, natural gas and petroleum fuels. In all cases, the emissions factors are defined relative to the site electricity supplied from the grid and site use of the fuel.

Table 13A.4.1 Site Combustion Emissions Factors

Species	Natural Gas g/mcf	Distillate Oil g/bbl
CH_4	1.03E+00	1.33E+01
CO_2	5.47E+04	4.46E+05
N_2O	1.03E-01	8.65E+00
NO_x	4.36E+01	3.62E+02
SO_2	2.73E-01	2.20E+02

Table 13A.4.2 Power Sector Emissions Factors for CO_2 (Short Tons per GWh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	487	243	208	190	178	162
Cooking	481	241	207	189	178	161
Freezers	497	248	213	194	182	165
Lighting	497	243	207	188	176	158
Refrigeration	496	248	213	194	182	165
Space Cooling	464	251	221	206	197	183
Space Heating	503	244	207	187	175	157
Water Heating	488	241	205	187	175	158
Other Uses	487	243	207	189	178	161
Commercial Sector						
Cooking	445	228	196	181	171	157
Lighting	455	232	199	183	174	159
Office Equipment (Non-Pc)	428	225	194	180	172	159
Office Equipment (Pc)	428	225	194	180	172	159
Refrigeration	482	241	206	188	177	161
Space Cooling	455	249	220	206	197	183
Space Heating	507	246	208	188	175	157
Ventilation	483	241	206	188	177	160
Water Heating	443	227	194	180	170	156
Other Uses	435	227	195	181	172	158
Industrial Sector						
All Uses	435	227	195	181	172	158

Table 13A.4.3 Power Sector Emissions Factors for CH_4 (Short Tons per GWh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	0.0401	0.0175	0.0160	0.0137	0.0122	0.0103
Cooking	0.0391	0.0171	0.0157	0.0134	0.0119	0.0101
Freezers	0.0413	0.0181	0.0166	0.0142	0.0126	0.0107
Lighting	0.0418	0.0181	0.0166	0.0142	0.0126	0.0106
Refrigeration	0.0413	0.0180	0.0165	0.0141	0.0126	0.0106
Space Cooling	0.0352	0.0158	0.0145	0.0125	0.0112	0.0096
Space Heating	0.0428	0.0186	0.0170	0.0145	0.0128	0.0108
Water Heating	0.0404	0.0176	0.0161	0.0138	0.0122	0.0103
Other Uses	0.0400	0.0175	0.0160	0.0137	0.0122	0.0103
Commercial Sector						
Cooking	0.0338	0.0149	0.0136	0.0117	0.0104	0.0089
Lighting	0.0353	0.0155	0.0142	0.0122	0.0109	0.0092
Office Equipment (Non-Pc)	0.0313	0.0139	0.0127	0.0109	0.0098	0.0084
Office Equipment (Pc)	0.0313	0.0139	0.0127	0.0109	0.0098	0.0084
Refrigeration	0.0393	0.0172	0.0157	0.0134	0.0120	0.0101
Space Cooling	0.0338	0.0153	0.0140	0.0121	0.0109	0.0094
Space Heating	0.0434	0.0188	0.0172	0.0147	0.0130	0.0110
Ventilation	0.0394	0.0172	0.0158	0.0135	0.0120	0.0102
Water Heating	0.0337	0.0149	0.0135	0.0116	0.0104	0.0089
Other Uses	0.0324	0.0144	0.0131	0.0113	0.0101	0.0086
Industrial Sector						
All Uses	0.0324	0.0144	0.0131	0.0113	0.0101	0.0086

Table 13A.4.4 Power Sector Emissions Factors for Hg (Short Tons per TWh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	0.00140	0.00052	0.00047	0.00038	0.00035	0.00035
Cooking	0.00137	0.00051	0.00046	0.00037	0.00034	0.00034
Freezers	0.00145	0.00054	0.00049	0.00039	0.00037	0.00036
Lighting	0.00147	0.00055	0.00049	0.00040	0.00037	0.00036
Refrigeration	0.00145	0.00054	0.00049	0.00039	0.00037	0.00036
Space Cooling	0.00120	0.00044	0.00040	0.00032	0.00030	0.00029
Space Heating	0.00152	0.00056	0.00051	0.00041	0.00038	0.00038
Water Heating	0.00142	0.00053	0.00048	0.00038	0.00036	0.00035
Other Uses	0.00140	0.00052	0.00047	0.00038	0.00035	0.00035
Commercial Sector						
Cooking	0.00115	0.00043	0.00038	0.00031	0.00029	0.00028
Lighting	0.00121	0.00045	0.00040	0.00033	0.00030	0.00030
Office Equipment (Non-Pc)	0.00105	0.00039	0.00035	0.00028	0.00026	0.00026
Office Equipment (Pc)	0.00105	0.00039	0.00035	0.00028	0.00026	0.00026
Refrigeration	0.00137	0.00051	0.00046	0.00037	0.00035	0.00034
Space Cooling	0.00114	0.00042	0.00038	0.00031	0.00029	0.00028
Space Heating	0.00154	0.00057	0.00052	0.00042	0.00039	0.00038
Ventilation	0.00138	0.00051	0.00046	0.00037	0.00035	0.00034
Water Heating	0.00115	0.00042	0.00038	0.00031	0.00029	0.00028
Other Uses	0.00109	0.00040	0.00036	0.00029	0.00027	0.00027
Industrial Sector						
All Uses	0.00109	0.00040	0.00036	0.00029	0.00027	0.00027

Table 13A.4.5 Power Sector Emissions Factors for N_2O (Short Tons per GWh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	0.00569	0.00245	0.00226	0.00192	0.00169	0.00143
Cooking	0.00555	0.00240	0.00220	0.00187	0.00166	0.00140
Freezers	0.00587	0.00253	0.00233	0.00198	0.00175	0.00147
Lighting	0.00594	0.00255	0.00235	0.00199	0.00176	0.00148
Refrigeration	0.00586	0.00253	0.00233	0.00198	0.00175	0.00147
Space Cooling	0.00497	0.00219	0.00202	0.00173	0.00153	0.00130
Space Heating	0.00609	0.00261	0.00240	0.00204	0.00180	0.00151
Water Heating	0.00573	0.00247	0.00227	0.00193	0.00170	0.00143
Other Uses	0.00568	0.00245	0.00225	0.00191	0.00169	0.00142
Commercial Sector						
Cooking	0.00477	0.00207	0.00190	0.00162	0.00143	0.00121
Lighting	0.00498	0.00216	0.00198	0.00169	0.00150	0.00126
Office Equipment (Non-Pc)	0.00439	0.00192	0.00176	0.00150	0.00133	0.00113
Office Equipment (Pc)	0.00439	0.00192	0.00176	0.00150	0.00133	0.00113
Refrigeration	0.00557	0.00240	0.00221	0.00188	0.00166	0.00140
Space Cooling	0.00477	0.00211	0.00194	0.00166	0.00148	0.00126
Space Heating	0.00617	0.00264	0.00243	0.00206	0.00182	0.00153
Ventilation	0.00559	0.00241	0.00222	0.00189	0.00167	0.00140
Water Heating	0.00475	0.00206	0.00189	0.00161	0.00143	0.00121
Other Uses	0.00455	0.00199	0.00182	0.00155	0.00138	0.00117
Industrial Sector						
All Uses	0.00455	0.00199	0.00182	0.00155	0.00138	0.00117

Table 13A.4.6 Power Sector Emissions Factors for NO_x (Short Tons per GWh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	0.255	0.115	0.103	0.096	0.085	0.060
Cooking	0.251	0.114	0.102	0.095	0.084	0.059
Freezers	0.261	0.118	0.106	0.099	0.087	0.062
Lighting	0.262	0.117	0.104	0.097	0.085	0.060
Refrigeration	0.261	0.118	0.106	0.099	0.087	0.061
Space Cooling	0.236	0.114	0.103	0.098	0.088	0.063
Space Heating	0.267	0.118	0.105	0.098	0.086	0.060
Water Heating	0.256	0.115	0.102	0.095	0.084	0.059
Other Uses	0.255	0.115	0.103	0.096	0.085	0.060
Commercial Sector						
Cooking	0.225	0.104	0.093	0.088	0.078	0.056
Lighting	0.232	0.107	0.095	0.090	0.080	0.057
Office Equipment (Non-Pc)	0.214	0.101	0.090	0.085	0.076	0.055
Office Equipment (Pc)	0.214	0.101	0.090	0.085	0.076	0.055
Refrigeration	0.251	0.114	0.102	0.095	0.084	0.059
Space Cooling	0.230	0.112	0.102	0.097	0.087	0.063
Space Heating	0.269	0.119	0.106	0.098	0.086	0.060
Ventilation	0.252	0.114	0.102	0.095	0.084	0.059
Water Heating	0.225	0.104	0.092	0.087	0.077	0.055
Other Uses	0.219	0.102	0.091	0.086	0.077	0.055
Industrial Sector						
All Uses	0.219	0.102	0.091	0.086	0.077	0.055

Table 13A.4.7 Power Sector Emissions Factors for SO_2 (Short Tons per Gwh of Site Electricity Use)

	2025	2030	2035	2040	2045	2050+
Residential Sector						
Clothes Dryers	0.149	0.074	0.070	0.057	0.051	0.049
Cooking	0.145	0.072	0.068	0.056	0.050	0.048
Freezers	0.154	0.077	0.073	0.059	0.053	0.051
Lighting	0.156	0.077	0.073	0.060	0.054	0.051
Refrigeration	0.154	0.077	0.072	0.059	0.053	0.051
Space Cooling	0.130	0.065	0.061	0.050	0.045	0.043
Space Heating	0.160	0.079	0.075	0.061	0.055	0.053
Water Heating	0.150	0.075	0.071	0.058	0.052	0.049
Other Uses	0.149	0.074	0.070	0.057	0.051	0.049
Commercial Sector						
Cooking	0.124	0.062	0.058	0.047	0.042	0.040
Lighting	0.130	0.064	0.061	0.050	0.044	0.042
Office Equipment (Non-Pc)	0.113	0.056	0.053	0.043	0.039	0.037
Office Equipment (Pc)	0.113	0.056	0.053	0.043	0.039	0.037
Refrigeration	0.146	0.073	0.068	0.056	0.050	0.048
Space Cooling	0.124	0.063	0.059	0.048	0.043	0.041
Space Heating	0.163	0.081	0.076	0.062	0.056	0.053
Ventilation	0.147	0.073	0.069	0.056	0.051	0.048
Water Heating	0.123	0.061	0.058	0.047	0.042	0.040
Other Uses	0.118	0.059	0.055	0.045	0.040	0.038
Industrial Sector						
All Uses	0.118	0.059	0.055	0.045	0.040	0.038

Table 13A.4.8 Electricity Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MWh	27.7	19.1	16.6	16.3	16.2	15.7
CH_4	g/MWh	2172.0	1554.8	1328.7	1349.8	1343.9	1302.1
Hg	g/MWh	5.3E-06	2.2E-06	1.8E-06	1.4E-06	1.2E-06	9.7E-07
N_2O	g/MWh	0.159	0.088	0.081	0.070	0.066	0.060
NO_x	g/MWh	372.5	265.6	231.3	229.3	228.9	223.2
SO_2	g/MWh	2.5	1.3	1.2	1.0	0.9	0.8

Table 13A.4.9 Natural Gas Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/MMcf	7.6	7.4	7.5	7.5	7.6	7.7
CH_4	g/MMcf	701.6	698.8	703.8	704.1	705.9	707.0
Hg	g/MMcf	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
N_2O	g/MMcf	0.012	0.012	0.012	0.012	0.012	0.012
NO_x	g/MMcf	108.5	105.4	107.6	107.4	108.8	110.2
SO_2	g/MMcf	0.033	0.032	0.032	0.032	0.033	0.033

Table 13A.4.10 Petroleum Fuels Upstream Emission Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO_2	kg/bbl	76.3	76.6	78.6	80.0	81.2	80.9
CH_4	g/bbl	1085.7	1094.0	1127.2	1147.7	1166.8	1164.8
Hg	g/bbl	4.3E-06	2.1E-06	1.8E-06	1.6E-06	1.5E-06	1.3E-06
N_2O	g/bbl	0.578	0.573	0.583	0.591	0.597	0.592
NO_x	g/bbl	764.0	769.1	784.9	796.8	807.3	802.4
SO_2	g/bbl	13.3	12.9	13.1	13.3	13.4	13.2

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APPENDIX 14A. SOCIAL COST OF GREENHOUSE GAS VALUES, 2020-2080

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14A.1 VALUES FOR SOCIAL COST OF GREENHOUSE GASES

This appendix presents the full set of annual estimates of the social cost of greenhouse gases (SC-GHG) used to estimate the monetary benefits likely to result from reduced emissions associated with this rule. As discussed in chapter 14, for this final rule, consistent with the July 2024 NODA, DOE is presenting climate benefits using both the 2021 Interim SC-GHG estimates and the 2023 SC-GHG estimates. DOE used both sets of SC-GHG values to monetize the climate benefits of the emissions reductions associated at each EL for gas-fired instantaneous water heaters. DOE is presenting monetized benefits of GHG emissions reductions in accordance with applicable Executive Orders, and DOE would reach the same conclusion presented in the final rule in the absence of the estimated benefits from reductions in GHG emissions, including the estimates published by EPA in December 2023 or the Interim Estimates presented by the Interagency Working Group in 2021.

The 2023 SC-GHG values are taken from the regulatory impact analysis of EPA's December 2023 Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review," EPA estimated climate benefits using a new set of Social Cost of Greenhouse Gas (SC-GHG) estimates.[a] These estimates were intended to reflect recent advances in the scientific literature on climate change and its economic impacts and incorporate recommendations made by the National Academies of Science, Engineering, and Medicine.[b] The SC-GHG reflects the societal net benefit of reducing emissions of the GHG by a metric ton.

The 2021 interim SC-GHG values in this appendix are taken from the model input files supporting the "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis" published by EPA in December 2021.[1,c] These values are themselves based on the 2020-2050 values in "Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide; Interim Estimates under Executive Order 13990", published by the Interagency Working Group on Social Cost of Greenhouse Gases in February 2021.[2] To derive values for 2051-2070, EPA extrapolated based on methods, assumptions, and parameters identical to the 2020-2050 estimates developed by the Interagency Working Group.

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[a] U.S. EPA. (2023). Supplementary Material for the Regulatory Impact Analysis for the Final Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review": EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. Washington, DC: U.S. EPA. https://www.epa.gov/controlling-air-pollution-oil-and-natural-gas-operations/epas-final-rule-oil-and-natural-gas

[b] National Academies of Sciences, Engineering, and Medicine. Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide. 2017. The National Academies Press: Washington, DC. nap.nationalacademies.org/catalog/24651/valuing-climate-damages-updating-estimation-of-the-social-cost-of.

[c] Model files available at: www3.epa.gov/otaq/ld/EPA-CCEMS-PostProcessingTool-Project-FRM.zip (last accessed January 18, 2022).

The values in the EPA files are in 2018$. DOE converted these to 2020$ using the GDP deflator.[d]

Table 14A.1.1 Annual SC-CO_2 Values Based on 2023 SC-GHG Estimates, 2020–2080 (2020$ per Metric Ton of CO_2)

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2020	117	193	337
2021	119	197	341
2022	122	200	346
2023	125	204	351
2024	128	208	356
2025	130	212	360
2026	133	215	365
2027	136	219	370
2028	139	223	375
2029	141	226	380
2030	144	230	384
2031	147	234	389
2032	150	237	394
2033	153	241	398
2034	155	245	403
2035	158	248	408
2036	161	252	412
2037	164	256	417
2038	167	259	422
2039	170	263	426
2040	173	267	431
2041	176	271	436
2042	179	275	441
2043	182	279	446
2044	186	283	451
2045	189	287	456
2046	192	291	462
2047	195	296	467
2048	199	300	472
2049	202	304	477
2050	205	308	482
2051	208	312	487

[d] For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2052	211	315	491
2053	214	319	496
2054	217	323	500
2055	220	326	505
2056	222	330	510
2057	225	334	514
2058	228	338	519
2059	231	341	523
2060	234	345	528
2061	236	348	532
2062	239	351	535
2063	241	354	539
2064	244	357	543
2065	246	360	547
2066	248	363	550
2067	251	366	554
2068	253	369	558
2069	256	372	562
2070	258	375	565
2071	261	378	569
2072	263	382	573
2073	266	385	576
2074	269	388	580
2075	271	391	583
2076	274	394	587
2077	276	398	591
2078	279	401	594
2079	282	404	598
2080	284	407	601

Table 14A.1.2 Annual SC-CO_2 Values Based on 2021 Interim SC-GHG Estimates, 2020–2070 (2020$ per Metric Ton of CO_2)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	14	51	76	151
2021	15	52	77	155
2022	15	53	79	158
2023	16	54	80	162
2024	16	55	81	165
2025	17	56	83	169
2026	17	57	84	172
2027	18	58	85	176
2028	18	59	87	179
2029	19	60	88	183
2030	19	62	89	186
2031	20	63	91	190
2032	20	64	92	194
2033	21	65	93	198
2034	22	66	95	201
2035	22	67	96	205
2036	23	68	97	209
2037	23	70	99	213
2038	24	71	100	217
2039	25	72	101	220
2040	25	73	103	224
2041	26	74	104	228
2042	26	75	105	231
2043	27	76	107	235
2044	28	78	108	238
2045	28	79	109	242
2046	29	80	111	245
2047	30	81	112	249
2048	30	82	113	252
2049	31	83	115	256
2050	32	84	116	259
2051	32	85	118	260
2052	33	86	119	261
2053	34	87	120	262
2054	34	88	121	263
2055	35	89	122	265
2056	35	90	123	267

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2057	36	91	124	269
2058	37	92	125	271
2059	37	92	127	273
2060	38	93	128	275
2061	39	95	129	280
2062	40	96	131	285
2063	41	98	132	290
2064	42	99	134	295
2065	44	100	135	300
2066	45	102	137	305
2067	46	103	138	311
2068	47	105	140	316
2069	48	106	141	321
2070	49	108	143	326

Table 14A.1.3 Annual SC-CH_4 Values Based on 2023 SC-GHG Estimates, 2020-2080 (2020$ per Metric Ton of CH_4)

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2020	1,257	1,648	2,305
2021	1,324	1,723	2,391
2022	1,390	1,799	2,478
2023	1,457	1,874	2,564
2024	1,524	1,950	2,650
2025	1,590	2,025	2,737
2026	1,657	2,101	2,823
2027	1,724	2,176	2,910
2028	1,791	2,252	2,996
2029	1,857	2,327	3,083
2030	1,924	2,403	3,169
2031	2,002	2,490	3,270
2032	2,080	2,578	3,371
2033	2,157	2,666	3,471
2034	2,235	2,754	3,572
2035	2,313	2,842	3,673
2036	2,391	2,929	3,774
2037	2,468	3,017	3,875
2038	2,546	3,105	3,975

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2039	2,624	3,193	4,076
2040	2,702	3,280	4,177
2041	2,786	3,375	4,285
2042	2,871	3,471	4,394
2043	2,955	3,566	4,502
2044	3,040	3,661	4,610
2045	3,124	3,756	4,718
2046	3,209	3,851	4,827
2047	3,293	3,946	4,935
2048	3,378	4,041	5,043
2049	3,462	4,136	5,151
2050	3,547	4,231	5,260
2051	3,624	4,320	5,363
2052	3,701	4,409	5,466
2053	3,779	4,497	5,569
2054	3,856	4,586	5,672
2055	3,933	4,675	5,774
2056	4,011	4,763	5,877
2057	4,088	4,852	5,980
2058	4,165	4,941	6,083
2059	4,243	5,029	6,186
2060	4,320	5,118	6,289
2061	4,389	5,199	6,385
2062	4,458	5,280	6,480
2063	4,527	5,361	6,576
2064	4,596	5,442	6,671
2065	4,666	5,523	6,767
2066	4,735	5,604	6,862
2067	4,804	5,685	6,958
2068	4,873	5,765	7,053
2069	4,942	5,846	7,149
2070	5,011	5,927	7,244
2071	5,085	6,013	7,344
2072	5,160	6,099	7,444
2073	5,234	6,184	7,545
2074	5,309	6,270	7,645
2075	5,383	6,355	7,745
2076	5,458	6,441	7,845

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2077	5,532	6,527	7,946
2078	5,607	6,612	8,046
2079	5,681	6,698	8,146
2080	5,756	6,783	8,246

Table 14A.1.4 Annual SC-CH_4 Values Based on 2021 Interim SC-GHG Estimates, 2020–2070 (2020$ per Metric Ton of CH_4)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	663	1,480	1,946	3,893
2021	691	1,527	2,002	4,021
2022	718	1,574	2,057	4,149
2023	745	1,620	2,112	4,277
2024	772	1,667	2,167	4,405
2025	799	1,714	2,223	4,533
2026	826	1,761	2,278	4,661
2027	853	1,807	2,333	4,789
2028	880	1,854	2,388	4,917
2029	908	1,901	2,444	5,045
2030	935	1,948	2,499	5,173
2031	969	2,003	2,563	5,326
2032	1,003	2,058	2,626	5,479
2033	1,038	2,113	2,690	5,632
2034	1,072	2,168	2,754	5,786
2035	1,106	2,224	2,817	5,939
2036	1,140	2,279	2,881	6,092
2037	1,175	2,334	2,945	6,245
2038	1,209	2,389	3,008	6,399
2039	1,243	2,444	3,072	6,552
2040	1,277	2,500	3,136	6,705
2041	1,315	2,555	3,199	6,849
2042	1,352	2,611	3,261	6,993
2043	1,389	2,667	3,324	7,138
2044	1,427	2,722	3,387	7,282
2045	1,464	2,778	3,450	7,426
2046	1,502	2,834	3,512	7,570
2047	1,539	2,890	3,575	7,714

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2048	1,576	2,945	3,638	7,859
2049	1,614	3,001	3,701	8,003
2050	1,651	3,057	3,763	8,147
2051	1,680	3,096	3,807	8,193
2052	1,703	3,128	3,841	8,228
2053	1,726	3,159	3,874	8,263
2054	1,749	3,190	3,908	8,297
2055	1,772	3,221	3,942	8,332
2056	1,797	3,256	3,979	8,373
2057	1,823	3,291	4,017	8,415
2058	1,848	3,326	4,055	8,456
2059	1,873	3,360	4,092	8,497
2060	1,899	3,395	4,130	8,539
2061	2,021	3,548	4,296	9,067
2062	2,143	3,702	4,462	9,594
2063	2,264	3,856	4,628	10,122
2064	2,386	4,009	4,794	10,650
2065	2,508	4,163	4,960	11,177
2066	2,632	4,325	5,141	11,758
2067	2,757	4,488	5,323	12,338
2068	2,881	4,651	5,504	12,919
2069	3,006	4,814	5,686	13,499
2070	3,130	4,976	5,867	14,079

Table 14A.1.5 Annual N_2O Values Based on 2023 SC-GHG Estimates, 2020–2080 (2020$ per Metric Ton of N_2O)*

	Near-term Ramsey Discount Rate		
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2020	35,232	54,139	87,284
2021	36,180	55,364	88,869
2022	37,128	56,590	90,454
2023	38,076	57,816	92,040
2024	39,024	59,041	93,625
2025	39,972	60,267	95,210
2026	40,920	61,492	96,796
2027	41,868	62,718	98,381
2028	42,816	63,944	99,966
2029	43,764	65,169	101,552
2030	44,712	66,395	103,137
2031	45,693	67,645	104,727
2032	46,674	68,895	106,316
2033	47,655	70,145	107,906
2034	48,636	71,394	109,495
2035	49,617	72,644	111,085
2036	50,598	73,894	112,674
2037	51,578	75,144	114,264
2038	52,559	76,394	115,853
2039	53,540	77,644	117,443
2040	54,521	78,894	119,032
2041	55,632	80,304	120,809
2042	56,744	81,714	122,586
2043	57,855	83,124	124,362
2044	58,966	84,535	126,139
2045	60,078	85,945	127,916
2046	61,189	87,355	129,693
2047	62,301	88,765	131,469
2048	63,412	90,176	133,246
2049	64,523	91,586	135,023
2050	65,635	92,996	136,799
2051	66,673	94,319	138,479
2052	67,712	95,642	140,158
2053	68,750	96,965	141,838
2054	69,789	98,288	143,517
2055	70,827	99,612	145,196
2056	71,866	100,935	146,876

Near-term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2057	72,904	102,258	148,555
2058	73,943	103,581	150,235
2059	74,981	104,904	151,914
2060	76,020	106,227	153,594
2061	76,920	107,385	155,085
2062	77,820	108,542	156,576
2063	78,720	109,700	158,066
2064	79,620	110,857	159,557
2065	80,520	112,015	161,048
2066	81,419	113,172	162,539
2067	82,319	114,330	164,030
2068	83,219	115,487	165,521
2069	84,119	116,645	167,012
2070	85,019	117,802	168,503
2071	86,012	119,027	170,013
2072	87,006	120,252	171,523
2073	87,999	121,477	173,033
2074	88,992	122,702	174,543
2075	89,985	123,926	176,053
2076	90,978	125,151	177,563
2077	91,971	126,376	179,073
2078	92,964	127,601	180,582
2079	93,958	128,826	182,092
2080	94,951	130,050	183,602

Table 14A.1.6 Annual N_2O Values Based on 2021 Interim SC-GHG Estimates, 2020–2070 (2020$ per Metric Ton of N_2O)

	Discount Rate and Statistics			
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2020	5,760	18,342	27,037	48,090
2021	5,961	18,777	27,592	49,293
2022	6,162	19,213	28,147	50,497
2023	6,363	19,649	28,702	51,700
2024	6,565	20,084	29,257	52,904
2025	6,766	20,520	29,811	54,108
2026	6,967	20,955	30,366	55,311
2027	7,168	21,391	30,921	56,515
2028	7,370	21,827	31,476	57,718
2029	7,571	22,262	32,031	58,922
2030	7,772	22,698	32,585	60,125
2031	8,019	23,188	33,195	61,480
2032	8,266	23,678	33,804	62,834
2033	8,513	24,168	34,413	64,189
2034	8,760	24,659	35,023	65,543
2035	9,007	25,149	35,632	66,898
2036	9,253	25,639	36,241	68,252
2037	9,500	26,129	36,850	69,606
2038	9,747	26,619	37,460	70,961
2039	9,994	27,110	38,069	72,315
2040	10,241	27,600	38,678	73,670
2041	10,530	28,127	39,320	75,089
2042	10,819	28,655	39,962	76,508
2043	11,109	29,183	40,604	77,928
2044	11,398	29,710	41,246	79,347
2045	11,687	30,238	41,888	80,766
2046	11,976	30,765	42,530	82,186
2047	12,265	31,293	43,172	83,605
2048	12,555	31,820	43,814	85,024
2049	12,844	32,348	44,456	86,443
2050	13,133	32,875	45,098	87,863
2051	13,479	33,426	45,727	88,606
2052	13,798	33,954	46,354	89,984
2053	14,118	34,483	46,981	91,362
2054	14,438	35,011	47,609	92,739
2055	14,758	35,539	48,236	94,117
2056	15,091	36,092	48,890	95,463

Discount Rate and Statistics				
Emissions Year	**5%, Average**	**3%, Average**	**2.5%, Average**	**3%, 95th**
2057	15,425	36,644	49,544	96,808
2058	15,758	37,196	50,199	98,154
2059	16,091	37,748	50,853	99,499
2060	16,424	38,300	51,507	100,845
2061	17,077	39,165	52,485	103,794
2062	17,730	40,030	53,463	106,743
2063	18,382	40,895	54,441	109,692
2064	19,035	41,760	55,419	112,641
2065	19,687	42,625	56,397	115,590
2066	20,354	43,515	57,403	118,657
2067	21,020	44,404	58,409	121,725
2068	21,686	45,293	59,416	124,793
2069	22,352	46,183	60,422	127,860
2070	23,018	47,072	61,428	130,928

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2. Interagency Working Group on Social Cost of Greenhouse Gasses, United States Government. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. February 2021. (Last accessed February 1, 2024.) https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

APPENDIX 14B. BENEFIT-PER-TON VALUES FOR NO_X AND SO_2 EMISSIONS FROM ELECTRICITY GENERATION

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14B.1 INTRODUCTION

This appendix describes the analytical methodology DOE uses to incorporate regional variability in NO_X and SO_2 valuations into the emissions monetization. The regional values assigned to these emissions are based on benefit-per-ton estimates published by EPA for a variety of sectors, including electricity generation. EPA provides high and low estimates of benefit-per-ton of NO_X and SO_2 emissions reductions in 40 regions of the continental USA. DOE combined these data with regional information on electricity consumption and emissions from the most recent edition of the *Annual Energy Outlook (AEO)* to define weighted-average national benefit-per-ton values for NO_X and SO_2.

14B.2 METHODOLOGY

14B.2.1 EPA Data

In 2023 EPA published an updated Technical Support Document (TSD) describing an approach for estimating the average avoided human health impacts and monetized benefits related to reducing emissions of $PM_{2.5}$ and ozone precursors including NO_X and SO_2 from 21 sectors.[a] The EPA TSD includes estimates of the present value of the benefits of NO_X and SO_2 emissions reductions (*benefit-per-ton* estimates or BPT) for 2025, 2030, 2035 and 2040. For NO_X, EPA provides values for $PM_{2.5}$ –related benefits and for ozone-related benefits. Because the pollutants associated with NO_X as $PM_{2.5}$ and SO_2 emissions persist in the atmosphere over a period of years, reductions in any given year will have benefits in subsequent years. These future benefits are discounted and summed to provide a single value for the reduction of one ton of emissions in the emissions year.

For Electricity generating units, EPA estimated regional BPT values for regions consisting of states or combinations of contiguous continental states. BPT values for NO_x and SO_2 as precursors to $PM_{2.5}$ include high and low impact scenarios; BPT values for NO_x as a precursor to ozone include short and long-term impacts. For all data two rates of discounting (3% and 7%) are provided.

DOE used linear interpolation to define values for the years between 2025 and 2030, 2030 and 2035, and 2035 and 2040; for years beyond 2040 the value is held constant. DOE defined the total value of NOx emissions reductions as the sum of the BPT value for $PM_{2.5}$ plus one half of the BPT value for ozone; the factor of one half accounts for the fact that ozone is

[a] U.S. Environmental Protection Agency. *Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors*. April 2023. https://www.epa.gov/system/files/documents/2021-10/source-apportionment-tsd-oct-2021_0.pdf

primarily produced during the May-September period, so approximately half of NOx emissions will produce ozone emissions.

14B.2.2 AEO Data

The *AEO* provides data on the distribution of electricity sales by region, and the magnitude of NO_X and SO_2 emissions by region. For this analysis DOE used the Reference case from *AEO2023*.[1] DOE used the total annual emissions of NO_x and SO_2 for each of the *AEO*'s 25 Electricity Market Module (EMM) regions,[2] and data tables published with the NEMS code package that allocate electricity sales within each EMM region to individual states.[b] The latter are used to map EMM regions to EPA regions, and to determine the relative fraction of emissions allocated to each EPA region. The data are then combined to create time series of national average BPT values.

14B.2.3 Equations and Results

Consistent with its treatment of other utility and environmental impacts, DOE defines a times series of national average estimates of NO_x and SO_2 values.

The same methodology is applied to each pollutant type and EPA scenario (low-7%, low-3%, etc.). The notation is:

- y is the analysis year,
- m is a label for the EMM region,
- z is a label for the EPA region,
- w(z,m) is a matrix that maps EPA regions to EMM regions; it is defined as the fraction of total electricity sales within m to region z; $\sum_z w(z,m) = 1$ for all m,
- p(z,y) is the BPT estimate in EPA region z and year y,
- M(m,y) is total pollutant emissions in EMM region m and year y.

The calculation proceeds in three steps:

1. Pollutant emissions are mapped from EMM regions to EPA regions:

$$M1(z, y) = \sum_m M(m, y) * w(z, m)$$

2. A weight is defined for EPA region z, based on pollutant emissions:

$$u(z, y) = M1(z, y)/[\ \sum_z M1(z, y)\ ]$$

[b] The NEMS package can be downloaded at https://www.eia.gov/outlooks/aeo/info_nems_archive.php. Once installed, the file path to the data files is aeo2021\reference\input\emm_db.zip. The data files are EMMCNTL_RDB.xlsx and LDSMSTR_RDB.xlsx.

3. The regional weights are used to define a national average BPT value:

$$P(y) = \sum z\ u(z, y) * p(z, y)$$

The results of this calculation are provided in Table 14B.2.1 for NO_X and in Table 14B.2.2 for SO_2. DOE's prices are not significantly different than the EPA estimate of the US average. Although the EPA prices are held constant after 2040, the DOE prices may vary slightly in the period 2040-2050 due to the projected changes in regional emissions.

Table 14B.2.1 NO_X Benefit-per-ton Values (2019$/ Short Ton)

Scenario	2025	2030	2035	2040	2045	2050
High, 3% Discount Rate	56,936	77,757	84,832	96,284	96,398	96,050
Low, 3% Discount Rate	50,652	70,516	76,799	87,889	88,002	87,782
High, 7% Discount Rate	50,976	69,705	76,145	86,359	86,459	86,146
Low, 7% Discount Rate	45,325	63,187	68,906	78,799	78,899	78,703

Table 14B.2.2 SO_2 Benefit-per-ton Values (2019$/ Short Ton)

Scenario	2025	2030	2035	2040	2045	2050
High, 3% Discount Rate	160,483	189,092	210,625	239,287	244,462	247,500
Low, 3% Discount Rate	74,849	91,454	104,488	120,693	123,281	124,822
High, 7% Discount Rate	144,312	170,084	189,573	215,359	220,016	222,755
Low, 7% Discount Rate	67,319	82,162	93,932	108,579	110,911	112,300

REFERENCES

1. U.S. Department of Energy– Energy Information Administration. *Annual Energy Outlook 2023 with Projections to 2050*. 2023. Washington, D.C. (Last accessed October 1, 2024.) https://www.eia.gov/outlooks/aeo/.

2. U.S. Energy Information Administration. Assumptions to the Annual Energy Outlook 2021: Electricity Market Module. 2021. https://www.eia.gov/outlooks/aeo/assumptions/pdf/electricity.pdf.

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APPENDIX 15A. UTILITY IMPACT ANALYSIS METHODOLOGY

15A.1 INTRODUCTION

In the utility impact analysis, the U.S. Department of Energy (DOE) analyzes the changes in electric installed capacity and power generation that result for each trial standard level (TSL). These changes are estimated by multiplying the site savings of electricity by a set of *impact factors* which measure the corresponding change in generation by fuel type, installed capacity, and power sector emissions. This Appendix describes the methods that DOE used to calculate these impact factors. The methodology is more fully described in Coughlin (2014; 2019).[1,2]

DOE's analysis uses output of the DOE/Energy Information Administration (EIA)'s most recent *Annual Energy Outlook* (*AEO*).[3] The *AEO* includes a reference case and a set of side cases that implement a variety of economic and policy scenarios. In 2015 EIA announced the adoption of a two-year release cycle for the *AEO*, alternating between a full set of scenarios and a shorter edition containing only five scenarios. DOE has adapted its calculation methodology to be independent of the type of scenarios available with each *AEO* publication.

15A.2 METHODOLOGY

Marginal reductions in electricity demand lead to marginal reductions in power sector generation, emissions, and installed capacity. Generally, DOE quantifies these reductions using marginal impact factors, which are time series defining the change in some power sector quantity that results from a unit change in site electricity demand. Because load shapes affect the mix of generation types on the margin, these impact factors depend on end-use and sector.

DOE's approach examines a series of *AEO* side cases to estimate the relationship between changes to power sector generation (TWh) by fuel type and changes to other supply-side power sector variables, including fuel consumption (quads) by fuel type, and installed capacity (GW) by fuel and technology type. DOE also calculates changes to power sector emissions; the methodology for computing these impacts is described in appendix 13A.

DOE uses load shape information from the NEMS code to relate marginal generation reductions by fuel type to marginal demand reductions by sector and end use. Because AEO side cases with electricity demand reductions are not always available, DOE defines the relationship between sector/end-use and generation fuel type using Reference case data. Specifically, DOE defines, for each sector and end-use, fuel-share weights equal to the percentage of each MWh used to serve that end-use load that is provided by each generation fuel type.

The load shape data provide an hourly profile defining total consumption of electricity for each sector/end-use. For each load DOE allocates consumption to one of 3 periods: on-peak, shoulder, and off-peak. These categories are used in the utility sector to correlate end-use consumption with supply types. On-peak hours are defined as 12pm to 5pm Monday through Saturday, June through September. Off-peak hours are 9pm to 6am daily and all day Sunday. All other hours are allocated to the shoulder period. This leads to a set of weights $w(p,u,y)$ where:

y = the analysis year
u = an index representing the sector/end-use (e.g. commercial cooling)
p = the time-of-day period
$w(p,u,y)$ = the fraction of load u that is served in period p

By definition the sum of $w(p,u,y)$ over periods p is equal to one. On the supply-side, DOE allocates generation by each fuel type to one of the time-of-day periods. The allocation is based on the following rules:

1.1. The data are normalized so that total annual generation equals total annual consumption by sector and end-use;

1.2. The demand-side data are summed over sector/end-use to define a total demand for generation in each time-of-day period;

1.3. All petroleum-based generation is allocated to peak periods;

1.4. Base-load generation (nuclear and coal) is assumed to be equally likely to be on in all hours; hence, it is allocated to each period in proportion to the number of hours in that period;

1.5. Any unmet peak period demand is allocated to natural gas;

1.6. The remaining generation of all types is allocated to the remaining periods proportionally.

This leads to a second set of weights $z(p,f,y)$ where:

f = the fuel type
$z(p,f,y)$ = the fraction of load in period p that is served by fuel f

These weights are used to allocate a MWh of demand reduction for a given end-use to each fuel type. In defining the fuel-share weights for demand reductions, DOE makes one adjustment to the factors calculated from the Reference case data. An examination of all available *AEO* scenarios shows that both generation and installed capacity for nuclear power are unchanged across the projection period. This implies that the use of nuclear power is not affected by small changes in the supply/demand balance; hence, DOE assumes that the factor $z(p,f,y)$ is zero for nuclear power. The values of $z(p,f,y)$ for the other fuels are renormalized so that the sum of $z(p,f,y)$ across the remaining fuel types is equal to one.

DOE defines the generation fuel share weights $g(u,f,y)$ as the product

$$g(u,f,y) = \sum_p w(p,u,y)\, z(p,f,y).$$

Eq. 15A.1

For the sector/end-use defined by u, the product of the total annual site electricity savings times the factor $g(u,f,y)$ defines the marginal generation reductions by fuel type. These marginal generation reductions can be related to marginal fuel use reductions (see appendix 10.B of this TSD) and to the marginal emissions reductions (see appendix 13A of this TSD). They are also related to the marginal installed capacity reductions through the capacity factor.

DOE uses a capacity factor to relate reductions in generation by fuel type to reductions in installed capacity by technology type. The capacity factor is defined as the magnitude of change in capacity given a unit change in generation. The technology types are coal, natural gas combined-cycle (NGCC), oil and gas steam (OGS), combustion turbine-diesel (CTD), and renewable sources. For NGCC the capacity factor is defined as the ratio of NGCC capacity to natural gas generation. DOE combines CTD and OGS DOE into a single *peak* capacity type, with capacity factor equal to the ratio of the sum of CTD plus OGS capacity to oil-fired generation. Each fuel type is then related to a unique capacity type. While marginal capacity factors can be calculated from *AEO* data, this approach produces results that are dominated by computational noise. Hence, DOE uses data for the *AEO Reference Case* to calculate grid-average capacity factors for each year of the analysis period, defined as *c(f,y).* The capacity change for fuel/technology type *f* induced by a unit reduction in demand for sector/end-use u is given by the product *g(u,f,y)*c(f,y).*

15A.3 MODEL RESULTS

Representative values of the impact factors for fuel share by fuel type, and capacity by technology type are provided in the tables below. The tables show the factors for two years, 2025 and 2050. The marginal heat rates are presented in appendix 10B and emissions factors are presented in in appendix 13A.

15A.3.1 Electricity Generation

Table 15A.3.1 and Table 15A.3.2 show the distribution across fuel types of a unit reduction in electricity demand by sector and end-use, referred to above as fuel-share weights. The fuel types are coal, natural gas, petroleum, and renewables. The values for cooling are representative of peaking loads, while the values for refrigeration are representative of flat loads. The data are shown for 2025 and 2050.

Table 15A.3.1 Fuel-Share Weights by Sector and End-Use (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	26.9%	35.5%	0.2%	37.4%
Cooking	26.2%	36.0%	0.2%	37.6%
Freezers	27.8%	35.2%	0.2%	36.8%
Lighting	28.3%	34.4%	0.1%	37.3%
Refrigeration	27.8%	35.2%	0.2%	36.9%
Space Cooling	23.0%	39.5%	0.6%	36.9%
Space Heating	29.1%	33.8%	0.0%	37.1%
Water Heating	27.2%	35.1%	0.1%	37.6%
Other Uses	26.8%	35.5%	0.2%	37.5%
Commercial Sector				
Cooking	22.1%	38.4%	0.3%	39.3%
Lighting	23.2%	37.7%	0.3%	38.8%
Office Equipment (Non-Pc)	20.1%	39.8%	0.4%	39.7%
Office Equipment (Pc)	20.1%	39.8%	0.4%	39.7%
Refrigeration	26.3%	35.9%	0.2%	37.7%
Space Cooling	21.8%	40.3%	0.7%	37.2%
Space Heating	29.5%	33.6%	0.0%	37.0%
Ventilation	26.4%	35.8%	0.2%	37.7%
Water Heating	22.0%	38.3%	0.3%	39.4%
Other Uses	21.0%	39.2%	0.3%	39.5%
Industrial Sector				
All Uses	21.0%	39.2%	0.3%	39.5%

Table 15A.3.2 Fuel-Share Weights by Sector and End-Use (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	6.5%	19.7%	0.0%	73.7%
Cooking	6.4%	20.1%	0.1%	73.5%
Freezers	6.8%	19.9%	0.1%	73.2%
Lighting	6.9%	18.1%	0.0%	75.0%
Refrigeration	6.8%	19.9%	0.1%	73.3%
Space Cooling	5.5%	26.6%	0.2%	67.7%
Space Heating	7.1%	17.3%	0.0%	75.6%
Water Heating	6.6%	18.8%	0.0%	74.6%
Other Uses	6.5%	19.6%	0.0%	73.8%
Commercial Sector				
Cooking	5.3%	21.6%	0.1%	73.0%
Lighting	5.6%	21.3%	0.1%	73.0%
Office Equipment (Non-Pc)	4.8%	23.2%	0.1%	71.9%
Office Equipment (Pc)	4.8%	23.2%	0.1%	71.9%
Refrigeration	6.4%	19.8%	0.0%	73.7%
Space Cooling	5.3%	27.5%	0.2%	67.1%
Space Heating	7.2%	17.2%	0.0%	75.6%
Ventilation	6.4%	19.7%	0.0%	73.8%
Water Heating	5.3%	21.4%	0.1%	73.2%
Other Uses	5.0%	22.6%	0.1%	72.3%
Industrial Sector				
All Uses	5.0%	22.6%	0.1%	72.3%

15A.3.2 Installed Capacity

Table 15A.3.3 and Table 15A.3.4 show the total change in installed capacity (GW) per unit of site electricity demand reduction for the five principal capacity types: coal, natural gas, peaking, renewables, and nuclear. The peaking category is the sum of the two NEMS categories oil and gas steam and combustion turbine/diesel. Data are shown for 2025 and 2050.

Table 15A.3.3 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2025)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.063	0.089	0.044	0.146
Cooking	0.062	0.090	0.050	0.147
Freezers	0.066	0.088	0.048	0.143
Lighting	0.067	0.086	0.016	0.145
Refrigeration	0.065	0.088	0.047	0.144
Space Cooling	0.054	0.099	0.166	0.144
Space Heating	0.069	0.085	0.002	0.145
Water Heating	0.064	0.088	0.027	0.147
Other Uses	0.063	0.089	0.041	0.146
Commercial Sector				
Cooking	0.052	0.096	0.074	0.153
Lighting	0.055	0.095	0.069	0.151
Office Equipment (Non-Pc)	0.047	0.100	0.101	0.155
Office Equipment (Pc)	0.047	0.100	0.101	0.155
Refrigeration	0.062	0.090	0.045	0.147
Space Cooling	0.051	0.101	0.180	0.145
Space Heating	0.069	0.084	0.000	0.144
Ventilation	0.062	0.090	0.043	0.147
Water Heating	0.052	0.096	0.071	0.153
Other Uses	0.049	0.098	0.091	0.154
Industrial Sector				
All Uses	0.049	0.098	0.091	0.154

Table 15A.3.4 Capacity Impact Factors in GW per TWh Reduced Site Electricity Demand (Values for 2050)

	Coal	Natural Gas	Oil	Renewables
Residential Sector				
Clothes Dryers	0.021	0.069	0.052	0.299
Cooking	0.020	0.070	0.059	0.298
Freezers	0.021	0.069	0.057	0.297
Lighting	0.022	0.063	0.019	0.304
Refrigeration	0.021	0.069	0.055	0.298
Space Cooling	0.017	0.093	0.196	0.275
Space Heating	0.022	0.060	0.002	0.307
Water Heating	0.021	0.065	0.032	0.303
Other Uses	0.021	0.068	0.049	0.300
Commercial Sector				
Cooking	0.017	0.075	0.088	0.296
Lighting	0.018	0.074	0.081	0.296
Office Equipment (Non-Pc)	0.015	0.081	0.119	0.292
Office Equipment (Pc)	0.015	0.081	0.119	0.292
Refrigeration	0.020	0.069	0.053	0.299
Space Cooling	0.017	0.095	0.212	0.272
Space Heating	0.023	0.060	0.000	0.307
Ventilation	0.020	0.068	0.051	0.300
Water Heating	0.017	0.075	0.083	0.297
Other Uses	0.016	0.079	0.107	0.293
Industrial Sector				
All Uses	0.016	0.079	0.107	0.293

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

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APPENDIX 17A. REGULATORY IMPACT ANALYSIS: SUPPORTING MATERIALS

17A.1 INTRODUCTION

This appendix contains sections discussing the following topics:

- Projections of annual market share increases for the alternative policies;
- NIA-RIA Integrated Model;
- Market penetration curves used to analyze consumer rebates and voluntary energy efficiency targets, including:
    - Background material on XENERGY's approach,
    - DOE's adjustment of these curves for this analysis, and
    - The method DOE used to derive interpolated, customized curves;
- Detailed table of rebates offered for the considered product, as well as DOE's approach to estimate a market representative rebate value for this RIA; and
- Background material on Federal and State tax credits for appliances.

17A.2 MARKET SHARE ANNUAL INCREASES BY POLICY

Table 17A.2.1 shows the annual increases in market shares of consumer gas-fired instantaneous water heaters (GIWHs) meeting the target efficiency level for the selected TSL (TSL 2). DOE used these market share increases as inputs to the NIA-RIA spreadsheet model.

Table 17A.2.1 Annual Increases in Market Shares Attributable to Alternative Policy Measures for Gas-Fired Instantaneous Water Heaters (TSL 2)

Year	Consumer Rebates	Consumer Tax Credits	Manufacturer Tax Credits	Vol Energy Eff Targets	Bulk Govt Purchases
2030	14.9%	8.9%	4.5%	1.6%	0.1%
2031	14.9%	8.9%	4.5%	3.1%	0.2%
2032	14.8%	8.9%	4.4%	4.6%	0.3%
2033	14.8%	8.9%	4.4%	6.0%	0.4%
2034	14.8%	8.9%	4.4%	7.3%	0.5%
2035	14.7%	8.8%	4.4%	8.6%	0.6%
2036	14.6%	8.8%	4.4%	9.8%	0.6%
2037	14.6%	8.8%	4.4%	11.0%	0.7%
2038	14.6%	8.8%	4.4%	12.1%	0.8%
2039	14.5%	8.7%	4.4%	13.1%	0.9%
2040	14.5%	8.7%	4.4%	13.0%	0.9%
2041	14.5%	8.7%	4.4%	12.8%	0.9%
2042	14.5%	8.7%	4.3%	12.6%	0.9%
2043	14.5%	8.7%	4.3%	12.4%	0.9%
2044	14.4%	8.6%	4.3%	12.2%	0.9%
2045	14.4%	8.6%	4.3%	12.1%	0.9%
2046	14.3%	8.6%	4.3%	12.0%	0.9%
2047	14.3%	8.6%	4.3%	11.8%	0.8%
2048	14.3%	8.6%	4.3%	11.6%	0.8%
2049	14.2%	8.5%	4.3%	11.4%	0.8%
2050	14.1%	8.5%	4.2%	11.2%	0.8%
2051	14.1%	8.5%	4.2%	11.1%	0.8%
2052	14.1%	8.4%	4.2%	10.9%	0.8%
2053	14.0%	8.4%	4.2%	10.8%	0.8%
2054	14.0%	8.4%	4.2%	10.6%	0.8%
2055	13.9%	8.4%	4.2%	10.5%	0.8%
2056	13.9%	8.3%	4.2%	10.3%	0.8%
2057	13.8%	8.3%	4.1%	10.1%	0.7%
2058	13.8%	8.3%	4.1%	10.0%	0.7%
2059	13.8%	8.3%	4.1%	9.8%	0.7%

17A.3 NIA-RIA INTEGRATED MODEL

For this analysis, DOE used its integrated NIA-RIA[a] model approach that the Department built on the NIA model discussed in chapter 10 and documented in appendix 10-A. The resulting integrated NIA-RIA model features both the NIA and RIA inputs, analyses and results. It has the capability to generate results, by product class and TSL, for the mandatory standards and each of the RIA policies. Separate modules estimate increases in market penetration of more efficient equipment for consumer rebates, voluntary energy efficiency targets and bulk government purchases.[b] The consumer rebates module calculates benefit-cost (B/C) ratios and market barriers, and generates customized market penetration curves for each product class; the voluntary energy efficiency targets module relies on the market barriers calculated in the consumer rebates module to project a reduction in those barriers over the first ten years of the analysis period and estimate the market effects of such a reduction; and the bulk government purchases module scales down the market for GIWHs to housing units in public housing authority. A separate module summarizes the market impacts from mandatory standards, calculated under the same market conditions as the alternative policies, and all policy alternatives. An additional module produces all tables and figures presented in chapter 17 as well as the tables of market share increases for each policy reported in Section 17A.2 of this appendix.

17A.4 MARKET PENETRATION CURVES

This section first discusses the theoretical basis for the market penetration curves that DOE used to analyze the Consumer Rebates and Voluntary Energy Efficiency Targets policies. Next it discusses the adjustments it made to the maximum penetration rates. It then refers to the method it used to develop interpolated penetration curves for GIWHs that meet the target efficiency level at each TSL. The resulting curve for the selected TSL are presented in chapter 17.

17A.4.1 Introduction

XENERGY, Inc.[c], developed a re-parameterized, mixed-source information diffusion model to estimate market impacts induced by financial incentives for purchasing energy efficient appliances.[1] The basic premise of the mixed-source model is that information diffusion drives the adoption of technology.

Extensive economic literature describes the diffusion of new products as technologies evolve. Some research focuses primarily on developing analytical models of diffusion patterns applicable to individual consumers or to technologies from competing firms.[2, 3, 4] One study records researchers' attempts to investigate the factors that drive diffusion processes.[5] Because a new product generally has its own distinct characteristics, few studies have been able to conclusively develop a universally applicable model. Some key findings, however, generally are accepted in academia and industry.

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[a] NIA = National Impact Analysis; RIA = Regulatory Impact Analysis

[b] As mentioned in chapter 17, the increase in market penetrations for consumer tax credits and manufacturer tax credits are estimated as a fraction of the increase in market penetration of consumer rebates.

[c] XENERGY is now owned by KEMA, Inc. (www.kema.com)

One accepted finding is that, regardless of their economic benefits and technological merits, new technologies are unlikely to be adopted by all potential users. For many products, a ceiling must be placed on the adoption rate. A second conclusion is that not all adopters purchase new products at the same time: some act quickly after a new product is introduced; others wait for the product to mature. Third, diffusion processes can be characterized approximately by asymmetric S-curves that depict three stages of diffusion: starting, accelerating, and decreasing (as the adoption ceiling is approached).

A so-called epidemic model of diffusion is used widely in marketing and social studies. The epidemic model assumes that (1) all consumers place identical value on the benefits of a new product, and (2) the cost of a new product is constant or declines monotonically over time. What induces a consumer to purchase a new product is information about the availability and benefits of the product. In other words, information diffusion drives consumers' adoption of a new product.[3] The model incorporates information diffusion from both internal sources (spread by word of mouth from early adopters to prospective adopters) and external sources (the "announcement effect" produced by government agencies, institutions, or commercial advertising). The model incorporates both internal and external sources by combining a logistic function with an exponential function.[4, 5]

The relative degree of influence from the internal and external sources determines the general shape of the diffusion curve for a specific product.[4, 5] If adoption of a product is influenced primarily by external sources of information (the announcement effect), for instance, a high rate of diffusion occurs at the beginning of the process. In this scenario, external sources provide immediate information exposure to a significant number of prospective adopters. In contrast, internal sources (such as a network of prospective adopters) are relatively small in size and reach, producing a more gradual exposure to prospective adopters. Graphically speaking, information diffusion dominated by external sources is represented by a concave curve (the exponential curve in Figure 17A.4.1). If adoption of a new product is influenced most strongly by internal sources of information, the number of adopters increases gradually, forming a convex curve (the logistic curve in Figure 17A.4.1).

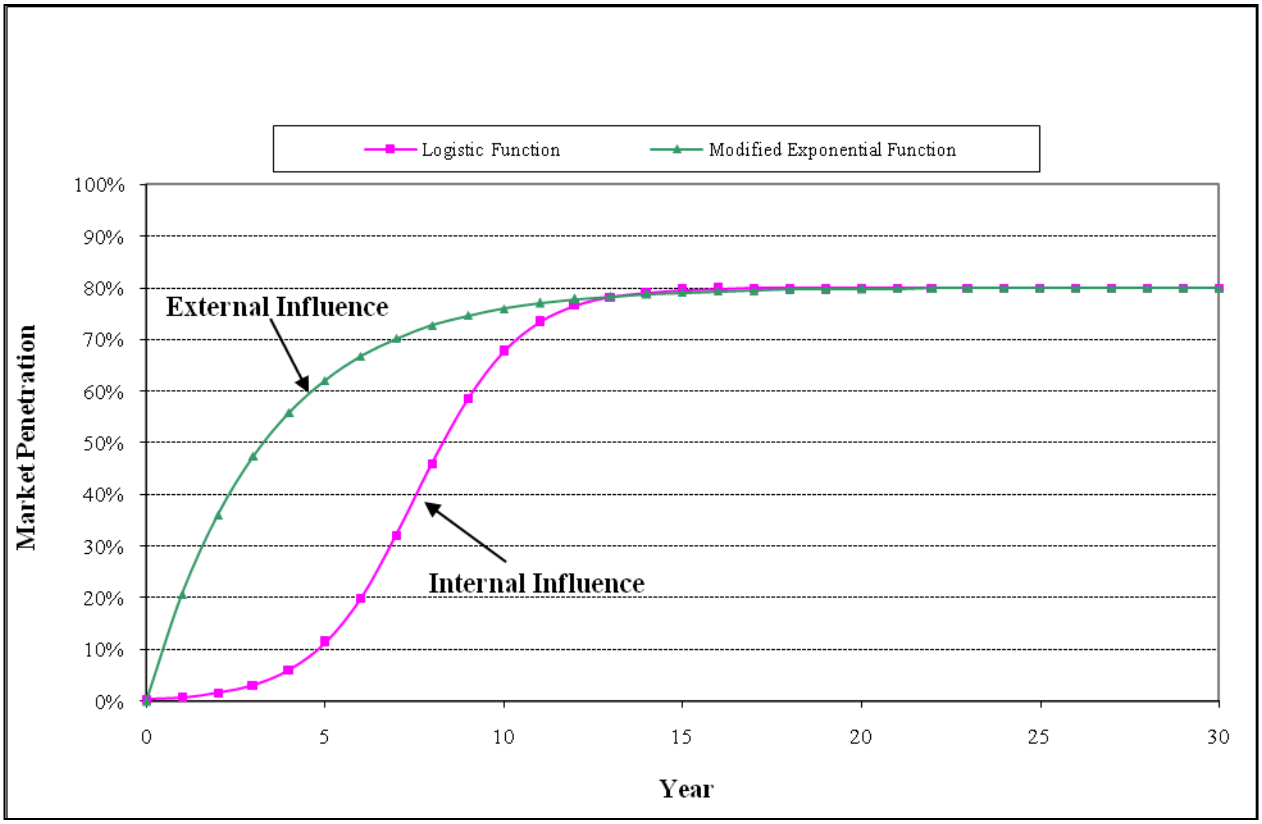

Figure 17A.4.1 S-Curves Showing Effects of External and Internal Sources on Adoption of New Technologies

17A.4.2 Adjustment of XENERGY Penetration Curves

In consultation with the primary authors of the 2002 XENERGY study who later conducted similar California studies, DOE made some adjustments to XENERGY's original implementation (penetration) curves. The experiences with utility programs since the XENERGY study indicate that incentive programs have difficulty achieving penetration rates as high as 80 percent. Consumer response is limited by barriers created by consumer utility issues and other non-economic factors. DOE therefore adjusted the maximum penetration parameters for some of the curves from 80 percent to the following levels:

Moderate Barriers:	70%
High Barriers:	60%
Extremely High Barriers:	50%

The *low barriers* and *no barriers* curves (the latter used only when a product has a very high base-case-market share) remained, respectively, with 80 percent and 100 percent as their maximum penetration rates. For the interpolated penetration curves (discussed below), DOE set the *no barriers* and *extremely high barriers* curves as the upper and lower bounds, respectively, for any benefit/cost ratio points higher or lower than the curves. It set another constraint such that the policy case market share cannot be great than 100 percent, as might occur for products with high no-new-standards case market shares of the target-level technology.

17A.4.3 Interpolation of Penetration Curves

As discussed above, the XENERGY penetration (implementation) curves followed a functional form to estimate the market implementation rate caused by energy efficiency measures such as consumer rebates.[d] The XENERGY report presents five reference market implementation curves that vary according to the level of market barriers to technology penetration.[1] Such curves have been used by DOE in the Regulatory Impact Analyses for rulemakings for appliance energy efficiency standards to estimate market share increases in response to rebate programs.[e] They provide a framework for evaluating technology penetration, yet require matching the studied market to the curve that best represents it. This approximate matching can introduce some inaccuracy to the analysis.

Blum et al (2011, appendix A)[6] presents an alternative approach to such evaluation: a method to estimate market implementation rates more accurately by performing interpolations of the reference curves. The referred report describes the market implementation rate function and the reference curves, the method to calibrate the function to a given market, and the limitations of the method.

DOE used the above referred method to interpolate market implementation curves, to generate a customized curve that was used to estimate the effects of consumer rebates and voluntary energy efficiency targets for the product class covered by this RIA. For consumer rebates, DOE derived such a curve based on an algorithm that finds the market implementation curve that best fits, for the first year of the analysis period, the B/C ratio of the target efficiency level and the market penetration of equipment with that level of energy efficiency in the no-new-standards case. For the analysis of voluntary energy efficiency targets, DOE departs from the market barriers level corresponding to the market implementation curve it derived for consumer rebates, to linearly decrease it over the ten initial years of the analysis period. For each year, as market barriers decline, the corresponding market implementation curve leads – for the same B/C ratio – to higher market penetrations.

[d] The RIA chapter refers to these curves as *penetration curves*. This section, in references to the original source, uses the term *implementation curve*.

[e] DOE has also used this method to estimate market share increases resulting from consumer tax credit and manufacturer tax credit programs, since the effects of tax credits on markets are considered in this RIA proportional to the impacts from rebates.

17A.5 CONSUMER REBATE PROGRAMS

DOE performed a review of existing rebate programs that offer incentives for GIWHs in September, 2024.[f] DOE did not find any rebate program and, therefore, assumed a rebate program would cover 50% of the incremental equipment cost. Table 17A.5.1 provides the rebate amounts for each TSL that DOE used in its analyses.

Table 17A.5.1 Rebates Amounts by TSL*

TSL 1	TSL 2	TSL 3	TSL 4
95.81	102.05	108.99	149.97

* In 2023$.

17A.6 FEDERAL AND STATE TAX CREDITS

This section summarizes the Federal and State tax credits available to consumers who purchase energy efficient appliances. This section also describes tax credits available to manufacturers who produce certain energy efficient appliances.

17A.6.1 Federal Tax Credits for Consumers

EPACT 2005 included Federal tax credits for consumers who installed efficient air conditioners or heat pumps; gas, oil and propane furnaces and boilers; furnace fans; and/or gas, oil, or electric heat pump water heaters in new or existing homes.[7] These tax credits were in effect in 2006 and 2007, expired in 2008, and were reinstated for 2009–2010 by the American Recovery and Reinvestment Act (ARRA).[8] There was a $1,500 cap on the credit per home, including the amount received for insulation, windows, and air and duct sealing. Congress extended this provision for 2011, with some modifications to eligibility requirements, and reductions in the cap to $500 per home. The American Taxpayer Relief Act of 2012 extended, with some modifications, residential tax credits for air conditioners, heat pumps, furnaces, and water heaters placed in service between January 1, 2012 and December 31, 2013.[9]
The tax credit for furnace fans was $50 in 2011, after which it expired.

The importance of the Federal tax credits has been emphasized in research in the residential heating industry on the impacts of the relatively large credits that were available for HVAC (heating, ventilating, and air conditioning) equipment. In a survey of HVAC distributors conducted by Vermont Energy Investment Corporation, respondents indicated that the ample credit had had a notable impact on sales of higher-efficiency heating and cooling equipment. Some distributors combined the Federal tax credits with manufacturer rebates and utility program rebates for a greater consumer incentive. However, when the amount of the Federal tax credit was reduced, smaller utility rebate incentives had not induced the same levels of equipment sales

[f] https://www.energystar.gov/rebate-finder/?scrollTo=2636.363525390625&sort_by=utility&sort_direction=asc&page_number=0&lastpage=0&zip_code_filter=&search_text=&product_clean_filter=Gas+Storage+Water+Heaters&product_clean_filter=Heat+Pump+Water+Heaters&product_clean_filter=Solar+Water+Heaters&product_clean_filter=Tankless+Gas+Water+Heaters&product_clean_isopen=0&product_types=Select+a+Product+Category

increases. The decrease in incentive size from a $1,500 cap in 2009-2010 to a $500 cap in 2011, during a period when the economy continued to be sluggish, resulted in a decline in total sales of residential HVAC products. Distributors stated that an incentive needed to cover 25 to 75 percent of the incremental cost of the efficient equipment to influence consumer choice. The industry publication "2011 HVAC Review and Outlook" noted a decline in sales of air conditioning units with >14 SEER in 2011 and a return in sales of units with >16 SEER to 2009 levels (after an increase in 2010). The large majority of distributors observed no impacts from the utility programs with their lower rebate amounts available in 2011. Distributors also commented on the advantages of the Federal tax credit being nationwide in contrast to utility rebate programs that target regional markets.[10]

In an effort to evaluate the potential impact of a Federal appliance tax credit program, DOE reviewed Internal Revenue Service (IRS) data on the numbers of taxpayers who claimed the tax credits during tax years 2006 and 2007. It estimated the percentage of taxpayers who filed Form 5695, *Residential Energy Credits.*[11] It also estimated the percentage of taxpayers with entries under Form 5695's section 3, *Residential energy property costs*, line 3b, *qualified natural gas, propane, or oil furnace or hot water boiler*. DOE reasoned that the percentage of taxpayers with an entry on Line 3b could serve as a rough indication of the potential of taxpayer participation in a Federal tax credit program for furnaces during the initial program years. DOE found that of all residential taxpayers filing tax returns, 0.8 percent in 2006 and 0.6 percent in 2007, claimed a credit for a furnace or boiler. DOE further found that the percentages of those filing Form 5695 for any qualifying energy property expenditure (which also included installation of efficient windows, doors and roofs) were 3.1 and 3.2 percent in 2006 and 2007 respectively.

DOE also reviewed data from an earlier Federal energy conservation tax credit program in place in the 1980s. While this tax credit was available from 1979 through 1985, DOE located data for only the first three years of the program.[12], [13], [14] For those three years - 1979, 1980, and 1981 - the percentages of taxpayers filing Form 5695 were 6.4 percent, 5.2 percent, and 4.9 percent. Given that the data from this earlier tax credit program were not disaggregated by type of energy property, this data series served only to indicate a possible trend of greater participation in the initial program year, followed by slightly smaller participation in subsequent years. However, DOE did not find detailed analysis of this program to indicate the possible reasons for such a trend. Also, this trend varies from the more stable trend shown in the EPAct 2005 energy tax credit program data for its first two program years.

As discussed in chapter 17, DOE analyzed the percentage of participation in consumer tax credit programs using its estimates of consumer participation in rebate programs that was based on benefit/cost data specific to the product class of GIWHs covered by this RIA. Hence it was difficult to compare these detailed estimates to the more general data analysis described above from the existing Federal tax credit program, or to use the IRS data analysis in its consumer tax credit analysis.

17A.6.2 Federal Tax Credits for Manufacturers

EPACT 2005 provided Federal Energy Efficient Appliance Credits to manufacturers that produced high-efficiency refrigerators, clothes washers, and dishwashers in 2006 and 2007.[15] The Emergency Economic Stabilization Act of 2008[16] amended the credits and extended them through

2010. The credits were extended again to 2011 with modifications in the eligibility requirements. Manufacturer tax credits were extended again, by the American Taxpayer Relief Act of 2012, for clothes washers, refrigerators, and dishwashers manufactured between January 1, 2012 and December 31, 2013.

Manufacturers who produce these appliances receive the credits for increasing their production of qualifying appliances. These credits had several efficiency tiers in 2011. For 2012-2013, credits for the higher tiers remain but were eliminated for the lowest (least efficient) tiers for clothes washers and dishwashers. The credit amounts applied to each unit manufactured. The credit to manufacturers of qualifying clothes washers, refrigerators and dishwashers was capped at $75 million for the period of 2008-2010. However, the most efficient refrigerator (30%) and clothes washer (2.2 MEF/4.5 wcf) models was not subject to the cap. The credit to manufacturers was capped at $25 million for 2011, with the most efficient refrigerators (35%) and clothes washers (2.8 MEF/3.5 WCF) exempted from this cap.[g]

17A.6.3 State Tax Credits

The States of Oregon and Montana have offered consumer tax credits for efficient appliances for several years, and the States of Kentucky, Michigan and Indiana began offering such credits in 2009. The Oregon Department of Energy (ODOE) has disaggregated data on taxpayer participation in credits for eligible products. (See the discussion in chapter 17, Section 17.3.3, on tax credit data for clothes washers.) Montana's Department of Revenue does not disaggregate participation data by appliance, although DOE reviewed Montana's overall participation trends and found them congruent with its analysis of Oregon's clothes washer tax credits.

Oregon's Residential Energy Tax Credit (RETC) was created in 1977. The Oregon legislature expanded the RETC program in 1997 to include residential refrigerators, clothes washers, and dishwashers, which significantly increased participation in the program. The program subsequently added credits for high-efficiency heat pump systems, air conditioners, and water heaters (2001); furnaces and boilers (2002); and duct/air sealing, fuel cells, heat recovery, and renewable energy equipment. Beginning in 2012 a Tax Credit Extension Bill (HB3672) eliminated refrigerators, clothes washers, dishwashers, air conditioners, and boilers from the RETC program, leaving credits for water heaters, furnaces, heat pumps, tankless water heaters, and heat pump water heaters.[17, 18] The technologies recognized by the Oregon Department of Energy as "premium efficiency" were eligible for a tax credit of $0.60 per kWh saved in the first year (up to $1,500).[17]

Montana had an Energy Conservation Tax Credit for residential measures starting in 1998.[19] The tax credit covered various residential energy and water efficient products, including split system central air conditioning; package system central air conditioning; split system air source heat pumps; package system heat pumps; natural gas, propane, or oil furnaces; hot water boilers; advanced main air circulating fans; heat recovery ventilators; gas, oil, or propane water

[g] For more information on federal tax credits for manufacturers see the following websites: https://programs.dsireusa.org/system/program/detail/1273/energy-efficient-appliance-manufacturing-tax-credit, https://energytaxincentives.org/

heaters; electric heat pump water heaters; low-flow showerheads and faucets; light fixtures; and controls. In 2002 the amount of the credit was increased from 5 percent of product costs (up to $150) to 25 percent (up to $500) per taxpayer. The credit could be used for products installed in new construction or remodeling projects. The tax credit covered only the part of the cost and materials that exceeded established standards of construction.

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