TECHNICAL SUPPORT DOCUMENT: CLEAN ENERGY FOR NEW FEDERAL BUILDINGS AND MAJOR RENOVATIONS OF FEDERAL BUILDINGS

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ES. EXECUTIVE SUMMARY

TABLE OF CONTENTS

LIST OF TABLES

EXECUTIVE SUMMARY

ES.1 OVERVIEW OF METHODOLOGY

Section 433 of the Energy Independence and Security Act of 2007 (Pub. L. 110-140) (EISA) directs the U.S. Department of Energy (DOE) to establish fossil fuel generated energy consumption limits for new Federal buildings and Federal buildings undergoing major renovations. (42 U.S.C. 6834(a)(3)(D)(i)) The statute requires fossil fuel generated energy consumption reductions starting at 55 percent in fiscal year (FY) 2010 and increasing to 100 percent in FY 2030 and beyond. These reduction targets are measured relative to "typical" building energy use, as measured by DOE's Commercial Building Energy Consumption Survey (CBECS) and Residential Energy Consumption Survey (RECS). These targets apply to new construction or major renovations with a total cost of $2.5 million (in 2007 dollars when adjusted for inflation to 2024 dollars this is $3,811,583) or more and "public buildings" (as defined at 40 U.S.C. 3301) for which a prospectus to Congress is required under 40 U.S.C. 3307. DOE notes that the $2.5 million construction cost threshold for this Clean Energy Rule generally rules out application of this rule to Federal low-rise residential buildings as does the "public building" requiring a prospectus threshold because the definition at 40 U.S.C. 3301 specifically excludes residential buildings. Thus, the technical analysis of this rule will focus on Federal commercial and multifamily high-rise residential buildings.

The underlying analysis for this rule consists of estimates of Federal new commercial and high-rise residential construction, prototypical building energy use, and prototypical building costs. The rule is evaluated at a level of compliance with the adopted standards (the "Clean Energy Rule compliant building level"), then compared to the baseline, which is ASHRAE Standard 90.1-2019. Using data derived from the General Services Administration's (GSA's) Federal Real Property Profile (and supplemented with the U.S. Department of Defense (DoD) privatized housing data, and from the Federal Compliance Tracking System (CTS)), DOE develops a profile of annual Federal buildings estimated to be built by building type, weighted by square footage and based on an average of buildings constructed in the past 10 years. The Federal building types are mapped to the energy and cost prototype building models developed by DOE's Building Energy Codes Program (BECP). DOE then extracted the energy and cost-effectiveness information for the BECP prototype buildings and weighted those values using the Federal mappings to calculate estimates of energy savings and cost effectiveness for building types found in the Federal commercial sector. The BECP energy and cost-effectiveness results for the ASHRAE determinations and associated cost-effectiveness analyses are then aggregated for the Federal government using the Federal building type weights, as discussed in more detail in chapter 1 of this technical support document (TSD). Emissions conversion factors and emissions monetization values are applied to the resulting energy savings to develop estimates of emissions reductions and monetized benefits.

ES.2 KEY RESULTS OF THE ANALYSIS

DOE conducted an analysis of the Clean Energy for New Federal Buildings and Major Renovations of Federal Buildings Rule (baseline ASHRAE Standard 90.1-2019) and found that the fuel source switching resulted in a net cost of $2.97 million annual life-cycle cost (LCC) (at a

3-percent discount rate) and a net savings of $0.01 million annual LCC (at a 7-percent discount rate) overall for an assumed 14.6 million square feet of affected annual new Federal construction in years 2025–2029 and 2.6 million square feet of affected Federal construction in years 2030–2054, with a cumulative net present value (NPV) of total benefits of the rule of $52.3 million (at a 3-percent discount rate) and $69.7 million (at a 3-percent discount rate). This NPV expresses the estimated total value of future operating cost savings minus the estimated increased building costs for new Federal construction for 2025–2054 with a 30-year lifetime, along with monetized climate and health benefits. These results are discussed in greater detail in chapter 1 of this TSD. DOE's assumptions and methodology for the supplemental review cost effectiveness of this rule are based on the cost-effectiveness analysis of ASHRAE Standard 90.1-2019 conducted by DOE's BECP, which uses a 30-year lifetime of buildings for the LCC analysis.

DOE also considered the estimated monetary impacts likely to result from the change in 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 this rule (see Table ES.2.5 through Table ES.2.8 and chapter 2 of this TSD). DOE estimates the monetized benefits of the reductions in greenhouse gas (GHG) 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 pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. DOE exercises its own judgment in presenting monetized climate benefits as recommended by applicable Executive Orders and guidance, and DOE would reach the same conclusion presented in this notice in the absence of the SC-GHGs, including the February 2021 interim estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

DOE recognized differences in Federal sector building types to those of the BECP prototypes and attempted to address these differences by drawing functional equivalencies among building types that were analyzed in the energy savings and cost-effectiveness analysis described above and more fully in chapter 1 of this TSD. DOE also calculated the weighted average incremental costs for the six Federal building types that most closely matched the prototypes analyzed in DOE's cost-effectiveness analysis of Standard 90.1-2019. These Federal building types comprise 79.3 percent of estimated Federal construction square footage. As described more fully in chapter 1 of this TSD, DOE assumes that all other Federal building types are represented by the average of the Federal buildings that were mapped to DOE's cost-effectiveness analysis building types. The results of this supplemental review are discussed in detail in chapters 1 and 2 of this TSD.

Table ES.2.1 through Table ES.2.8 summarize the economic and environmental benefits and costs expected to result from updating the Federal new commercial and multifamily high-rise residential building energy efficiency code. These tables present the costs and benefits associated with Federal new commercial and multi-family high-rise buildings built in 2025–2054. These results include benefits to consumers which accrue after 2054 from the buildings constructed in 2025−2054.

Table ES.2.1 Summary of Analytical Results – Cost Effectiveness Relative to ASHRAE 90.1 2019 Baseline

Category	3% Discount Rate	7% Discount Rate
Cumulative LCC Net Savings (2022$)	-$54.87 million	$0.089 million
Annualized Net LCC Savings (2022$)	-$2.97 million	$0.0082 million
Simple Payback Period (years)	NA	NA
Annualized Energy Cost Savings (2022$)	-$2.38/ft^2	-$1.82/ft^2
Annualized Energy Cost Savings (2022$)	-$11.05 million	-$8.43 million
Incremental First Cost (2022$)	-$1.07/ft^2	-$0.66/ft^2
Total Incremental First Cost (2022$)	-$149.2 million	-$91.5 million

Table ES.2.2 Summary of Analytical Results – Annual Energy Savings

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Annual Site National Energy Savings (Trillion Btu)	-0.502
Annual Upstream National Energy Savings (Trillion Btu)	0.020
Annual Full Fuel Cycle National Energy Savings (Trillion Btu)	-0.482

* Negative values represent an increase in energy use.

Table ES.2.3 Summary of Analytical Results – Cumulative Energy Savings (30-year analysis period)

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Cumulative Site National Energy Savings (quads)	-0.013
Cumulative Upstream National Energy Savings (quads)	0.001
Cumulative Full Fuel Cycle National Energy Savings (quads)	-0.014

* Negative values represent an increase in energy use.

Table ES.2.4 Summary of Analytical Results – Cumulative Lifetime Energy Savings (2025-2054 plus 30-Year Lifetime)

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Cumulative Lifetime Site National Energy Savings (quads)	-0.031
Cumulative Lifetime Upstream National Energy Savings (quads)	0.00221
Cumulative Lifetime Full Fuel Cycle National Energy Savings (quads)	-0.029

* Note: Negative values represent an increase in energy use.

Table ES.2.5 Summary of Monetized Economic Benefits and Costs (Million 2022$) (2025-2054 plus 30-Year Lifetime)

	Million $2022
3% Discount Rate	
Capital Cost Savings of Equipment*	149.2
Climate Benefits**	51.3
Health Benefits***	55.9

	Million $2022
Total Benefits†	256.4
Operating Costs††	-204.1
Net Benefits	52.3
7% Discount Rate	
Capital Cost Savings of Equipment*	91.5
Climate Benefits**	51.3
Health Benefits***	18.4
Total Benefits†	161.1
Operating Costs††	-91.4
Net Benefits	69.7

Note: This table presents the costs and benefits associated with compliant buildings built and operated in 2025–2084. These results include consumer, climate, and health benefits and disbenefits that accrue after 2054 from the buildings constructed or renovated in 2025−2054.

* Capital costs of equipment are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.

** Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO_2), methane (SC-CH_4), and nitrous oxide (SC-N_2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.

*** 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. See Chapter 2 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 3-percent discount rate.

†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

Table ES.2.6 Annualized Monetized Benefits, Costs, and Net Benefits (million 2022$) (2025-2054 plus 30-Year Lifetime)

Category	*million 2022$/year*	
	3% Discount Rate	**7% Discount Rate**
Capital Costs of Equipment Savings*	8.08	8.44
Climate Benefits**	2.77	2.77
Health Benefits***	3.03	1.69
Total Benefits†	13.88	12.91
Operating Costs††	-11.05	-8.43
Net Benefits	2.83	4.48

Note: This table presents the costs and benefits associated with Federal new commercial and multifamily high-rise buildings built in 2025–2084. These results include benefits to consumers and disbenefits that accrue after 2054 from the buildings constructed in 2025−2054.

* Capital costs of equipment are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.

** Climate benefits are calculated using four different estimates of the SC-GHG (see Chapter 2 of this document). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.

*** 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. See chapter 2 of this TSD for more details.

† Total and net benefits include 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 3-percent discount rate.

†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

Table ES.2.7 Summary of Analytical Results – Cumulative Full-Fuel Cycle (FFC) Emission Reductions (Total FFC Emissions) (30-Year Analysis Period)

Category	Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline
CO_2 (million metric tons)	0.49
SO_2 (thousand tons)	-0.27
NO_X (thousand tons)	2.04
Hg (tons)	-0.002
CH_4 (thousand tons)	9.85
N_2O (thousand tons)	-0.006

Table ES.2.8 Summary of Analytical Results – Cumulative Full-Fuel Cycle (FFC) Emission Reductions (Total FFC Emissions) (2025–2054 with a 30-Year Lifetime)

Category	Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline
CO_2 (million metric tons)	0.9
SO_2 (thousand tons)	-0.4
NO_X (thousand tons)	3.3

Category	Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline
Hg (tons)	-0.003
CH_4 (thousand tons)	15.8
N_2O (thousand tons)	-0.009

The numbers presented in this executive summary reflect the base case scenario for future electric grid cleanliness as predicted by the Energy Information Administration's (EIA) Annual Energy Outlook for 2023 (AEO2023). AEO2023 is likely a conservative estimate of future grid fuel cleanliness and was based on information available around November 2023. EIA AEO represents a "business as usual" case and lower boundary of what the savings associated with this rule could be. To provide additional estimates and an upper boundary of possible savings additional future grid emission cases representing a faster transition to a cleanliness are presented in subsequent chapters of this TSD. Most notably, alternatives to Table ES.2.5 and Table ES.2.6 are presented in Chapter 1 where overall positive net benefits are achieved. Additional information on the impacts of emission factor projections on non-monetized emissions can be found in Chapter 1.

CHAPTER 1. ENERGY AND COST-EFFECTIVENESS ANALYSIS METHODOLOGY

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1. ENERGY AND COST-EFFECTIVENESS ANALYSIS METHODOLOGY

The underlying analysis for this rule consists of estimates of Federal new commercial and high-rise residential construction, prototypical building energy use, and prototypical building costs. The rule is evaluated at the Clean Energy Rule compliant building level, then compared to the baseline, which is ASHRAE Standard 90.1-2019. Using data derived from the U.S. General Services Administration (GSA) Federal Real Property Profile (and supplemented with U.S. Department of Defense (DoD) privatized housing data), the U.S. Department of Energy (DOE) develops a profile of annual Federal building construction estimated to be built by building type, weighted by square footage, and based on an average of buildings constructed in the past 10 years and meeting the cost threshold required of the Clean Energy Rule (*i.e.*, $2.5 million ($2007)). The Federal building types are mapped to the energy and cost prototype building models developed by DOE's Building Energy Codes Program (BECP).[a] The BECP energy and cost-effectiveness results for the ASHRAE determinations and associated cost-effectiveness analyses are then aggregated for the Federal government using the Federal building type weights. Emissions factors are then applied to the resulting energy savings to calculate the emission reductions.

1.1 NEW COMMERCIAL AND MULTIFAMILY HIGH-RISE CONSTRUCTION

GSA data were used to find the distribution of existing Federal building types.[1] A database query was run on the Federal Real Property Profile Management System (FRPP MS) to identify Federally owned buildings 100 square feet and greater and meeting the cost threshold in March 2021. [b,c] The results of this query were used as detailed in this technical support document (TSD) to determine the characteristics of new commercial and multifamily high-rise construction added to the database from 2011 through 2020. These buildings were aggregated to the Federal building types used in the FRPP MS.[d] DOE does not have data about planned new Federal construction for the 30-year analysis period; therefore, DOE conducted this analysis at the national level and assumed that new Federal construction would have a similar distribution between building types that have been constructed in the previous 10-year period. As discussed in following sections, the Federal building types in the FRPP MS were mapped to the DOE BECP building prototypes and cost prototypes to calculate energy savings, emissions reductions, and cost effectiveness. In order to better map Federal buildings into the DOE building prototypes, additional FRPP MS building characteristic data about Reporting Agency and Asset Height Range were utilized.

Reporting Agency data were used to disaggregate Federal dormitories and barracks to estimate new construction of dormitories, which are predominantly residential in nature, and

[a] DOE's prototype buildings are described at www.energycodes.gov/prototype-building-models.
[b] Buildings less than 100 square feet, buildings marked as "Report of Excess Submitted" or "Report of Excess Accepted," buildings outside the United States and territories, and buildings not owned by the Federal government were not included in the database query. The FRPP MS was accessed on March 2, 2021.
[c] DOE selected 100 square feet as a reasonable cutoff to capture smaller buildings such as security booths and comfort stations.
[d] See the FRPP MS Data Dictionary at www.gsa.gov/cdnstatic/FY_2020_FRPP_DATA_DICTIONARY_v2_final2.pdf for description of Federal building types reported.

training barracks, which include non-residential spaces such as classrooms, meeting spaces, and recreational areas. DoD agencies were assumed to construct training barracks, while non-DoD agencies were assumed to construct dormitories. Non-DoD dormitory buildings less than 30 feet in height (using the Asset Height Range data) were assumed to be outside the scope of this rulemaking as they would be considered low-rise residential buildings.

Asset Height Range was used to disaggregate non-DoD Federal dormitories and barracks (hereafter referred to as dormitories), family housing, and office building types. Because not all buildings in the FRPP MS included Asset Height Range data, the fractions of square footage with that data included were applied to the remaining buildings that did not have Asset Height Range entries.

The Asset Height Range data input consists of four categories: (1) "Height > 0 feet and ≤ 30 feet above ground level," (2) "Height > 30 feet and ≤ 100 feet above ground level," (3) "Height > 100 feet and < 200 feet above ground level," and (4) "Height ≥ 200 feet." The Asset Height Range of 0 to 30 feet was assumed to represent three stories or less, and therefore delineates between low-rise residential construction and multifamily high-rise construction for the dormitories and family housing building types; since this rulemaking applies only to residential buildings four stories or greater, only dormitories and family housing buildings estimated to be greater than 30 feet in height were included in the commercial building floorspace estimates. Additionally, there are three DOE BECP office building prototypes defined by number of stories, so the Asset Height Range was used to disaggregate the Federal office building type to better align with the DOE building prototypes. For the offices, the Asset Height Range of 0 to 30 feet was assumed to represent "small office;" the Asset Height Range of 30 to 100 feet was split equally between "medium office" and "large office;" and the Asset Height Range greater than 100 feet was assigned to "large office." Table 1.1.1 provides the percentages by relevant building type and Asset Height Range category.

Table 1.1.1 Percent of Square Feet by Asset Height Category*

FRPP Building Type	No Entry	Height > 0 Feet and ≤ 30 Feet Above Ground Level	Height > 30 Feet and ≤ 100 Feet Above Ground Level	Height > 100 Feet
Non-DoD Dormitories and Barracks	1%	83%	6%	10%
Family Housing	20%	57%	23%	0%
Office	64%	25%	9%	3%

* For Federal buildings built 2011–2020 with at least 100 square feet and not marked for excess.

Additionally, DoD data were used to provide an estimate of high-rise privatized housing. This estimate was combined with an estimate of the average turnover of DoD housing stock of 50 years to develop an annual estimate and was combined with the FRPP MS family housing numbers.[e]

[e] The Facilities Investment and Management (FIM) Office of the Assistant Secretary of Defense for Energy, Installations and Environment, The Pentagon, Room 5C646 Washington, DC 20301. Estimate prepared based on data as of 30 September 2015 by Patricia Coury, Deputy to the DASD for that office. Estimate confirmed total DoD privatized family housing units of 12 high-rise privatized unaccompanied housing buildings. The high-rise buildings

DOE identified a rate of new Federal commercial construction of 13.3 million square feet per year with a distribution of building types as shown in Table 1.1.2 for buildings in years 2025–2029. Starting in the year 2030, section 205(c)(ii) of Executive Order 14057, "Catalyzing Clean Energy Industries and Jobs Through Federal Sustainability" (December 8, 2021) requires agencies to "design new construction and modernization projects greater than 25,000 gross square feet to be net-zero emissions by 2030." This effectively reduces the impact of this rule to apply to new construction and major renovation projects that fall above the cost threshold but are also below 25,000 gross square feet. For the year 2030 and beyond, the estimated new Federal commercial and multifamily high-rise residential building construction volume per year will be 2.2 million square feet per year with a distribution of building types as shown in Table 1.1.3. This assumption is based on the FRPP MS data (and DoD privatized high-rise housing data) and represents the annual average of the square footage extracted during the query described above. The distribution shown in Table 1.1.3 was used to disaggregate new Federal commercial and multifamily high-rise construction and apply the mapped building prototypes, discussed in later sections.
Additionally, DOE identified an estimated rate of Federal major renovation projects that would be influenced by this rule. To do so, DOE utilized data from the Federal Energy Management Program's (FEMP) Compliance Tracking System (CTS) where agencies report data on building efficiency improvement projects. The data from CTS was queried to include only those projects that would meet the cost threshold and have impacts on the site fossil fuel energy consumption. Because not all agencies are compliant in reporting data into CTS, results were scaled up to account for agencies out of compliance. CTS does not supply data on the types of buildings for the reported projects; therefore, the distribution of eligible Federal buildings for a renovation that would meet the cost threshold was applied to the estimated project square footage. DOE identified a rate of new Federal major renovation construction of 1.36 million square feet per year with a distribution of building types as shown in Table 1.1.2. Starting in the year 2030, Executive Order (EO) 14057 will effectively reduces the impact of this rule to apply to projects that fall above the cost threshold but are also below 25,000 gross square feet. For the year 2030 and beyond, the estimated new Federal commercial and multifamily high-rise residential building major renovation construction volume per year will be 0.4 million square feet per year with a distribution of building types as shown in Table 1.1.2 and

Table 1.1.3. New construction and major renovation estimated yearly construction volumes are shown in Table 1.1.4.

Table 1.1.2 Annual Construction Volumes by Building Type and Year Constructed

	New Construction	Major Renovation	Combined Total
SF Building / year 2030–2054	13,317,707	1,357,055	14,674,762
SF Building / year 2025–2030	2,230,380	404,411	2,634,791

were converted to housing units using an average of 311 units per building based on the DoD data. Additional discussions between DoD and DOE confirmed that for purposes of estimating annual construction, a turnover of 50 years was appropriate.

Table 1.1.3 Estimated Floor Area Fraction of New Federal Commercial Building Construction for years 2025–2029 (Based on New Federal Building Square Footage Meeting Cost Threshold, 2011–2020)

Facility Type	Percent
Office *Small Office* *Medium Office* *Large Office*	17.77% *12.08%* *3.73%* *1.95%*
Dormitories and Barracks*	14.57%
School	15.65%
Service	15.16%
Other Institutional Uses	5.76%
Hospital	7.80%
Warehouses	2.95%
Laboratories	4.24%
All Other	2.74%
Outpatient Healthcare Facility	5.00%
Industrial	1.63%
Child Care Center	0.89%
Communications Systems	1.42%
Prisons and Detention Centers	0.18%
Family Housing*	1.06%
Navigation and Traffic Aids	0.53%
Land Port of Entry	0.68%
Border/Inspection Station	0.64%
Facility Security	0.25%
Data Centers	0.34%
Museum	0.74%
Comfort Station/Restrooms	0.01%
Public Facing Facility	0.02%
Aviation Security Related	0.00%
Post Office	0.00%
Grand Total	100.00%

* Percent of square footage estimated to be subject to 10 CFR 433.

Table 1.1.4 Estimated Floor Area Fraction of New Federal Commercial Building Construction for years 2030–2054 (Based on New Federal Building Square Footage Meeting Cost Threshold under 25,000 SF, 2011–2020)

Facility Type	Percent
Office *Small Office* *Medium Office* *Large Office*	14.24% 12.92% 1.32% 0.00%

Facility Type	Percent
Dormitories and Barracks*	4.02%
School	10.88%
Service	18.34%
Other Institutional Uses	12.63%
Hospital	2.97%
Warehouses	6.88%
Laboratories	4.37%
All Other	5.58%
Outpatient Healthcare Facility	7.66%
Industrial	2.05%
Child Care Center	2.67%
Communications Systems	0.87%
Prisons and Detention Centers	0.26%
Family Housing*	1.49%
Navigation and Traffic Aids	1.95%
Land Port of Entry	0.99%
Border/Inspection Station	0.36%
Facility Security	1.36%
Data Centers	0.19%
Museum	0.10%
Comfort Station/Restrooms	0.03%
Public Facing Facility	0.09%
Aviation Security Related	0.00%
Post Office	0.00%
Grand Total	100.00%

* Percent of square footage estimated to be subject to 10 CFR 433.

1.2 ENERGY USE METHODOLOGY

DOE's assumptions and methodology for the energy savings impact of this rule are based on the energy savings analysis of ASHRAE Standard 90.1-2019 conducted by DOE's State BECP.[2,3] Energy use intensity (EUI) is the energy consumed by a building per square foot per year. As noted previously, DOE develops a profile of annual Federal buildings estimated to be built by building type, weighted by floorspace, and based on an average of buildings constructed in the past 10 years. As DOE does not have data on the types of buildings that agencies may construct in the future, DOE relies on historical averages in developing a national estimate of the impacts to Federal building construction. The national average EUIs were calculated using a weighted average of EUIs for the types of buildings that the Federal government is assumed to construct (shown in Table 1.1.3 and Table 1.1.4). To determine the EUI of the Federal buildings listed in Table 1.1.3, DOE mapped the Federal building stock to various building prototypes used in DOE's BECP determination of energy savings for ANSI/ASHRAE/IES Standard 90.1-2019.[4]

BECP has developed prototype buildings and incorporated their characteristics into computer simulations that are used to estimate energy use in each building type. These prototype buildings represent 16 building types and are simulated in 17 climate zones; they are referred to here as BECP's Commercial Prototype Building models.[5,f]

The 16 prototype buildings are representative of the characteristics of new construction in the United States. It is not feasible to simulate all building types and possible permutations of building design. Further, data are not available to correctly weight each possible permutation in each U.S. climate zone as a fraction of the national building construction mix. Hence, the quantitative analysis focuses on the use of prototype buildings that reflect a representative mix of typical construction practices. As noted in the DOE BECP analysis, not all the ASHRAE 90.1 changes that impact energy use can be captured by the quantitative analysis due to the fixed nature of the prototypes. Thus, the impact resulting from the quantitative analysis can be considered conservative. At the same time, the impact could be considered generous because the changes that were included impacted all buildings of a given type (*i.e.*, the weighting factors carried the impact to all buildings of a given type in a climate zone even though some of those buildings may not fit the descriptions of the prototype buildings). For example, the DOE BECP analysis assumes all large office buildings have water-cooled chillers—a property of the large office prototype. In reality, some have air-cooled, some have packaged equipment, some have variable refrigerant volume systems, etc. If the water-cooled chiller efficiency improved more than the other systems, the analysis overestimates savings, whereas, if the efficiency improved less than the other systems, the analysis would have underestimated savings.[6,7]

The mapping of Federal building types to the BECP prototypes used for this rule is shown in Table 1.2.1. Where BECP prototypes are not one-to-one matches with Federal building types, DOE mapped the Federal building type to one of the BECP prototypes based on similarities of building use and characteristics (*e.g.*, the Federal public facing facility building type has the primary mission of interacting with the public conducting personal business; therefore, DOE assumed that the building characteristics would be similar to a retail building).

Table 1.2.1 Mapping of Federal Building Types to BECP Prototypes for Energy Use Analysis

Federal Building Type	Match to BECP Building Prototypes
Office	Small Office, Medium Office, Large Office (weighted by estimated percentages in FRPP MS data)
Dormitories and Barracks*	Small Hotel, Mid-Rise Apartment, High-Rise Apartment (weighted by estimated percentages in FRPP MS data)
School	Secondary School
Service	50% Stand-Alone Retail, 50% Non-Refrigerated Warehouse
Other Institutional Uses	None
Hospital	Hospital
Laboratories	25% Medium Office, 75% Hospital
Warehouses	Non-refrigerated Warehouse
Outpatient Healthcare Facility	Outpatient Health Care
All Other	None

[f] DOE's prototype buildings are described at www.energycodes.gov/prototype-building-models.

Federal Building Type	Match to BECP Building Prototypes
Industrial	None
Child Care Center	Primary School
Prisons and Detention Centers	None
Communications Systems	None
Land Port of Entry	Non-Refrigerated Warehouse
Family Housing*	Mid-Rise Apartment
Border/Inspection Station	75% Small Office, 25% Non-Refrigerated Warehouse
Navigation and Traffic Aids	None
Museum	None
Facility Security	Small Office
Data Centers	None
Aviation Security Related	Small Office
Public Facing Facility	Stand-Alone Retail
Post Office	Stand-Alone Retail
Comfort Station/Restrooms	Non-refrigerated Warehouse

* Dormitories and family housing less than three stories are assumed to be constructed under 10 CFR 435; training barracks are assumed to be constructed under 10 CFR 433.

As can be seen in Table 1.1.3 and Table 1.2.1, a number of Federal building types representing approximately 15 percent of estimated new Federal floorspace have no specific match to BECP prototype buildings. These Federal building types, including other institutional uses, all other, and industrial (to name the three largest by percentage) are assumed to have EUIs equal to the average of all mapped Federal building types.[g] Table 1.2.1 also shows that a large number of Federal building types are mapped to the BECP small office (for buildings assumed to be more administrative in function with a consistent workforce) and stand-alone retail (for buildings assumed to have "customers" entering and exiting the building throughout the day, in addition to a consistent workforce), which are assumed to be the most plausible match. As noted in section 1.1, DOE used Asset Height Range information within the FRPP MS to estimate the percentage of Federal family housing and dormitories buildings built subject to this rulemaking.

It should also be noted that five Federal building types—offices, dormitories, service, border and inspection stations, and laboratories—are mapped to multiple BECP building prototypes. As described in section 1.1, DOE utilized the Asset Height Range information in the FRPP MS to estimate the BECP office category (small, medium, or large office) that each building would fall into and weighted the Federal offices using those percentage weights. Because the Asset Height Range of "greater than 30 and less than or equal to 100 feet" would include both the medium office (four to six stories) and large office (seven or more stories), the

[g] This assumption is made presuming that the 15 percent of buildings that are not mapped have an EUI that falls somewhere within the range of EUIs exhibited by other Federal buildings. This assumption may not apply to industrial and manufacturing buildings that may have much higher EUIs than other Federal buildings. In the absence of any BECP prototype for these buildings or other information on the EUI on Federal manufacturing and industrial facilities, DOE believes the use of this assumption is appropriate. DOE also points out that while Federal manufacturing and industrial buildings may have higher EUIs, the actual manufacturing and industrial loads in those buildings are exempt from this rule and therefore the potentially high EUI for these buildings is of minimal concern.

fraction of floorspace assigned to that height range was divided equally between the two categories. Similarly, DOE utilized the Reporting Agency and Asset Height Range information for dormitories to distinguish between dormitories and training barracks, and to determine the percent of floorspace built under 10 CFR 433 (subject to this rule) versus those more likely be built under 10 CFR 435 (new Federal low-rise residential). The resulting percentages were used to weight Federal dormitories into the BECP prototype categories of small hotel, mid-rise apartment, and high-rise apartment. As with the office building types, the Asset Height Range of "greater than 30 and less than or equal to 100 feet" would encompass both the mid-rise apartment (four to seven stories) and high-rise apartment (eight or more stories), so the fraction of floorspace assigned to that height range was divided equally between the two categories. For the Federal service category, DOE assumed an average of the BECP stand-alone retail and non-refrigerated warehouse to represent customer-facing and storage areas. Similarly, Federal border and inspection stations were represented by 75 percent BECP small office and 25 percent non-refrigerated warehouse to represent administrative functions and storage spaces. DOE assumed that Federal laboratories would best be represented by 25 percent BECP medium office for office spaces and 75 percent hospital for more intensive laboratory energy loads.

The BECP site fossil fuel use estimated EUIs for each of the building prototypes for ASHRAE 90.1-2019[3] were then converted to site electric use EUIs by applying separate conversion factors for heating systems, service hot water systems, and cooking systems.[h] A summary of the assumptions behind the equipment efficiencies used to determine conversion factors is listed in Table 1.1.2. Many of the electric conversion efficiencies shown in Table 1.2.2 represent a conservative selection; as a result, higher efficiency electric systems (*e.g.*, heat pump water heaters, variable refrigerant volume heat pumps) have not been incorporated in this analysis. The choice of replacement electric technologies is in the purview of the Federal agencies meeting the requirements of the rule.

Table 1.2.2 Summary of Natural Gas to Electricity Equipment Site Energy Use Efficiency Factors

Prototype Conversion Efficiency Assumptions			
Building Prototype	**Notes***	**Gas Eff**	**Electric Eff**
Space Heat			
Small Office	Convert using AFUE for gas furnace and estimated AFUE for electric furnace. Small office prototype uses heat pump with furnace backup	0.810	0.990
Medium Office	Convert using pre 1/1/2023 Et estimated Et for Furnaces assuming 0.75% casing loss	0.793	0.993
Large Office	Convert using Et Estimate for boilers	0.820	0.990
Stand-Alone Retail	Convert using furnace efficiency (including 0.75% casing loss) and national weighted heat pump/electric backup system efficiency from small office prototype variant	0.793	1.763
Strip Mall	Not Used Federal Sector		

[h] EUIs by fuel type are available at www.energycodes.gov/sites/default/files/documents/2019EndUseTables.zip.

Prototype Conversion Efficiency Assumptions			
Building Prototype	**Notes***	**Gas Eff**	**Electric Eff**
Primary School	Approx. ¼ gas furnaces, ¾ gas boilers by capacity. Capacity weighted Et was converted to estimated electric equivalents	0.813	0.991
Secondary School	Convert using Et estimate for boilers	0.820	0.990
Outpatient Health Care	Convert using Et estimate for boilers	0.820	0.990
Hospital	Convert using Et estimate for boilers	0.820	0.990
Small Hotel	Convert using gas furnace AFUE and AFUE estimate for electric where furnace was used	0.810	0.990
Large Hotel	Not Used Federal Sector		
Quick-service Restaurant	Not Used Federal Sector		
Full-service Restaurant	Not Used Federal Sector		
Mid-Rise Apartment	Convert from gas furnace AFUE estimate to HSPF	0.810	2.403
High-Rise Apartment	Convert using Et estimate for boilers	0.820	0.990
Warehouse	Gas heating efficiency based on approximate weight of furnace and unit heater rated efficiencies. Electric equipment efficiencies estimated	0.793	0.993
Service Water Heat			
Small Office	No conversion. Already electric.	--	--
Medium Office	Convert using Et. SL not taken into account	0.800	1.000
Large Office	Convert using Et. SL not taken into account	0.800	1.000
Stand-Alone Retail	Convert using UEF 40 Gal Medium Draw Gas to 50 Gal Medium Draw Electric	0.580	0.921
Strip Mall	Not Used Federal Sector		
Primary School	Convert Using Et. SL not taken into account	0.800	1.000
Secondary School	Convert using Et. SL not taken into account	0.800	1.000
Outpatient Health Care	Convert using Et. SL not taken into account	0.800	1.000
Hospital	Convert using Et. SL not taken into account	0.800	1.000
Small Hotel	Convert using Et. SL not taken into account	0.800	1.000
Large Hotel	Not Used Federal Sector		
Quick-service Restaurant	Not Used Federal Sector		
Full-service Restaurant	Not Used Federal Sector		

Prototype Conversion Efficiency Assumptions			
Building Prototype	**Notes***	**Gas Eff**	**Electric Eff**
Mid-Rise Apartment	No conversion. Already electric	--	--
High-Rise Apartment	Convert using Et. SL not taken into account	0.800	1.000
Warehouse	No conversion. Already electric	--	--
Gas Cooking			
Small Office	No Conversion - no modeled cooking loads	--	--
Medium Office	No Conversion - no modeled cooking loads	--	--
Large Office	No Conversion - no modeled cooking loads	--	--
Stand-Alone Retail	No Conversion - no modeled cooking loads	--	--
Strip Mall	Not Used Federal Sector		
Primary School	Commercial Equipment Standard Gas Efficiency to Standard Electric Efficiency	0.400	0.700
Secondary School	Commercial Equipment Standard Gas Efficiency to Standard Electric Efficiency	0.400	0.700
Outpatient Health Care	No Conversion - no modeled cooking loads	--	--
Hospital	Commercial Equipment Standard Gas Efficiency to Standard Electric Efficiency	0.400	0.700
Small Hotel	Commercial Equipment Standard Gas Efficiency to Standard Electric Efficiency	0.400	0.700
Large Hotel	Not Used Federal Sector	0.400	0.700
Quick-service Restaurant	Not Used Federal Sector	0.400	0.700
Full-service Restaurant	Not Used Federal Sector	0.400	0.700
Mid-Rise Apartment	No Conversion - no modeled cooking loads	--	--
High-Rise Apartment	No Conversion - no modeled cooking loads	--	--
Warehouse	No Conversion - no modeled cooking loads	--	--

* Et = Rated Thermal Efficiency, AFUE = Annual Fuel Utilization Efficiency, HSPF = Heating Seasonal Performance Factor, SL = Standby Loss, UEF = Uniform Energy Factor

By using the floorspace weights and building prototype mappings contained in Table 1.1.3 and Table 1.2.1, DOE estimated Federal site EUI savings of 2.35 thousand British thermal units (kBtu) per square foot per year (comprising natural gas savings of 8.06 kBtu per square foot per year and site electric increase of 5.71 kBtu per square foot per year). It should be noted that many of the electric conversion efficiencies represent a conservative assessment based on minimum equipment efficiencies in ASHRAE 90.-2019; as a result, higher efficiency electric systems (*e.g.*, heat pump water heaters, variable refrigerant volume heat pumps) have not been incorporated at this stage. The choice of replacement electric technologies is in the purview of the Federal agencies meeting the requirements, and additional savings and different first cost impacts would impact the cost effectiveness of individual projects.

1.3 COST-EFFECTIVENESS METHODOLOGY

DOE's assumptions and methodology for the cost effectiveness of this rule are based on the cost-effectiveness analysis of ASHRAE Standard 90.1-2019 conducted by DOE's State BECP.[6,7] As discussed in section 1.1, DOE identified a rate of new Federal commercial construction of 13.3 million square feet per year with a distribution of building types, as shown in Table 1.1.3 for buildings in effective years 2025–2029. Starting in the year 2030, Executive Order 14057will effectively reduces the impact of this rule to apply to projects greater than 25,000 gross square feet to be net-zero emissions by 2030." This effectively reduces the impact of this rule to apply to new construction and major renovation projects that fall above the cost threshold but are also below 25,000 gross square feet. For the year 2030 and beyond, the estimated new Federal commercial and multifamily high-rise residential building construction volume per year will be 2.2 million square feet per year with a distribution of building types as shown in Table 1.1.4.

As noted previously, DOE BECP has developed a set of building energy prototype models for 16 buildings, and DOE mapped the estimated Federal building new construction to those prototypes to quantify the energy savings of Clean Energy Rule compliant building compared to ASHRAE 90.1-2019. As with the development and use of building energy prototypes for representative buildings, it is not feasible to simulate the costs associated with all building types and possible permutations of building design to develop the cost-effectiveness analysis. For their cost-effectiveness analysis, DOE BECP identified a subset of the 16 prototype buildings covering six representative prototype buildings and five climate zones and developed costs for these to determine the cost effectiveness of the Clean Energy Rule compliant building and ASHRAE Standard 90.1-2019.[6,7] The six prototype models DOE BECP selected for the cost-effectiveness analysis were chosen because they provide a good representation of the overall ASHRAE code cost effectiveness without requiring simulation of all 16 prototype models and represent the energy impact of five of the eight commercial principal building activities that account for 72 percent of the new commercial construction by floor area covered by the full suite of 16 prototypes.[7]

The mapping of Federal building types to these cost prototypes is shown in Table 1.3.1. DOE mapped the Federal building types to the BECP subset of cost prototypes based on the energy use prototype mappings to develop the potential national cost-effectiveness analysis. As with the energy calculations, DOE similarly extracted the cost-effectiveness information for the prototype buildings and weighted those values using the floorspace weights to obtain an average cost-effectiveness value for building types found in the Federal commercial sector. The Building types that mapped to "none" were not specifically mapped to a cost prototype but were still cost modeled by feeding their impact back into the modeled cost prototypes at the distribution rates that reported building resulted in. This was calculated to be ~17% pre EO10457 (2030) and ~31.5% post 2030 of the expected construction volume.

Table 1.3.1 Mapping of Federal Buildings to BECP Cost Prototypes for Cost-Effectiveness Analysis

Building Type	Assumed BECP Prototypes for Cost Effectiveness
Office	Small Office, Large Office
Dormitories and Barracks	7% Small Hotel, 93% Mid-Rise Apartment
School	Primary School
Service	Stand-Alone Retail
Other Institutional Uses	None
Hospital	50% Small Office, 50% Large Office
Warehouses	None
Laboratories	50% Small Office, 50% Large Office
All Other	None
Outpatient Healthcare Facility	Small Office
Industrial	None
Child Care Center	Primary School
Communications Systems	None
Prisons and Detention Centers	None
Family Housing	Mid-rise Apartment
Navigation and Traffic Aids	None
Land Port of Entry	None
Border/Inspection Station	Small Office
Facility Security	Small Office
Data Centers	None
Museum	None
Comfort Station/Restrooms	None
Public Facing Facility	Stand-Alone Retail
Aviation Security Related	Small Office
Post Office	Stand-Alone Retail

DOE has determined incremental cost, annualized energy cost savings, and the life-cycle cost (LCC) net savings information for the building types and climate zones analyzed for Clean Energy Compliant Buildings versus ASHRAE Standard 90.1-2019 (see Table 1.3.2).

Table 1.3.2 Incremental Construction First Cost (2022$) for Clean Energy Compliant Building Design vs. ASHRAE Standard 90.1-2019

Prototype	Value	ASHRAE Climate Zone*				
		2A	3A	3B	4A	5A
Small Office	First Cost	$673	$584	$515	$1,666	$641
	$/ft^2	$0.12	$0.11	$0.09	$0.30	$0.12
Large Office	First Cost	$261,781	$268,194	$196,408	$354,808	$223,553
	$/ft^2	$0.52	$0.54	$0.39	$0.71	$0.45
Stand-Alone Retail	First Cost	$19,608	$20,240	$19,740	$21,563	$19,363
	$/ft^2	$0.79	$0.82	$0.80	$0.87	$0.78
Primary	First Cost	($126,946)	($121,994)	($116,139)	($94,722)	($122,894)

Prototype	Value	ASHRAE Climate Zone*				
		2A	3A	3B	4A	5A
School	$/ft²	($1.72)	($1.65)	($1.57)	($1.28)	($1.66)
Small Hotel	First Cost	($104,866)	($104,624)	($104,396)	($101,194)	($103,044)
	$/ft²	($2.43)	($2.42)	($2.42)	($2.34)	($2.38)
Mid-Rise Apartment	First Cost	($18,343)	($17,490)	($18,113)	($12,445)	($25,126)
	$/ft²	($0.54)	($0.52)	($0.54)	($0.37)	($0.74)

* Negative costs (shown in parentheses) indicate a reduction in cost due to changes in the code, usually due to reduced heating, ventilation, and air conditioning (HVAC) capacity. In this particular transition from 90.1-2013 to 90.1-2016, the cost reduction was mainly because of smaller and less expensive HVAC equipment since the building HVAC load had decreased. This cost reduction is part of the first cost calculation. Note that in addition to reduced equipment costs, there is reduced ductwork or piping costs as well.

DOE used data from Table 1.1.3 and Table 1.3.1 to calculate preliminary values for overall incremental first cost of construction for Federal commercial and high-rise multifamily residential buildings. DOE calculated the incremental first cost of the Federal building types based on the DOE cost prototypes shown in Table 1.3.1. DOE then calculated the weighted average incremental cost for mapped Federal building types based on their corresponding BECP prototypes, which represent an estimated 79.3 percent of new Federal construction. This weighted incremental cost was assigned to unmapped Federal building types.

The national incremental first cost for building types was developed by multiplying the average (across climate zones) incremental first cost of the prototypes[6,7] by the fraction of the Federal sector construction volume shown in Table 1.1.3, and then multiplying that by the total estimate of Federal new construction floorspace as described previously. The resulting building type incremental first costs were then summed together to determine an overall incremental first cost for the entire Federal commercial and high-rise multifamily residential buildings sector. DOE estimates that total first cost outlays for new Federal buildings will be less under Clean Energy Rule compliant designs than ASHRAE Standard 90.1-2019, primarily due to lower heating, ventilation, and air conditioning (HVAC) equipment costs for some building types. The resulting total incremental first cost estimate is a savings of $8.62 million per year. The average first cost decrease is $1.86 per square foot. DOE determined that the total incremental first cost estimate for Federal buildings (as mapped to the prototype buildings as described previously) is a savings of $139.4 million (at a 3-percent discount rate) and a savings of $85.5 million (based on a 7-percent discount rate), with an annualized decrease of $1.0 per square foot (at a 3-percent discount rate) and $0.61 per square foot (at a 3-percent discount rate).

DOE also analyzed the relative impact of today's rule on the first cost of new constructed Federal buildings as a percentage of the overall annual cost of newly constructed Federal commercial and high-rise buildings. To estimate the total cost of construction for new Federal buildings, DOE obtained estimated construction costs for new Federal commercial and high-rise multifamily buildings from RSMeans[8] for the six building cost prototypes analyzed in DOE's cost-effectiveness report. These new construction costs were weighted by the percent of Federal floorspace to develop an average cost of a new Federal building of $198 per square foot, as shown in Table 1.3.3. This average construction cost may be multiplied by the overall total of 19.54 million square feet of new Federal construction per year used in this rulemaking to estimate the annual total cost of all new Federal commercial and high-rise multifamily construction of $3.86 billion. As previously noted, first cost savings associated with this rulemaking are estimated at $8.62 million per year, indicating a potential cost reduction in new Federal construction costs of 0.223 percent ($8.62 million divided by $3.86 billion).

Table 1.3.3 First Cost of Typical New Federal Building in $/ft^2 (2022$)

Federal Building Type	Weight	First Cost*	Weighted Cost
Office	20.74%	$210	$43.51
Barracks and Dormitories	14.85%	$217	$32.18
School	14.33%	$225	$32.25
Service	13.31%	$116	$15.44
Hospital	5.57%	$200	$11.14
Laboratories	4.37%	$200	$8.73
Outpatient Healthcare Facility	3.35%	$220	$7.38
Child Care Center	1.18%	$225	$2.67
Family Housing >3 Stories	0.68%	$218	$1.48
Border/Inspection Station	0.49%	$220	$1.07
Facility Security	0.31%	$220	$0.69
Aviation Security Related	0.01%	$220	$0.02
Public Facing Facility	0.05%	$116	$0.06
Post Office	0.01%	$116	$0.01
Remaining Federal Stock	20.75%	$198	$41.00
Federal Average	100.00%	$198	$197.62

*All building first cost data from RSMeans 2020.

For annualized energy cost savings, DOE used a similar approach to that used for incremental first cost. That is, DOE developed the national annual energy cost savings[i] for building types by multiplying the average (across climate zones) energy cost savings (determined from the DOE ASHRAE Standard 90.1 cost-effectiveness analysis) by the fraction of the Federal sector construction volume shown in Table 1.1.3, and then multiplying that by the total estimate of Federal new construction floorspace.[j] The results of the building type energy cost savings were then summed together to determine the overall annual energy cost savings for the entire Federal commercial and high-rise multifamily buildings sector. Table 1.3.4 shows the annual energy cost savings by prototype buildings for Clean Energy Rule compliant building compared to ASHRAE Standard 90.1-2019. As was done for the incremental cost analysis, the 2019 energy cost savings analysis was adjusted to use the same underlying economic assumptions as the Clean Energy Rule compliant version, including fuel prices, fuel price escalations, labor and material costs, and the removal of sales tax. The resulting total annual energy cost savings for the Clean Energy Rule affected buildings to be 14.7 million square feet of annual construction for years 2025–2029 and 2.6 million square feet of annual construction for years 2030–2054 was estimated to be -$11.05 million (at a 3-percent discount rate) and -$8.43 million (at a 7-percent

[i] The energy costs used were the national average energy costs used by ASHRAE in the development of Standard 90.1-2019. To quote the cost-effectiveness analysis report "Energy rates used to calculate the energy costs from the modeled energy usage were $0.98/therm for fossil fuel and $0.1063/kWh for electricity. These rates were used for the 90.1-2019 energy analysis and derived from the EIA data. These were the values approved by the SSPC 90.1 for cost-effectiveness for the evaluation of individual addenda during the development of 90.1-2019."

[j] For the Federal office building, the small and large office prototype LCCs were weighted by estimated fraction of small and large offices observed in the FRPP MS database over the past 10 years of construction. For the Federal education building, the primary school prototype LCC was used. For the Federal dorm/barracks building type, the small office, small hotel and mid-rise apartment prototype LCCs were averaged.

discount rate). The annualized energy cost savings was estimated to be -$2.38 per square foot (at a 3-percent discount rate) and -$1.82 per square foot (at a 3-percent discount rate). Note the annual energy cost savings are for 1 year of Federal commercial and high-rise multifamily residential construction and that those savings or costs would accumulate over the evaluation period.

Table 1.3.4 Annualized Energy Cost Savings (2022$) for Clean Energy Compliant Building Design vs. ASHRAE Standard 90.1-2019 vs. by BECP Prototype

Building Prototype	Total Prototype Usage	Annualized Energy Cost Savings (M2022$)		Annualized Energy Cost Savings Intensity (M2022$/SF)	
		3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Small Office	14.78%	($1.63)	($1.25)	($0.35)	($0.27)
Medium Office	5.53%	($0.61)	($0.47)	($0.13)	($0.10)
Large Office	2.26%	($0.25)	($0.19)	($0.05)	($0.04)
Stand-Alone Retail	8.76%	($0.97)	($0.74)	($0.21)	($0.16)
Strip Mall	0.00%	$0.00	$0.00	$0.00	$0.00
Primary School	1.02%	($0.11)	($0.09)	($0.02)	($0.02)
Secondary School	18.06%	($2.00)	($1.52)	($0.43)	($0.33)
Outpatient Health Care	5.76%	($0.64)	($0.49)	($0.14)	($0.10)
Hospital	12.68%	($1.40)	($1.07)	($0.30)	($0.23)
Small Hotel	1.18%	($0.13)	($0.10)	($0.03)	($0.02)
Large Hotel	0.00%	$0.00	$0.00	$0.00	$0.00
Quick-service Restaurant	0.00%	$0.00	$0.00	$0.00	$0.00
Full-service Restaurant	0.00%	$0.00	$0.00	$0.00	$0.00
Mid-Rise Apartment	8.95%	($0.99)	($0.75)	($0.21)	($0.16)
High-Rise Apartment	7.90%	($0.87)	($0.67)	($0.19)	($0.14)
Non-Refrigerated Warehouse	13.12%	($1.45)	($1.11)	($0.31)	($0.24)
Total	100.00%	($11.05)	($8.43)	($2.38)	($1.82)

Note: Negative values, shown in parentheses, represent costs rather than cost savings.

For LCC net savings, DOE used a similar approach to that used for incremental first cost. That is, DOE developed the national annual LCC net savings[k] for building types by multiplying

[k] The energy costs used were the national average energy costs used by ASHRAE in the development of Standard 90.1-2019. To quote the cost-effectiveness analysis report, "Energy rates used to calculate the energy costs from the modeled energy usage were $0.98/therm for fossil fuel and $0.1063/kWh for electricity. These rates were used for the 90.1-2019 energy analysis and derived from the EIA data. These were the values approved by the SSPC 90.1 for cost-effectiveness for the evaluation of individual addenda during the development of 90.1-2019."

the average (across climate zones) LCC net savings[6,7] by the fraction of the Federal sector construction volume shown in Table 1.1.3, and then multiplying that by the total estimate of Federal new construction floorspace.

Table 1.3.5 shows annual LCC net savings by prototype buildings for the Clean Energy Rule compliant case compared to ASHRAE Standard 90.1-2019. As was done for the incremental cost analysis, the 2019 LCC analysis was adjusted to use the same underlying economic assumptions as the Clean Energy Rule compliant case, including fuel prices, fuel price escalations, labor and material costs, and the removal of sales tax. The resulting total LCC net savings for 14.7 million square feet of annual construction for years 2025–2029 and 2.6 million square feet of annual construction for years 2030–2054 were estimated to be a cost of $54.87 million (at a 3-percent discount rate) and a savings of $.089 million (based on a 7-percent discount rate). The average LCC net impacts in year one was estimated to be a cost of $2.97 million (at a 3-percent discount rate) and a savings of $0.01 million (based on a 7-percent discount rate). Note the annual LCC savings are for 1 year of Federal commercial and high-rise multifamily residential construction and that those savings or costs would accumulate over the LCC evaluation period. DOE relied on a 30-year period.[9]

Table 1.3.5 Annual LCC Net Savings (2022$) for ASHRAE Standard 90.1-2019 vs. Clean Energy Compliant Building Design

Building Prototype	Total Prototype Usage	Annualized LCC Savings, Cumulative (M2022$)		Annualized LCC Savings, Annualized (M2022$)	
		3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Small Office	14.78%	($8.11)	$0.013	($0.44)	$0.0015
Medium Office	5.53%	($3.03)	$0.005	($0.16)	$0.0006
Large Office	2.26%	($1.24)	$0.002	($0.07)	$0.0002
Stand-Alone Retail	8.76%	($4.81)	$0.008	($0.26)	$0.0009
Strip Mall	0.00%	$0.00	$0.000	$0.00	$0.0000
Primary School	1.02%	($0.56)	$0.001	($0.03)	$0.0001
Secondary School	18.06%	($9.91)	$0.016	($0.54)	$0.0018
Outpatient Health Care	5.76%	($3.16)	$0.005	($0.17)	$0.0006
Hospital	12.68%	($6.96)	$0.011	($0.38)	$0.0013
Small Hotel	1.18%	($0.65)	$0.001	($0.04)	$0.0001
Large Hotel	0.00%	$0.00	$0.000	$0.00	$0.0000
Quick-service Restaurant	0.00%	$0.00	$0.000	$0.00	$0.0000
Full-service Restaurant	0.00%	$0.00	$0.000	$0.00	$0.0000
Mid-Rise Apartment	8.95%	($4.91)	$0.008	($0.27)	$0.0009
High-Rise Apartment	7.90%	($4.33)	$0.007	($0.23)	$0.0008

Building Prototype	Total Prototype Usage	Annualized LCC Savings, Cumulative (M2022$)		Annualized LCC Savings, Annualized (M2022$)	
		3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Non-Refrigerated Warehouse	13.12%	($7.20)	$0.012	($0.39)	$0.0013
Total	100.00%	($54.87)	$0.089	($2.97)	$0.01

1.4 NATIONAL ENERGY SAVINGS

DOE used the resulting site energy savings per square foot calculated in section 1.2 and multiplied that by the estimated Federal construction in each year to yield a total of 1.83 trillion Btu (TBtu). DOE then used site energy consumption to calculate primary energy consumption by applying a conversion factor to account for losses associated with the generation, transmission, and distribution of electricity. The conversion factor is a multiplicative factor used to convert site energy consumption into primary or source energy consumption, expressed in quads. DOE used annual conversion factors based on the version of the National Energy Modeling System (NEMS)[1] that corresponds to the Energy Information Administration (EIA) *Annual Energy Outlook* for 2023 (*AEO2023*)[10]. The factors are marginal values, which represent the response of the system to an incremental decrease in consumption. For electricity, the conversion factors change over time in response to projected changes in generation sources (*i.e.,* the types of power plants projected to provide electricity to the Nation). The factors also vary between commercial and residential consumer sectors because the pattern of usage varies between sectors. The values derived from the *AEO2023* NEMS end in 2050. DOE assumed that conversion factors remain at the 2050 values throughout the rest of the forecast. For natural gas, the primary energy savings are considered to be equal to the site energy savings because they are supplied to the user without transformation from another form of energy.

The full-fuel-cycle (FFC) measures 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 source fuels. To calculate the FFC by incorporating the energy consumed in extracting, processing, and transporting or distributing source fuels, referred to as upstream activities, DOE developed FFC multipliers using the data and projections generated by the NEMS used for *AEO2023*. The *AEO2023* 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

[1] For more information on NEMS, please refer to the DOE EIA documentation. A useful summary is *National Energy Modeling System: An Overview 2018*, DOE/EIA-0581 (2018), April 2019. EIA approves use of the name NEMS to describe only an official version of the model without any modification to code or data. Because this analysis entails some minor code modifications and the model is run under various policy scenarios that are variations on EIA assumptions, DOE refers to the model by the name NEMS-BT (BT is DOE's Building Technologies Program, under whose aegis this work has been performed). NEMS-BT was previously called NEMS-BRS.

production. This information can help define a set of parameters that represents the energy intensity of energy production. The approach to determining FFC is discussed in Coughlin (2019).[11]

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 2050 value was held constant for the analysis period beyond 2050, which is the last year in the *AEO2023* projection. The multiplier for electricity reflects the shares of various primary fuels in total electricity generation throughout the forecast period.

For this analysis, a 30-year period with Federal construction reflecting the volumes presented in section 1.1 each year was used to determine total national energy savings, as presented in Table 1.4.1 (annual energy savings), Table 1.4.2 (cumulative energy savings within the 30-year analysis period), and Table 1.4.3 (cumulative energy savings for 2025–2054 with a 30-year lifetime).

Table 1.4.1 Annual Energy Savings

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Annual Site National Energy Savings (Trillion Btu)	-0.523 TBtu
Annual Upstream National Energy Savings (Trillion Btu)	0.037 TBtu
Annual FFC National Energy Savings (Trillion Btu)	-0.487 TBtu

* Negative values represent an increase in energy use.

Table 1.4.2 Cumulative Energy Savings (30-Year Analysis Period)

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Cumulative Site National Energy Savings (quads)	-0.019 quads
Cumulative Upstream National Energy Savings (quads)	0.001 quads
Cumulative FFC National Energy Savings (quads)	-0.018 quads

* Negative values represent an increase in energy use.

Table 1.4.3 Cumulative Lifetime Energy Savings (2025-2054 plus 30-Year Lifetime)

Category	Results – Clean Energy Rule Building Compared to the ASHRAE 90.1-2019Baseline*
Cumulative Lifetime Site National Energy Savings (quads)	-0.030 quads
Cumulative Lifetime Upstream National Energy Savings (quads)	0.001 quads

Cumulative Lifetime FFC National Energy Savings (quads)	-0.029 quads

* Negative values represent an increase in energy use.

1.5 NET PRESENT VALUE

DOE calculated the net present value (NPV) of the change in equipment cost and reduced operating cost associated with the difference between Clean Energy Rule compliant building and ASHRAE 90.1-2019. The NPV is the value in the present of a time-series of costs and savings, equal to the present value of savings in operating cost minus the present value of the increased total equipment cost to consumers.

DOE determined the total increased equipment cost for each year of the analysis period (2025–2054) using the incremental construction cost described in section 1.3. DOE determined the present value of operating cost savings for each year from the beginning of the analysis period to the year when all Federal buildings constructed by 2054 have been retired, assuming a 30-year lifetime of the building.

The average annual operating cost includes the costs for energy, repair or replacement of building components (*e.g.*, heating and cooling equipment, lighting, and envelope measures), and maintenance of the building. DOE determined the per-unit annual savings in operating cost based on the savings in energy costs plus replacement and maintenance cost savings, which were calculated by DOE BECP. While DOE used the methodology and prices described in section 1.3 to calculate first year energy cost savings and LCC net savings, for the NPV calculations, DOE determined the per-unit annual savings in operating cost by multiplying the per square foot annual electricity and natural gas savings in energy consumption by the appropriate energy price from *AEO2021*.[12] DOE forecasted energy prices based on projected average annual price changes in *AEO2021* to develop the operating cost savings through the analysis period.

DOE uses national discount rates to calculate national NPV. DOE estimated NPV using both a 3-percent and a 7-percent real discount rate, in accordance with the Office of Management and Budget's (OMB's) guidance to Federal agencies on the development of regulatory analysis, particularly section E therein: *Identifying and Measuring Benefits and Costs*.[13] The NPV is the sum over time of the discounted net savings.

The present value of increased equipment costs is the annual total cost increase in each year (the difference between Clean Energy Rule compliant building and ASHRAE 90.1-2019), discounted to the present, and summed throughout the analysis period (2025 through 2054). Because new construction is held constant through the analysis period, the installed cost is constant. DOE notes that the amount of construction affects the magnitude of the impacts of the rule linearly (prior to taking into account discounting cashflow). The timing of such construction coupled with the discounting would impact the overall costs and benefits of the rule if the construction activity in any given year deviates significantly from the constant estimates that are informed by the data used for this rulemaking.

The present value of savings in operating cost is the annual savings in operating cost (the difference between Clean Energy Rule compliant building and ASHRAE 90.1-2019), discounted to the present and summed through the analysis period (2025 through 2054). Savings are decreases in operating cost associated with the higher energy efficiency associated with buildings designed to Clean Energy Rule compliant building compared to ASHRAE 90.1-2019. Total annual savings in operating cost are the savings per square foot multiplied by the number of square feet that survive in a particular year, through the lifetime of the buildings constructed in the last year of the analysis period.

DOE also considered the estimated monetary benefits likely to result from the reduced emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), nitrogen oxides (NO_X), and sulfur dioxide (SO_2) that are expected to result from this rule (see chapter 2 of this TSD). On March 16, 2022, the Fifth Circuit Court of Appeals (No. 22-30087) granted the Federal government's emergency motion for stay pending appeal of the February 11, 2022, preliminary injunction issued in Louisiana v. Biden, No. 21-cv-1074-JDC-KK (W.D. La.). As a result of the Fifth Circuit's order, the preliminary injunction is no longer in effect, pending resolution of the Federal government's appeal of that injunction or a further court order. Among other things, the preliminary injunction enjoined the defendants in that case from "adopting, employing, treating as binding, or relying upon" the interim estimates of the social cost of greenhouse gases—which were issued by the Interagency Working Group on the Social Cost of Greenhouse Gases on February 26, 2021—to monetize the benefits of reducing greenhouse gas emissions. As reflected in this rule, DOE has reverted to its approach prior to the injunction and presents monetized greenhouse gas abatement benefits where appropriate and permissible under law. DOE exercises its own judgment in presenting monetized climate benefits and disbenefits as recommended by applicable Executive Orders and guidance, and DOE would reach the same conclusion presented in this notice in the absence of the social cost of greenhouse gases, including the February 2021 Interim Estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

Table 1.5.1 and Table 1.5.2 summarize the economic benefits and costs and annualized economic benefits and costs, including these monetized climate and health benefits, that are estimated to result from the rule.

Table 1.5.1 Summary of Monetized Economic Benefits and Costs (Million 2022$) (2025-2054)

	Million 2022$
3% discount rate	
Capital Cost Savings of Equipment*	149.2
Climate Benefits**	51.3
Health Benefits***	55.9
Total Benefits†	256.4
Operating Costs††	-204.1
Net Benefits	52.3
7% discount rate	
Capital Cost Savings of Equipment*	91.5
Climate Benefits**	51.3
Health Benefits***	18.4
Total Benefits†	161.1
Operating Costs††	-91.4
Net Benefits	69.7

Note: This table presents the costs and benefits associated with compliant buildings built and operated in 2025–2084. These results include consumer, climate, and health benefits and disbenefits that accrue after 2054 from the buildings constructed or renovated in 2025−2054.
* Capital costs are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.
** Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO_2), methane (SC-CH_4), and nitrous oxide (SC-N_2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.
*** 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. See section Chapter 2 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 3-percent discount rate.
†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

Table 1.5.2 Annualized Monetized Benefits and Costs of Final Regulation Base Scenario using AEO 2023 (million 2022$) (2025-2084)

Category	***million 2022$/year***	
	3% Discount Rate	**7% Discount Rate**
Capital Costs of Equipment Savings*	8.08	8.44
Climate Benefits**	2.77	2.77
Health Benefits***	3.03	1.69

Total Benefits†	13.88	12.91
Operating Costs††	-11.05	-8.43
Net Benefits	2.83	4.48

Note: This table presents the costs and benefits associated with this final rule impacted buildings in 2025−2084. These results include consumer, climate, and health benefits and disbenefits which accrue after 2054 from the buildings constructed in 2025−2054.
* Capital costs of equipment are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.
** Climate benefits are calculated using four different estimates of the SC-GHG (see Chapter 2 of this document). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.
*** 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.
† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate.
†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

1.6 ALTERNATIVE CASE 100 BY 2035

DOE's analysis is sensitive to how emission factors per unit of grid electricity purchased change over time. The no-new-standards case presented in this rulemaking utilizes emission factors obtained through *AEO2023*. This is consistent with the methodology used in other rulemakings (including the efficiency portions for the analysis behind 10 CFR 433 and 435) and representative of an expected or "business as usual" case. However, *AEO2023* does not account for goals or plans to green the grid in an accelerated manner. Such accelerated clean grid scenarios can significantly impact the overall emissions profile of the rule allowing for more climate benefits sooner in the life-cycle of the expected projects.

To demonstrate this rulemaking's sensitivity to purchased electricity emission factor "cleanliness" projections, DOE analyzed an additional case where the future grid emission factors were assumed to follow a "100 percent reduction by 2035" (100 percent by 2035) profile as defined in National Renewable Energy Laboratory's (NREL's) *2022 Standard Scenarios Report: A U.S. Electricity Sector Outlook*[m]. This case represents a change in national electricity generation that assumes national power sector CO_2 emissions reach 100 percent below 2005 levels by 2035. For comparison, the renewable mix from the AEO2023 case starts at 26% for the year 2024 and increases by 4-5% through 2030 at which point reductions continue but at a slower rate of about 1-2% per year, resulting in a 56% renewable grid mix in 2035 (the reduction continues at a slow pace culminating at 62% in the year 2050). The more aggressive 100 percent by 2035 case results in immediate decreases CO_2 equivalent (CO_2e) gas emissions. Results for the 100 percent by 2035 case are presented in Table 1.6.1 and Table 1.6.2.

[m] Commercial sector price projections for the NREL 100 by 2035 case were not available for explicit modeling, so EIA projections were utilized. If the electric prices in these scenarios differ from the EIA AEO projections it would change the financial outlook in that lower electricity costs would improve the overall cost profile and higher electricity costs would lead to increased operating costs and lower the overall cost profile. It should be noted however that energy costs happen over the 30 year + 30 years of operational lifetime, so these costs are subject to discounted cashflow analytics which eases the overall impact and sensitivity to rates.

To estimate climate and health benefits for the 100 percent by 2035 case, emission rates of direct CO_2, CH_4, and N_2O were provided by NREL based on their analysis of anticipated grid production generation mix. For NO_X and SO_2, national average emission rates by generation type from the Emissions & Generation Resource Integrated Database (eGrid) were multiplied by projected annual generation by type to produce projected annual emissions. Projected annual emissions were divided by total projected annual generation to provide emission rates per unit of grid electricity. These rates were then multiplied by energy savings to produce gross emission and monetization impacts. (Monetization methodology is described further in chapter 2 of this TSD.)

Table 1.6.1 Summary of Monetized Economic Benefits and Costs (Million 2022$) (2025-2054 plus 30-Year Lifetime) for 100 Percent by 2035 Emissions Reductions Case

	Million 2022$	
	3% discount rate	**7% discount rate**
Capital Costs of Equipment Savings*	149.2	91.5
Climate Benefits**	94.6	94.6
Health Benefits***	93.9	33.0
Total Benefits†	337.7	219.1
Operating Costs††	-204.1	-91.4
Net Benefits	133.7	127.7

Note: This table presents the costs and benefits associated with compliant buildings built and operated in 2025–2084. These results include consumer, climate, and health benefits and disbenefits that accrue after 2054 from the buildings constructed or renovated in 2025−2054.
* Capital costs are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.
** Climate benefits are calculated using four different estimates of the social cost of carbon (SC-CO_2), methane (SC-CH_4), and nitrous oxide (SC-N_2O) (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). Together these represent the social cost of greenhouse gases (SC-GHG). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.
*** 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. See Chapter 2 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 3-percent discount rate.
†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

Table 1.6.2 Annualized Monetized Benefits and Costs (million 2022$) for 100 Percent by 2035 Emissions Reductions Case

Category	million 2022$/year	
	3% Discount Rate	**7% Discount Rate**
Capital Costs of Equipment Savings*	8.08	8.44
Climate Benefits**	5.12	5.12
Health Benefits***	5.08	3.04
Total Benefits†	18.28	16.60
Operating Costs††	-11.05	-8.43
Net Benefits	7.24	8.17

Note: This table presents the costs and benefits associated with this final rule impacted buildings in 2025−2084. These results include consumer, climate, and health benefits and disbenefits which accrue after 2054 from the buildings constructed in 2025−2054.

* Capital costs of equipment are a savings to consumers due to the base level efficiency electric equipment being less expensive than equivalent gas equipment as well as infrastructure savings from avoided gas line installation and exhaust venting.

** Climate benefits are calculated using four different estimates of the SC-GHG (see Chapter 2 of this document). For presentational purposes of this table, the climate benefits associated with the average SC-GHG at a 3 percent discount rate are shown; however, DOE emphasizes the importance and value of considering the benefits calculated using all four sets of SC-GHG estimates. To monetize the benefits of reducing GHG emissions, this analysis uses the interim estimates presented in the February 2021 SC-GHG TSD.

*** 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.

† Total benefits for both the 3-percent and 7-percent cases are presented using the average SC-GHG with 3-percent discount rate.

†† Negative number indicates an increased cost to building owners, driven primarily by higher relative cost of electricity compared to natural gas.

1.7 ENVIRONMENTAL CONVERSION METHODOLOGY

The emissions analysis for this rule begins by estimating the effect of Federal building standards on power sector emissions and, if present, site combustion emissions of CO_2, NO_X, SO_2, and mercury (Hg). The second component estimates the impacts of potential standards on emissions of two additional greenhouse gases, 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. These upstream activities comprise extraction, processing, and transporting fuels to the site of combustion. The associated emissions are referred to as upstream emissions. Electricity production ultimately used in Federal commercial buildings is assumed to have the same distribution of fuel/energy sources (*e.g.*, coal, nuclear) as overall national electricity production. DOE mapped the existing buildings in the Federal portfolio to eGrid regions and found that this method resulted in a weighted average emissions rate of 3.97% better than the national average number. This was also done for the buildings built in the last 10 years (to match the gross construction volume estimates) and that weighted average was 3.72% better than the national average. In absence of more granular data around future Federal construction location, DOE believes this is a good approximation based on historical data.

The analysis of power sector emissions uses emissions intensity factors intended to represent the marginal impacts of the change in electricity consumption associated with revised efficiency standards. The methodology is based on results published for the *AEO*, including a set of side cases that implement a variety of efficiency-related policies. The methodology is described in the report *Utility Sector Impacts of Reduced Electricity Demand: Updates to Methodology and Results*.[11] The analysis presented herein uses projections from the *AEO2023*.[10] Because the emissions intensity factors are calculated for each end use, a simple average was calculated using the following factors for the end uses estimated to be affected by commercial building energy codes: space heating, space cooling, water heating, lighting, refrigeration, and ventilation. Because the *AEO* only includes projections through 2050, the 2050 factors were used for 2051 and subsequent years for this analysis.

For site combustion of natural gas, the emissions of CO_2 and NO_X are estimated using emissions intensity factors from a publication of the Environmental Protection Agency (EPA).[14] Combustion emissions of CH_4 and N_2O are estimated using emissions intensity factors published by the EPA.[15]

Summary tables of all the emissions factor data used by DOE for rules using *AEO2023* are presented in Table 1.7.1 through Table 1.7.9. Table 1.7.1 provides combustion emissions factors for natural gas, commonly used in buildings. Table 1.7.2 to Table 1.7.7 present the marginal power sector emissions factors as a function of sector and end use for a selected set of years; for this analysis, an average of these factors was used. Table 1.7.8 and Table 1.7.9 provide the upstream emissions factors for all pollutants, for site electricity and natural gas. In all cases, the emissions factors are defined relative to site use of the fuel.

Table 1.7.1 Site Combustion Emissions Factors

Species	Units	Natural Gas
CO_2	kg/mcf	54.7
SO_2	g/mcf	0.273
NO_X	g/mcf	43.6
Hg	g/mcf	0
N_2O	g/mcf	0.103
CH_4	g/mcf	1.032

Table 1.7.2 Power Sector Emissions Factors for CO_2 (Million Short Tons (MMsT)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	0.28	0.14	0.12	0.11	0.10	0.09
Service Hot Water	0.13	0.07	0.06	0.05	0.05	0.04
Cooking	0.07	0.03	0.03	0.03	0.02	0.02

Table 1.7.3 Power Sector Emissions Factors for CH_4 (Million Short Tons (MMst)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	2.38E-05	1.04E-05	9.82E-06	8.55E-06	7.68E-06	6.54E-06
Service Hot Water	1.02E-05	4.45E-06	3.88E-06	3.24E-06	2.84E-06	2.38E-06

Cooking	5.06E-06	2.21E-06	1.94E-06	1.62E-06	1.42E-06	1.20E-06

Table 1.7.4 Sector Emissions Factors for Hg (Short Tons (sT)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	8.43E-04	3.15E-04	2.95E-04	2.44E-04	2.30E-04	2.27E-04
Service Hot Water	3.48E-04	1.27E-04	1.10E-04	8.61E-05	7.85E-05	7.56E-05
Cooking	1.72E-04	6.31E-05	5.47E-05	4.30E-05	3.93E-05	3.79E-05

Table 1.7.5 Power Sector Emissions Factors for N_2O (Million Short Tons (MMsT)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	4.45E-06	3.90E-06	3.34E-06	2.95E-06	2.67E-06	2.51E-06
Service Hot Water	5.72E-06	5.02E-06	4.31E-06	3.81E-06	3.44E-06	3.24E-06
Cooking	4.43E-06	3.88E-06	3.32E-06	2.94E-06	2.65E-06	2.50E-06

Table 1.7.6 Power Sector Emissions Factors for NO_X (Million Short Tons (MMsT)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	1.48E-04	6.58E-05	6.06E-05	5.73E-05	5.10E-05	3.60E-05
Service Hot Water	6.80E-05	3.10E-05	2.65E-05	2.43E-05	2.11E-05	1.49E-05
Cooking	3.37E-05	1.54E-05	1.32E-05	1.21E-05	1.06E-05	7.47E-06

Table 1.7.7 Sector Emissions Factors for SO_2 (Million Short Tons (MMsT)/TWh of Site Electricity Use)

Commercial Sector	2025	2030	2035	2040	2045	2050
Space Heating	8.90E-05	4.45E-05	4.35E-05	3.63E-05	3.32E-05	3.19E-05
Service Hot Water	3.72E-05	1.83E-05	1.65E-05	1.31E-05	1.15E-05	1.08E-05
Cooking	1.85E-05	9.10E-06	8.23E-06	6.54E-06	5.76E-06	5.41E-06

Table 1.7.8 Electricity Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO2	kg/MWh	27.7	19.1	16.6	16.3	22.7	22.7
SO2	g/MWh	2.5	1.3	1.2	1.0	1.4	1.4
NOx	g/MWh	373	266	231	229	312	312
Hg	g/MWh	0.00001	0.00000	0.00000	0.00000	0.00000	0.00000
N2O	g/MWh	0.159	0.088	0.081	0.070	0.102	0.102
CH4	g/MWh	2172	1555	1329	1350	1958	1958

Table 1.7.9 Natural Gas Upstream Emissions Factors

Species	Unit	2025	2030	2035	2040	2045	2050+
CO2	kg/mcf	7.6	7.4	7.5	7.5	7.6	7.6
SO2	g/mcf	0.033	0.032	0.032	0.032	0.033	0.033
NOx	g/mcf	109	105	108	107	109	109
Hg	g/mcf	0	0	0	0	0	0
N2O	g/mcf	0.01197	0.01162	0.01186	0.01184	0.01197	0.01199
CH4	g/mcf	702	699	704	704	702	706

The emissions intensity factors are expressed in terms of physical units of site energy savings. Total emissions reductions are estimated by multiplying the emissions intensity factor by the energy savings. DOE estimates that the standards would result in cumulative emission (30 years of construction plus lifetime) impacts of an decrease of 0.9 million metric tons (Mt) of CO_2, an increase of 0.4 thousand tons of SO_2, a savings of 3.3 thousand tons of NO_X, a savings of 15.8 thousand tons of CH_4, an increase of 0.009 thousand tons of N_2O, and an increase of 0.003 tons of Hg.

1.8 EMISSIONS IMPACT PROGRESSION

The electric grid emission factors utilized as predicted by *AEO2023* improve gradually over time. Despite an initial net negative CO_2e gas emission total, improving emissions rates from purchased electricity over time results in yearly CO_2e savings starting in the year 2028, with net cumulative savings starting in the year 2029. See Figure 1.8.1 for the yearly and cumulative net CO_2e emissions profile of the impact of the rulemaking utilizing *AEO2023* emission factor projections.

Over time, the emissions savings of reducing and eliminating Scope 1 fossil fuel usage (primarily in the form of methane and direct CO_2 emissions, whose rates of emission per unit of energy consumed remain constant over time per the previous tables) by shifting to an ever-improving electric grid result in positive CO_{2e} emissions savings. Cumulative emission reductions for 30 years of construction (2025 through 2054) and operation under the reduced on-site fossil fuel usage associated with the action depend on both the building fuel mix and the energy generation mix used in future years, as well as a forecast of new construction.

The emissions factors and energy savings used in the base calculations for this environmental assessment represent the estimated current building fuel use (by building type) and the *AEO2023* Reference case energy generation mix and projections; therefore, they do not account for trends, such as electrification within buildings or additional (unfunded or uncommitted) decarbonization of the electrical grid. Cumulative emission impacts for 30 years of construction and operation for Federal buildings built during the analysis period (2025 through 2054) were estimated to be an decrease of 851,857.54 metric tons of CO_2, a savings of 15,785.41 tons of CH_4, and an increase of 8.72 tons of N_2O (accounting for the total “Greenhouse Gas Impacts” as presented in the rule); along with an increase of 399.84 tons of SO_2 and a savings of 3,346.47 tons of NO_X (accounting for the total “Other Emission Impacts” as presented in the rule).[n] To estimate the overall significance of these emissions the EPA's Greenhouse Gas Equivalencies Calculator was utilized to combine the direct CO_2, CH_4, N_2O into a single equivalency metric CO_2e.[o] Utilizing the CO_2e metric results in a total savings of 1,291,538 metric tons of CO_2e.

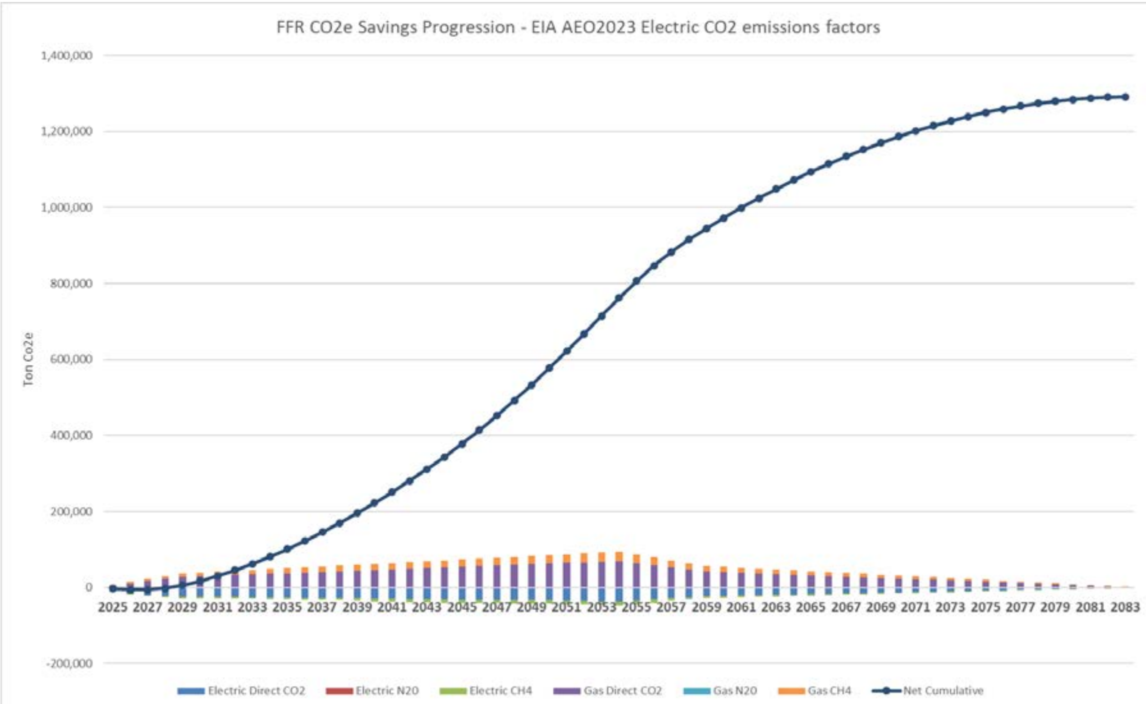

Figure 1.8.1. CO_2e Yearly Emissions Profile for Projects Affected by the Clean Energy Rule using Standard EIA 2023 Electric Grid Emissions Factor Progression Over Time (Note that CO_2e savings is presented as a positive number)

It should be noted that *AEO2023* is a conservative case representing "business as usual" or a lower bound for estimating the future "greenness" of the grid. Other projections such as the *AEO* Corporate Goal Case or cases from NREL's 2021 *Standard Scenarios Report: A U.S. Electricity Sector Outlook* show that accelerated adoption of no and low emitting generation sources can significantly improve the outlook of emissions factors for future purchases of electricity by orders of magnitude thus improving the timeframe to and cumulative amplitude of CO_2e savings.

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[n] Actual reductions would depend on the level of energy efficiency that is LCC effective for each new building design. For example, under the no action alternative, agencies are required to design all new Federal commercial and multifamily high-rise residential buildings at 30 percent more efficient than ASHRAE Standard 90.1-2013, if LCC effective. Under the action, agencies would be required to design buildings that are 30 percent more efficient than ASHRAE Standard 90.1-2019, if LCC effective. A comparison of the no-action alternative to the adopted action yields an estimated first year emissions reduction for CO_2 of 9,612 metric tons. The values shown in the text correspond to buildings that just meet ASHRAE 90.1-2013 and ASHRAE 90.1-2019. In the draft EA, values for NO_X, CH_4, and N_2O were presented in metric tons; values here are presented in short tons, in accordance with conventional unit reporting.

[o] The EPA GHG equivalency Calculator at https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator#results utilizes methodology for CO_2 emissions equivalence at https://www.epa.gov/ghgemissions/overview-greenhouse-gases#carbon-dioxide.

Specifically, the 100 percent by 2035 mid case presented by NREL (where national power sector CO_2 emissions decline to 100 percent below 2005) results in yearly CO_2e savings starting in first year of implementation of the rule and accumulating throughout the 30 year + 30 year lifetime analysis period. In this case the long-run marginal CO_2, CH_4 and N_20 emission rates for the 2021 standard scenario mid-case 100 percent by 2035 sourced from the NREL Cambium database were utilized for presentation, monetization, and conversion CO_2e emissions for presentation in Figure 1.8.2. Utilizing the CO_2e metric results in a total savings of 2,494,301 metric tons of CO_2e.

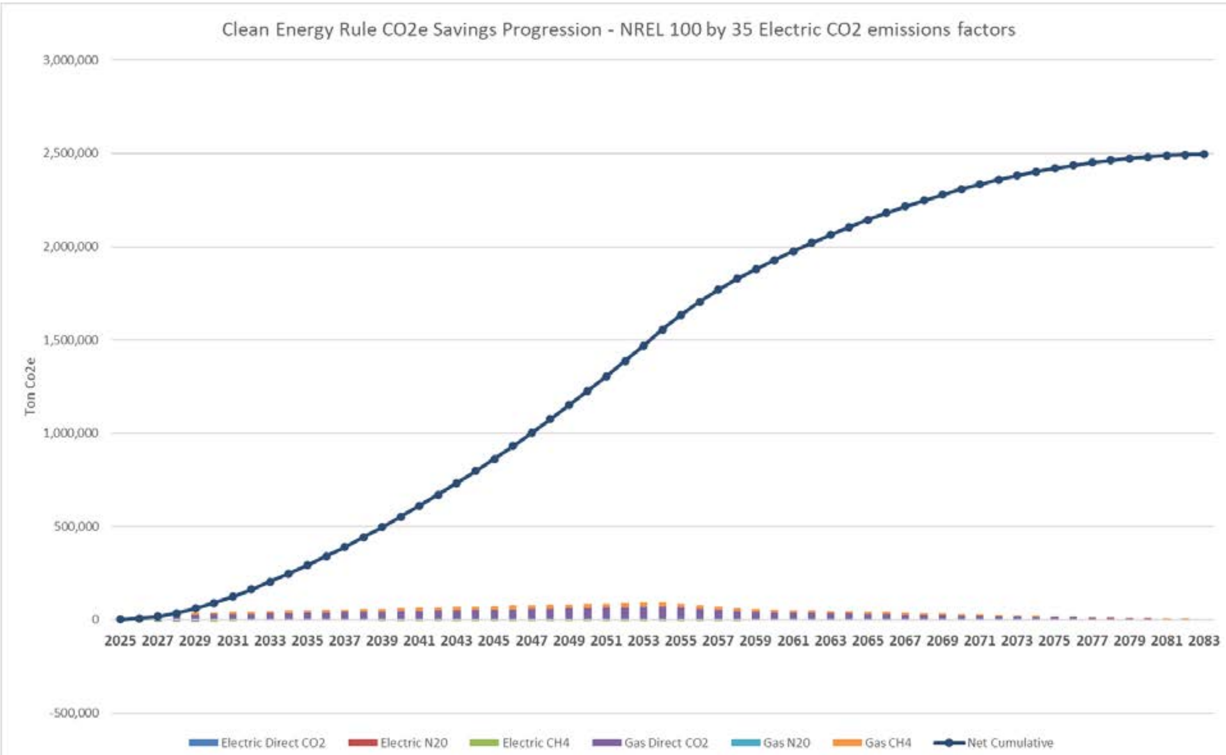

Figure 1.8.2 CO_2e Yearly Emissions Profile for Projects Affected by the Clean Energy Rule using NREL 100 Percent by 2035 Derived Electric Grid Emissions Factor Progression Over Time (Note that CO_2e savings is presented as a positive number)

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CHAPTER 2. MONETIZED BENEFITS METHODOLOGY

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER 2. MONETIZED BENEFITS METHODOLOGY

As part of its assessment, the U.S. Department of Energy (DOE) considered the estimated the 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 this rule. This chapter summarizes the basis for the benefit-per-ton values used for each of these emissions.

2.1 MONETIZING AVOIDED GREENHOUSE GAS EMISSIONS

DOE estimates the monetized benefits of the reductions in greenhouse gas (GHG) 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 pollutants in a given year, or the benefit of avoiding that increase. These estimates are intended to include (but are not limited to) climate-change-related changes in net agricultural productivity, human health, property damages from increased flood risk, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. DOE exercises its own judgment in presenting monetized climate benefits as recommended by applicable Executive Orders and guidance, and DOE would reach the same conclusion presented in this notice in the absence of the SC-GHGs, including the February 2021 interim estimates presented by the Interagency Working Group on the Social Cost of Greenhouse Gases.

DOE estimated the global social benefits of CO_2, CH_4, and N_2O reductions using SC-GHG values that were based on the interim 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).[1] The SC-GHG is the monetary value of the net harm to society associated with a marginal increase in emissions in a given year, or the benefit of avoiding that increase. In principle, SC-GHGs includes the value of all climate change impacts, including (but not limited to) changes in net agricultural productivity, human health effects, property damage from increased flood risk and natural disasters, disruption of energy systems, risk of conflict, environmental migration, and the value of ecosystem services. The SC-GHGs therefore, reflects the societal value of reducing emissions of the gas in question by one metric ton. The SC-GHGs is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect CO_2, N_2O and CH_4 emissions. As a member of the IWG involved in the development of the February 2021 SC-GHG TSD, DOE agrees that the interim SC-GHG estimates represent the most appropriate estimate of the SC-GHG until revised estimates have been developed reflecting the latest peer-reviewed science. The SC-GHGs estimates presented here were developed over many years, using a transparent process, peer-reviewed methodologies, the best science available at the time of that process, and with input from the public. Specifically, in 2009, an IWG that included the DOE and other executive branch agencies and offices was established to ensure that agencies had access to the best information when quantifying the benefits of reducing CO_2 emissions in the benefit-cost analyses. The IWG published SC-CO_2 estimates in 2010 that were developed from an ensemble of three widely cited integrated assessment models (IAMs) that estimate climate damages using highly aggregated representations of climate processes and the global economy combined into a single modeling framework. The three IAMs were run using a common set of input assumptions in each model for future population, economic, and CO_2 emissions growth, as well as equilibrium climate sensitivity (ECS)—a measure of the globally averaged temperature response to increased atmospheric CO_2 concentrations. These estimates were updated in 2013 based on new versions of each IAM. In August 2016, the IWG published estimates of the social cost of methane (SC-CH_4) and social cost of nitrous oxide (SC-N_2O) using methodologies that are consistent with the methodology underlying the SC-CO_2 estimates. The modeling approach that extends the IWG SC-CO_2 methodology to non-CO_2 GHGs has undergone multiple stages of peer review. The SC-CH_4 and SC-N_2O estimates were developed by Marten et al. (2015) and underwent a standard double-blind peer review process prior to journal publication.[2]

In 2015, as part of the response to public comments received to a 2013 solicitation for comments on the SC-CO_2 estimates, the IWG announced a National Academies of Sciences, Engineering, and Medicine review of the SC-CO_2 estimates to offer advice on how to approach future updates to ensure that the estimates continue to reflect the best available science and methodologies. In January 2017, the National Academies released their final report, *Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide*, and recommended specific criteria for future updates to the SC-CO_2 estimates, a modeling framework to satisfy the specified criteria, and both near-term updates and longer-term research needs pertaining to various components of the estimation process.[3] Shortly thereafter, in March 2017, President Trump issued EO 13783, which disbanded the IWG, withdrew the previous TSDs, and directed agencies to ensure SC-CO_2 estimates used in regulatory analyses are consistent with the guidance contained in Office of Management and Budget's (OMB's) 2003 Circular A-4,[a] "including with respect to the consideration of domestic versus international impacts and the consideration of appropriate discount rates" (EO 13783, Section 5(c)). Benefit-cost analyses following EO 13783 used SC-GHG estimates that attempted to focus on the U.S.-specific share of climate change damages as estimated by the models (and so did not reflect many pathways by which impacts outside the United States affect the welfare of U.S. citizens and residents) and were calculated using two default discount rates recommended by Circular A-4, 3 percent and 7 percent. All other methodological decisions and model versions used in SC-GHG calculations remained the same as those used by the IWG in 2010 and 2013, respectively.

On January 20, 2021, President Biden issued EO 13990, which re-established the IWG and directed it to develop updated estimates of the social cost of carbon and other GHGs that reflect the best available science and the recommendations of the National Academies. The IWG was tasked with first reviewing the SC-GHG estimates currently used in Federal analyses and publishing interim estimates within 30 days of the EO that reflect the full impact of GHG emissions, including by taking global damages into account. As noted above, DOE participated in the IWG but has also independently evaluated the interim SC-GHG estimates published in the February 2021 TSD and determined they are appropriate to use here to estimate the climate benefits and disbenefits associated with the rule. DOE and other agencies intend to undertake a fuller update of the SC-GHG estimates that takes into consideration the advice of the National Academies (2017) and other recent scientific literature.

[a] Note all references in this document to Circular A-4 refer to the 2003 version, and not the revised 2023 version.

The February 2021 TSD provides a complete discussion of the IWG's initial review conducted under EO 13990. In particular, the IWG found that the SC-GHG estimates used under EO 13783 fail to reflect the full impact of GHG emissions in multiple ways. First, the IWG found that the SC-GHG estimates used under EO 13783 fail to fully capture many climate impacts that affect the welfare of U.S. citizens and residents, and those impacts are better reflected by global measures of the SC-GHG. Examples of effects omitted from the EO 13783 estimates include direct effects on U.S. citizens, assets, and investments located abroad; supply chains; U.S. military assets and interests abroad; tourism; and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concerns. In addition, assessing the benefits of U.S. GHG mitigation activities requires consideration of how those actions may affect mitigation activities by other countries, as those international mitigation actions will provide a benefit to U.S. citizens and residents by mitigating climate impacts that affect U.S. citizens and residents. A wide range of scientific and economic experts have emphasized the issue of reciprocity as support for considering global damages of GHG emissions. If the United States does not consider impacts on other countries, it is difficult to convince other countries to consider the impacts of their emissions on the United States. The only way to achieve an efficient allocation of resources for emissions reduction on a global basis—and so benefit the U.S. and its citizens—is for all countries to base their policies on global estimates of damages. As a member of the IWG involved in the development of the February 2021 TSD, DOE agrees with this assessment; therefore, in this rule DOE centers attention on a global measure of SC-GHG. This approach is the same as that taken in DOE regulatory analyses from 2012 through 2016. A robust estimate of climate damages to U.S. citizens and residents that accounts for the myriad of ways that global climate change reduces the net welfare of U.S. populations does not currently exist in the literature. As explained in the February 2021 TSD, existing estimates are both incomplete and an underestimate of total damages that accrue to the citizens and residents of the United States because they do not fully capture the regional interactions and spillovers discussed previously, nor do they include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature. As noted in the February 2021 TSD, the IWG will continue to review developments in the literature, including more robust methodologies for estimating a U.S.-specific SC-GHG value, and explore ways to better inform the public of the full range of carbon impacts. As a member of the IWG, DOE will continue to follow developments in the literature pertaining to this issue.

Second, the IWG found that the use of the social rate of return on capital (7 percent under current OMB Circular A-4 guidance) to discount the future benefits of reducing GHG emissions inappropriately underestimates the impacts of climate change for the purposes of estimating the SC-GHG. Consistent with the findings of the National Academies[2] and the economic literature, the IWG continued to conclude that the consumption rate of interest is the theoretically appropriate discount rate in an intergenerational context (IWG 2010, 2013, 2016a, 2016b), and recommended that discount rate uncertainty and relevant aspects of intergenerational ethical considerations be accounted for in selecting future discount rates.[4,5,6,7] Furthermore, the damage estimates developed for use in the SC-GHG are estimated in consumption-equivalent terms, and so an application of OMB Circular A-4's guidance for regulatory analysis would then use the consumption discount rate to calculate the SC-GHG. DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue. DOE also notes that while OMB Circular A-4, as published in 2003, recommends using 3-percent and 7-percent discount rates as "default" values, Circular A-4 also reminds agencies that "different regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues and the sensitivity of the benefit and cost estimates to the key assumptions." On discounting, Circular A-4 recognizes that "special ethical considerations arise when comparing benefits and costs across generations," and Circular A-4 acknowledges that analyses may appropriately "discount future costs and consumption benefits…at a lower rate than for intragenerational analysis." In the 2015 response to comments on the Social Cost of Carbon for Regulatory Impact Analysis, OMB, DOE, and the other IWG members recognized that "Circular A-4 is a living document" and "the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A-4 itself." Thus, DOE concludes that a 7-percent discount rate is not appropriate to apply to value the SC-GHGs in the analysis presented in this analysis. In this analysis, to calculate the present and annualized values of climate benefits, DOE uses the same discount rate as the rate used to discount the value of damages from future GHG emissions, for internal consistency. That approach to discounting follows the same approach that the February 2021 TSD recommends "to ensure internal consistency—*i.e.*, future damages from climate change using the SC-GHG at 2.5 percent should be discounted to the base year of the analysis using the same 2.5-percent rate." DOE has also consulted the National Academies' 2017 recommendations on how SC-GHG estimates can "be combined in regulatory impact analyses with other cost and benefits estimates that may use different discount rates." The National Academies reviewed "several options," including "presenting all discount rate combinations of other costs and benefits with [SC-GHG] estimates."

As a member of the IWG involved in the development of the February 2021 TSD, DOE agrees with this assessment and will continue to follow developments in the literature pertaining to this issue.

While the IWG works to assess how best to incorporate the latest peer-reviewed science to develop an updated set of SC-GHG estimates, it recommended the interim use of the most recent SC-GHG estimates developed by the IWG prior to the group being disbanded in 2017. The estimates rely on the same models and harmonized inputs and are calculated using a range of discount rates. As explained in the February 2021 TSD, the IWG has recommended that agencies revert to the same set of four values drawn from the SC-GHG distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment. For each discount rate, the IWG combined the distributions across models and socioeconomic emissions scenarios (applying equal weight to each) and then selected a set of four values recommended for use in benefit-cost analyses—an average value resulting from the model runs for each of three discount rates (2.5 percent, 3 percent, and 5 percent), plus a fourth value, selected as the 95th percentile of estimates based on a 3-percent discount rate. The fourth value was included to provide information on potentially higher-than-expected economic impacts from climate change. As explained in the February 2021 TSD, and DOE agrees, this update reflects the immediate need to have an operational SC-GHG for use in regulatory benefit-cost analyses and other applications that was developed using a transparent process, peer-reviewed methodologies, and the science available at the time of that process. Those estimates were subject to public comment in the context of dozens of proposed rulemakings as well as in a dedicated public comment period in 2013.

There are a number of limitations and uncertainties associated with the SC-GHG estimates. First, the current scientific and economic understanding of discounting approaches suggests discount rates appropriate for intergenerational analysis in the context of climate change are likely to be less than 3 percent, near 2 percent or lower.[1] Second, the IAMs used to produce these interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" (*i.e.*, the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic, both market and nonmarket, damages lag behind the most recent research). For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the IAMs, their incomplete treatment of adaptation and technological change, the incomplete way in which interregional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Likewise, the socioeconomic and emissions scenarios used as inputs to the models do not reflect new information from the last decade of scenario generation or the full range of projections. The modeling limitations do not all work in the same direction in terms of their influence on the SC-CO_2 estimates. However, as discussed in the February 2021 TSD, the IWG has recommended that, taken together, the limitations suggest that the interim SC-GHG estimates used in this rule likely underestimate the damages from GHG emissions. DOE concurs with this assessment.

DOE's derivations of the SC-CO_2, SC-N_2O, and SC-CH_4 values used for this rule are discussed in the following sections.

2.1.1 Social Cost of Carbon Dioxide

The SC-CO_2 values used for DOE's analysis were generated using the values presented in the 2021 update from the IWG, which end in 2050, and values after 2050 based on modeling conducted by EPA using the same methods, assumptions, and parameters as were used in developing the 2020-2050 estimates published by the IWG. [b] Table 2.1.1 shows the four sets of annual SC-CO_2 estimates from 2020 to 2070.[8] DOE expects additional climate impacts to accrue from CO_2 emissions changes post 2070, but a lack of available SC-CO_2 estimates for emissions years beyond 2070 prevents DOE from monetizing these additional benefits in this analysis. The case labeled "95th percentile" refers to values in the 95th percentile of simulations. For purposes of capturing the uncertainties involved in regulatory impact analysis, the IWG emphasizes the importance of including all four sets of SC-CO_2 values.

Table 2.1.1 Annual SC-CO_2 Value Based on 2021 Interagency Update and 2021 EPA Analysis, 2020–2070 (2020$ per metric ton)*

Year	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
2020	14	51	76	151

[b] See "Revised 2023 and Later Model Year Light-Duty Vehicle GHG Emissions Standards: Regulatory Impact Analysis," published by EPA in December 2021. Available at: www.epa.gov/system/files/documents/2021-12/420r21028.pdf.

Year	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
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
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

Year	Discount Rate and Statistic			
	5%	3%	2.5%	3%
	Average	Average	Average	95th Percentile
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

* For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

DOE multiplied the CO_2 emissions reduction estimated for each year by the SC-CO_2 value for that year in each of the four cases. DOE adjusted the values to 2022$ using the implicit price deflator for gross domestic product ("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 four cases using the specific discount rate that had been used to obtain the SC-CO_2 values in each case.

2.1.2 Social Cost of Methane and Nitrous Oxide

The SC-CH_4 and SC-N_2O values used for the present analysis were generated using the values presented in the 2021 update from the IWG.[1] Table 2.1.2 shows the four sets of annual SC-CH_4 and SC-N_2O estimates from the latest interagency update from 2020 to 2070. DOE expects additional climate impacts to accrue from CH_4 and N_2O emissions changes post 2070, but a lack of available SC-CH_4 and SC-N_2O estimates for years beyond 2070 prevents DOE from monetizing these additional impacts in this analysis. For purposes of capturing the uncertainties involved in regulatory impact analysis, the IWG emphasizes the importance of including all four sets of SC-CH_4 and SC-N_2O values.

Table 2.1.2. Annual SC-CH_4 and SC-N_2O Values Based on 2021 Interagency Update and 2021 EPA Analysis, 2020–2070 (2020$ per Metric Ton)*

Year	SC-CH_4				SC-N_2O			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5%	3%	2.5%	3%	5%	3%	2.5 %	3%
	Average	Average	Average	95th percentile	Average	Average	Average	95th percentile
2020	660	1500	1900	3900	5800	18000	27000	48000
2021	690	1500	2000	4000	6000	19000	28000	49000
2022	720	1600	2100	4100	6200	19000	28000	50000
2023	750	1600	2100	4300	6400	20000	29000	52000
2024	770	1700	2200	4400	6600	20000	29000	53000
2025	800	1700	2200	4500	6800	21000	30000	54000
2026	830	1800	2300	4700	7000	21000	30000	55000
2027	850	1800	2300	4800	7200	21000	31000	57000
2028	880	1900	2400	4900	7400	22000	31000	58000
2029	910	1900	2400	5000	7600	22000	32000	59000
2030	940	1900	2500	5200	7800	23000	33000	60000
2031	970	2000	2600	5300	8000	23000	33000	61000

Year	SC-CH_4				SC-N_2O			
	Discount Rate and Statistic				Discount Rate and Statistic			
	5%	3%	2.5%	3%	5%	3%	2.5 %	3%
	Average	Average	Average	95th percentile	Average	Average	Average	95th percentile
2032	1000	2100	2600	5500	8300	24000	34000	63000
2033	1000	2100	2700	5600	8500	24000	34000	64000
2034	1100	2200	2800	5800	8800	25000	35000	66000
2035	1100	2200	2800	5900	9000	25000	36000	67000
2036	1100	2300	2900	6100	9300	26000	36000	68000
2037	1200	2300	2900	6200	9500	26000	37000	70000
2038	1200	2400	3000	6400	9700	27000	37000	71000
2039	1200	2400	3100	6600	10000	27000	38000	72000
2040	1300	2500	3100	6700	10000	28000	39000	74000
2041	1300	2600	3200	6800	11000	28000	39000	75000
2042	1400	2600	3300	7000	11000	29000	40000	77000
2043	1400	2700	3300	7100	11000	29000	41000	78000
2044	1400	2700	3400	7300	11000	30000	41000	79000
2045	1500	2800	3500	7400	12000	30000	42000	81000
2046	1500	2800	3500	7600	12000	31000	43000	82000
2047	1500	2900	3600	7700	12000	31000	43000	84000
2048	1600	2900	3600	7900	13000	32000	44000	85000
2049	1600	3000	3700	8000	13000	32000	44000	86000
2050	1700	3100	3800	8100	13000	33000	45000	88000
2051	1700	3100	3800	8200	13000	33000	46000	89000
2052	1700	3100	3800	8200	14000	34000	46000	90000
2053	1700	3200	3900	8300	14000	34000	47000	91000
2054	1700	3200	3900	8300	14000	35000	48000	93000
2055	1800	3200	3900	8300	15000	36000	48000	94000
2056	1800	3300	4000	8400	15000	36000	49000	95000
2057	1800	3300	4000	8400	15000	37000	50000	97000
2058	1800	3300	4100	8500	16000	37000	50000	98000
2059	1900	3400	4100	8500	16000	38000	51000	99000
2060	1900	3400	4100	8500	16000	38000	52000	100000
2061	2000	3500	4300	9100	17000	39000	52000	100000
2062	2100	3700	4500	9600	18000	40000	53000	110000
2063	2300	3900	4600	10000	18000	41000	54000	110000
2064	2400	4000	4800	11000	19000	42000	55000	110000
2065	2500	4200	5000	11000	20000	43000	56000	120000
2066	2600	4300	5100	12000	20000	44000	57000	120000
2067	2800	4500	5300	12000	21000	44000	58000	120000
2068	2900	4700	5500	13000	22000	45000	59000	120000
2069	3000	4800	5700	13000	22000	46000	60000	130000
2070	3100	5000	5900	14000	23000	47000	61000	130000

* For 2020-2050, there are slight differences from the IWG report in a few cases that are likely due to the GDP deflator used.

DOE multiplied the net changes in CH_4 and N_2O emissions estimated for each year by the SC-CH_4 and SC-N_2O estimates for that year in each of the cases. 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.

2.2 SENSITIVITY ANALYSIS USING UPDATED 2023 SC-GHG ESTIMATES

In 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. These estimates incorporate recent research addressing recommendations of the National Academies (2017), responses to public comments on an earlier sensitivity analysis using draft SC-GHG estimates, and comments from a 2023 external peer review of the accompanying technical report.

The full set of annual values is presented in Appendix 2A of the final rule TSD. Although DOE continues to review EPA's estimates, for this rulemaking, DOE used these updated SC-GHG values to conduct a sensitivity analysis of the value of GHG emissions reductions associated with this rule. This sensitivity analysis provides an expanded range of potential climate benefits associated. The final year of the 2023 SC-GHG estimates is 2080; therefore, DOE did not monetize the climate benefits of GHG emissions reductions occurring after 2080.

The overall climate benefits are larger using when using the higher, updated 2023 SC-GHG estimates, compared to the climate benefits using the older IWG SC-GHG estimates. The results of the sensitivity analysis are presented in appendix 2A of the final rule TSD.

2.3 VALUATION OF OTHER EMISSIONS REDUCTIONS

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. DOE estimated monetized values of NO_x and SO_2 emissions reductions and increases from electricity generation using the latest benefit-per-ton estimates for that sector from the EPA's Benefits Mapping and Analysis Program.[c] 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.[d]

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.[e] Therefore, DOE only applied a corresponding benefit-per-ton value to half of the estimated avoided NOx emissions from potential standards.[f]

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[c] U.S. Environmental Protection Agency. September 18, 2023. *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

[d] 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.

[e] https://www.epa.gov/power-sector/progress-report-emissions-reductions

[f] For the purposes of this analysis, DOE assumes that NOx emissions associated with electricity savings from new building construction and renovation are spread evenly over the year.

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. 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.

The 2023 EPA TSD does not have a category that would be appropriate to represent houses as an emissions source. To monetize the value of these emissions reductions, DOE used benefit-per-ton estimates from the Benefits Mapping and Analysis Program's 2018 "Technical Support Document Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors."[8] Although none of the sectors refers specifically to residential and commercial buildings, the sector called "Area sources" would be a reasonable proxy for residential and commercial buildings. "Area sources" represents all emission sources for which states do not have exact (point) locations in their emissions inventories. Because exact locations would tend to be associated with larger sources, "area sources" would be fairly representative of small dispersed sources like homes and businesses.

The EPA document provides high and low estimates for 2025 and 2030 at 3 and 7 percent discount rates (see table below). DOE converted the values to 2022$, and interpolated and extrapolated values in a similar manner as described above.

Table 2.3.1. Summary of the Total Dollar Value per Ton of Directly Emitted $PM_{2.5}$ Precursor Reduced from Area Sources (2015$)

Year of Emission	Low		High	
	3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
	NO_X			
2025	9,700	8,800	22,000	20,000
2030	11,000	9,500	24,000	21,000
	SO_2			
2025	61,000	55,000	140,000	120,000
2030	67,000	60,000	150,000	140,000

2.4 RESULTS

Table 2.4.1 presents the present value of monetized climate impacts of changes in CO_2, CH_4, and N_2O emissions. Table 2.4.2 through Table 2.4.4 present the present value of monetized health benefits of changes in NO_X and SO_2 emissions.

Table 2.4.1. Estimated Present Social Value of Monetized Climate Benefits from Changes in Emissions for GHGs for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime

GHG	5-Percent Discount Rate, Average	3-Percent Discount Rate, Average	2.5-Percent Discount Rate, Average	3-Percent Discount Rate, 95th Percentile
million 2022$				
CO_2	6.98	31.56	50.06	95.74
CH_4	6.50	19.82	27.82	52.52
N_2O	-0.03	-0.13	-0.20	-0.34

GHG	5-Percent Discount Rate, Average	3-Percent Discount Rate, Average	2.5-Percent Discount Rate, Average	3-Percent Discount Rate, 95th Percentile
	million 2022$			

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5-, 3-, and 2.5-percent) is used to calculate the present value of SC-GHGs for internal consistency. Climate benefits and disbenefits associated with GHG emissions changes occur over 2025–2070. DOE expects additional climate impacts to accrue from GHG emissions changes post 2070, but a lack of available SC-CO_2, SC-CH_4, and SC-N_2O estimates for years beyond 2070 prevents DOE from monetizing these additional impacts in this analysis.

Table 2.4.2 Estimated Present Social Value of Monetized Health Benefits from Changes in NO_X and SO_2 Emissions for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime

	3-Percent Discount Rate (Low)	7-Percent Discount Rate (Low)	3-Percent Discount Rate (High)	7-Percent Discount Rate (High)
	million 2022$			
NO_X	81.19	28.80	99.54	35.81
SO_2	-25.27	-10.45	-50.61	-21.10

Table 2.4.3 presents the monetized climate impacts of changes in CO_2, CH_4, and N_2O emissions for 100 percent by 2035 (100 by 35) emissions reductions case. Table 2.4.4 presents the monetized climate impacts of changes in NO_X and SO_2 emissions for 100 by 35 emissions reductions case.

Table 2.4.3 Estimated Present Social Value Monetized Climate Benefits from Changes in Emissions for GHGs for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime for 100 Percent by 2035 Emissions Reductions Case

GHG	5-Percent Discount Rate, Average	3-Percent Discount Rate, Average	2.5-Percent Discount Rate, Average	3-Percent Discount Rate, 95th Percentile
	million 2022$			
CO_2	16.93	74.66	117.67	226.55
CH_4	6.54	19.93	27.98	52.82
N_2O	0.01	0.05	0.07	0.12

Notes: The present value of reduced GHG emissions is calculated differently than other benefits. The same discount rate used to discount the value of damages from future emissions (SC-GHGs at 5-, 3-, 2.5-percent) is used to calculate the present value of SC-GHGs for internal consistency. Climate benefits and disbenefits associated with GHG emissions changes occur over 2025–2070. DOE expects additional climate impacts to accrue from GHG emissions changes post 2070, but a lack of available SC-CO_2, SC-CH_4, and SC-N_2O estimates for years beyond 2070 prevents DOE from monetizing these additional impacts in this analysis.

Table 2.4.4 Estimated Present Social Value Monetized Health Benefits from Changes in NO_X and SO2 Emissions for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime for 100 Percent by 2035 Emissions Reductions Case

	3-Percent Discount Rate (Low)	7-Percent Discount Rate (Low)	3-Percent Discount Rate (High)	7-Percent Discount Rate (High)
	million 2022$			
NO_X	103.6	37.8	124.1	45.8
SO_2	-9.6	-4.9	-19.5	-10.0

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APPENDIX 2A. SENSITIVITY ANALYSIS WITH UPDATED SOCIAL COST OF GREENHOUSE GAS VALUES

TABLE OF CONTENTS

LIST OF TABLES

APPENDIX 2A. SENSITIVITY ANALYSIS WITH UPDATED SOCIAL COST OF GREENHOUSE GAS VALUES

2A.1 INTRODUCTION

In December 2023, the U.S. EPA issued a report that presents new estimates of the social cost of carbon (SC-CO_2), social cost of methane (SC-CH_4), and social cost of nitrous oxide (SC-N_2O), collectively referred to as the "social cost of greenhouse gases" (SC-GHG).[a][b] These estimates 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.[c] The SC-GHG reflects the societal net benefit of reducing emissions of the GHG by a metric ton.

DOE has used these new SC-GHG values to conduct a sensitivity analysis of the value of GHG emissions reductions associated with new federal building construction and major renovation. Due to a lack of available SC-GHG estimates for emissions years beyond 2080, DOE did not monetize the climate benefits of GHG emissions reductions occurring after 2080 using these new estimates.

The following section presents the new SC-GHG estimates, and the final section presents the results of the sensitivity analysis using these values.

2A.2 NEW ESTIMATES OF VALUES FOR SOCIAL COST OF GREENHOUSE GASES

The tables in this section present EPA's new estimates of the SC-CO_2, SC-CH_4, and SC-N_2O. For detailed discussion of the development of these values, see the EPA report cited above. The EPA estimates are in 2020$. DOE converted these to 2022$ using the GDP deflator.

Table 2A.1 Annual Unrounded SC-CO_2 Values Based on 2023 EPA report, 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

[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] U.S. Environmental Protection Agency. *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*. November 2023. Available at: https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf.

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Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
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
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

Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
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 2A.2 Annual Unrounded SC-CH_4 Values Based on 2023 EPA report, 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

Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
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
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

Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
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
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 2A.3 Annual Unrounded SC-N_2O Values Based on 2023 EPA report, 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

Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
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
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

Near-Term Ramsey Discount Rate			
Emissions Year	**2.5%**	**2.0%**	**1.5%**
2080	94,951	130,050	183,602

2A.3 SENSITIVITY ANALYSIS RESULTS

Table 2A.4 and Table 2A.5 present the results of an analysis of the monetized value of GHG emissions reductions associated clean energy construction impacts that use the 2023 EPA report new SC-GHG estimates.

Table 2A.4 Estimated Present Social Value of Monetized Climate Benefits and Disbenefits based on 2023 EPA report for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime

GHG	Near-Term Ramsey Discount Rate		
	2.5%	**2.0%**	**1.5%**
	million 2022$		
CO_2	93	162	293
CH_4	27	37	54
N_2O	(0.3)	(0.5)	(0.8)

Table 2A.5 Estimated Present Social Value of Monetized Climate Benefits and Disbenefits based on 2023 EPA report for Clean Energy Rule Construction Impacts 2025–2054 with a 30-Year Lifetime for 100 Percent by 2035 Emissions Reductions Case

GHG	Near-Term Ramsey Discount Rate		
	2.5%	**2.0%**	**1.5%**
	million 2022$		
CO_2	215	372	672
CH_4	27	37	54
N_2O	0.1	0.2	0.3