Regulatory Impact Analysis Addendum:

Analysis of the Economic Impact and Benefits of the Final Rule: Management of Certain Hydrofluorocarbons and Substitutes Under Subsection (h) of the American Innovation and Manufacturing Act of 2020

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3. List of Acronyms

AC	Air conditioning
AIM Act	American Innovation and Manufacturing Act of 2020, codified at 42 U.S.C. § 7675
ALD	Automatic Leak Detection
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
BAU	Business as usual
CAA	Clean Air Act
CARB	California Air Resources Board
CC	Comfort cooling
CFC	Chlorofluorocarbon
CO_2	Carbon dioxide
CONUS	Contiguous United States
CR	Commercial refrigeration
CWA	Clean Water Act
DSCIM	Data-driven Spatial Climate Impact Model
EAV	Equivalent annualized value
ECHO	Enforcement and Compliance History Online
EPA	Environmental Protection Agency
EO	Executive Order
ER&R	Emissions Reduction and Reclamation
FrEDI	Framework for Evaluating Damages and Impacts
FRS	Facility Registry Service
GDP	Gross Domestic Product
GHGs	Greenhouse gases
GIVE	Greenhouse Gas Impact Value Estimator
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HFCs	Hydrofluorocarbons
HFOs	Hydrofluoroolefins
IAM	Integrated Assessment Model
ICR	Information Collection Request
IPCC	Intergovernmental Panel on Climate Change
IPR	Industrial process refrigeration
IWG	Interagency Working Group on the SC-GHG
MAC	Marginal abatement cost
MACC	Marginal abatement cost curve
MT	Metric ton
$MTCO_2eq$	Metric tons of CO_2 equivalent
$MMTCO_2eq$	Million metric tons of CO_2 equivalent
NPDES	National Pollutant Discharge Elimination System
NPRM	Notice of Proposed Rulemaking
NPV	Net Present Value

NSPS/EG	New Source Performance Standard / Emission Guidelines
ODS	Ozone-depleting substances
O&M	operations and maintenance
PV	Present value
RACHP	Refrigeration, AC, and heat pump
RCRA	Resource Conservation and Recovery Act
RIA	Regulatory Impact Analysis
RMP	Refrigerant Management Program
SBREFA	Small Business Regulatory Enforcement Fairness Act of 1996
SC-CH_4	Social Cost of Methane
SC-CO_2	Social Cost of Carbon
SC-GHG	Social Cost of Greenhouse Gases
SC-HFCs	Social cost of HFCs
SC-N_2O	Social Cost of Nitrous Oxide
SISNOSE	Substantial Number of Small Entities
U.S.	United States

Executive Summary

This Regulatory Impact Analysis (RIA) addendum provides an assessment of the costs and benefits of the final rule implementing provisions under subsection (h) of the American Innovation and Manufacturing Act of 2020, codified at 42 U.S.C. § 7675 (AIM Act or the Act), titled *Phasedown of Hydrofluorocarbons: Management of Certain Hydrofluorocarbons and Substitutes under Subsection (h) of the American Innovation and Manufacturing Act of 2020*, also referred to in this document as the Emissions Reduction and Reclamation (ER&R) rule. Subsection (h) of the AIM Act, entitled "Management of regulated substances," directs the United States (U.S.) Environmental Protection Agency (EPA) to promulgate regulations to control, where appropriate, any practice, process, or activity regarding the servicing, repair, disposal, or installation of equipment that involves: a regulated substance (used interchangeably with "HFCs" in the final rulemaking and in this RIA addendum), a substitute for a regulated substance, the reclaiming of a regulated substance used as a refrigerant, or the reclaiming of a substitute for a regulated substance used as a refrigerant.

This rulemaking follows an already finalized rule issued separately under the AIM Act, *Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act* (Allocation Framework Rule, 86 FR 55116, October 5, 2021), as well as a later rule for the same program, *Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years* (2024 Allocation Rule, 88 FR 46836, July 20, 2023).[1] This rulemaking also follows the final rule issued under subsection (i) of the AIM Act, *Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons Under the American Innovation and Manufacturing Act of 2020* (2023 Technology Transitions Rule, 88 FR 73098, October 24, 2023).[2] The analysis presented in the sections below provides estimated economic costs and environmental impacts of the provisions of the ER&R rule. The analysis also provides a comparison of these costs and benefits with those assessed for the previously finalized 2023 Technology Transitions and Allocation Rules to provide the public with an understanding of any potential changes in economic and environmental impacts relative to existing regulations. Results and methods from these analyses are referenced throughout this document. As with the 2024 Allocation Rule analysis and the 2023 Technology Transitions Rule analysis, this document is presented as an addendum to the original Allocation Framework RIA. In addition, for the purposes of identifying potential environmental justice

[1] Throughout this document, we use "Allocation Framework RIA" and "2024 Allocation Rule RIA Addendum" to refer to the analyses of these rules. We use "Allocation Rules" and "Allocation Rules RIA" to refer to combined or cumulative effect of those two rules; i.e., the Allocation Framework RIA as updated by the 2024 Allocation Rule RIA Addendum.
[2] Throughout this document, we use "2023 Technology Transitions RIA" to refer to the analysis of this rule, noting this analysis included the Allocation Rules RIA as the reference case from which costs and benefits were derived.

issues, the analysis presents EPA's assessment of the characteristics of communities near facilities reclaiming HFCs that are expected to be affected by the rule.

This analysis is intended to provide the public with information on the relevant costs and benefits of this rule and to comply with executive orders. While significant, the estimated benefits detailed in this document are considered incidental and secondary to the rule's objectives of serving the purposes identified in subsection (h) of the AIM Act, including maximizing reclamation and minimizing releases of certain hydrofluorocarbons (HFCs) from equipment.

Climate Benefits

The climate benefits of this rule derive from reducing damages from climate change induced by reduced emissions of greenhouse gases (GHGs), specifically HFCs. The reduction in HFC emissions stem from provisions contained in the final rule aimed at maximizing reclamation and minimizing the release of certain HFCs and substitutes. The benefits of avoided climate damages are monetized using the same social cost of HFCs (SC-HFCs) estimates applied in the proposal RIA addendum and are presented in Table ES-1. As discussed in the proposal RIA the methodology underlying these SC-HFC estimates are consistent with the interim social cost of greenhouse gas (SC-GHG) estimates recommended by the Interagency Working Group on the SC-GHG (IWG) under Executive Order 13990. In our base case estimate of incremental climate benefits, the final rule's provisions are estimated to produce a present value (PV) of climate benefits of $8.4 billion over 2026 to 2050, in 2022 dollars and discounted to 2024 at 3 percent. We also present the net climate benefits using updated SC-HFC estimates that reflect scientific advances, including the latest evidence on appropriate consumption-based discounting for intergenerational impacts.

Compliance Costs

Incremental compliance costs stem from factors including industry transitions in service and maintenance practices as well as installation of equipment required to comply with provisions contained in the final rule. These include leak repair and inspection costs as well as Automatic Leak Detection (ALD) system costs for owners and operators of affected equipment. Incremental costs also stem from recordkeeping and reporting requirements detailed in the final rule. Reducing HFC emissions due to fixing leaks earlier will also be anticipated to lead to savings for some system owner/operators, as less new refrigerant would need to be purchased to replace leaked refrigerant. The estimated combined net incremental compliance costs (costs less anticipated savings) stemming from all provisions contained in the final rule are shown in Table ES-1 in 2022 dollars, discounted to 2024 at 2 percent, 3 percent, and 7 percent.[3] The present value of total compliance costs resulting from provisions contained in the rule is estimated to be $1.5 billion at a 2 percent discount rate, $1.3 billion at a 3 percent discount rate, or $0.9 billion at a 7 percent discount rate. The equivalent annual value for each is $77 million, $77 million, and $76 million, respectively.

Net Benefits

The net benefits of the final rule are estimated as the climate benefits minus the net compliance costs (i.e., including any monetary benefits from reduced need of HFCs) in each year. Undiscounted annual costs, benefits, and net benefits for select years over the 2026–2050 time period are presented in Table ES-1, along with the present value and equivalent annualized value at various discount rates. End of year discounting is used throughout this document. When a discount rate of 2 percent is used for the costs, the present value of the incremental net benefits is estimated at $6.9 billion. When a discount rate of 3 percent is used for the costs, the present value of the incremental net benefits is estimated at $7 billion. When a discount rate of 7 percent is used for the costs, the present value of the incremental net benefits is estimated at $7.5 billion. These estimates are equivalent to $403-$404 million in incremental annual net benefits over a 25-year period.

Table ES-1: Summary of Undiscounted Annual Values, Present Values, and Equivalent Annualized Values select years for the 2026–2050 Timeframe for Estimated Compliance Costs, Benefits, and Net Benefits for this Rule (millions of 2022$, discounted to 2024) – Base Case Scenario [a,b,c,d,e]

Year	Climate Benefits	Costs			Net Benefits		
2026	$428	$92			$336		
2030	$676	$102			$574		
2035	$613	$87			$526		
2040	$466	$67			$399		
2045	$315	$51			$264		
2050	$263	$52			$211		
Discount rate	**3%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**
PV	$8,356	$1,499	$1,335	$884	$6,857	$7,021	$7,471
EAV	$480	$77	$77	$76	$403	$403	$404

[3] Results using the 2 percent discount rate were not included in the analysis for the proposal for this action. The 2003 version of OMB's Circular A-4 had generally recommended 3 percent and 7 percent as default rates to discount social costs and benefits. The analysis of the proposed rule used these two recommended rates. In November 2023, OMB finalized an update to Circular A-4, in which it recommended the general application of a 2 percent rate to discount social costs and benefits (subject to regular updates), which is an estimate of consumption-based discount rate. Given the substantial evidence supporting a 2 percent discount rate, we include results calculated using a 2 percent discount rate consistent with the update to Circular A-4. While climate benefits are calculated using the same SC-HFC estimates used in the proposal RIA addendum, we also present in Appendix J the climate benefits of the final rule using a new set of SC-HFC estimates that incorporate recent research and methodological advances, including an updated approach to discounting intergenerational impacts.

[a] Benefits include only those related to climate. Climate benefits are based on changes (reductions) in HFC emissions and are calculated using four different estimates of the social cost of HFCs (SC-HFCs): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. For the presentational purposes of this table, we show the benefits associated with the average SC-HFC at a 3 percent discount rate. See Chapter 5 for more discussion of the SC-HFC methodology.
[b] Rows may not appear to add correctly due to rounding.
[c] Present values are calculated using end of year discounting.
[d] The annualized present value of costs and benefits are calculated as if they occur over a 25-year period.
[e] The PV for the net benefits column is found by taking the difference between the PV of climate benefits at 3 percent and the PV of costs discounted at 7 percent, 3 percent or 2 percent. Because the SC-HFC estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the social rate of return on capital (7 percent under OMB Circular A-4 (2003)) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-HFC. See Chapter 5 for more discussion.

Relationship to Previously Estimated Results for Allocation Rules and 2023 Technology Transitions Rules

EPA has previously estimated costs and benefits of the HFC phasedown, which are detailed in the Allocation Framework RIA and 2024 Allocation Rule RIA Addendum. EPA has also estimated further incremental costs and benefits of the 2023 Technology Transitions Rule, detailed in 2023 Technology Transitions Rule RIA Addendum. The final ER&R Rule focuses on statutory provisions under the AIM Act that are separate from those addressed in the Allocation Framework Rule and 2023 Technology Transitions Rules. However, in order to avoid double counting or overestimating of costs and benefits, for the purposes of this analysis EPA's prior estimates are assumed to be the status quo from which incremental benefits may be calculated. Specifically, the compliance pathways and associated costs and benefits evaluated in the 2023 Technology Transitions Rule RIA Addendum serve as the reference case[4] for this analysis, thus ensuring that results presented in this document are reflective of the most up-to-date policy status quo.

As detailed in the Allocation Framework Rule RIA, 2024 Allocation Rule RIA Addendum, and 2023 Technology Transitions Rule RIA Addendum, EPA relied upon a marginal abatement cost curve (MACC) approach in order to estimate the full set of industry transitions and associated compliance costs required to meet statutory requirements. Analysis for this rule builds on this previously used methodology by adding on additional measures required by the final ER&R Rule and evaluating their incremental impact relative to the previously modeled set of transitions.

[4] Incremental costs and benefits in this analysis calculated relative to a policy status quo derived from EPA's previous analyses conducted for the Allocation and 2023 Technology Transitions Rules. This status quo is referred to as a "reference case" rather than "baseline" throughout this document to avoid confusion with the statutory baseline for the Allocation Rules.

Results from this analysis indicate that the final rule will yield incremental HFC emissions reductions relative to the previously modeled compliance pathways.[5] However, the extent of these incremental benefits depends in part on whether some of the HFC consumption- and emissions-reducing activities required by this final rule would have already been undertaken by industry in order to comply with, or otherwise address market outcomes from, the Allocation and 2023 Technology Transitions rules. As detailed in the 2023 Technology Transitions RIA Addendum, the precise set of transitions that will be undertaken by industry in response to both the Allocation and 2023 Technology Transitions Rules is uncertain, leading to a range in potential incremental benefits.

For the primary, base case analysis presented in this RIA Addendum, all measures found to be required to meet compliance with the Allocation and 2023 Technology Transitions Rules, based on EPA's prior analyses, are assumed to occur in the reference case. Additional measures included in EPA's prior analyses as possible industry outcomes that are not explicitly required to meet compliance with the Allocation and 2023 Technology Transitions rules are excluded. These include measures such as improvements to leak repair, enhanced recovery, and transitions in the fire suppression sector. Given the uncertainty regarding whether industry may undertake these measures in the absence of explicit requirements, in Appendix F EPA has also provided an alternative scenario where we assume that these measures do occur as reference case assumptions, effectively illustrating a lower-bound of the incremental benefits of the final ER&R rule.

More details on these assumptions can be found in Chapter 3 as well as the appendices accompanying this document. Finally, EPA notes that these assumptions are made for technical analytic purposes and to avoid double counting of benefits. They should not be interpreted as a reflection of the merits of any particular provision contained in the final rule.

Chapter 1. Introduction

1.1 Statutory Purposes

This Regulatory Impact Analysis (RIA) addendum evaluates the impact associated with the Final Rulemaking referred to in this document as the "Emissions Reduction and Reclamation" or ER&R rule. Under the American Innovation and Manufacturing Act of 2020 (the AIM) Act or the Act), the United States (U.S.) Environmental Protection Agency (EPA) is directed under subsection (h), "Management of Regulated Substances," to promulgate certain regulations for purposes that include maximizing

[5] However, the schedule for the production and consumption phasedown is not made more stringent than the schedule under subsection (e)(2)(C) of the AIM Act (i.e., the production and consumption caps contained in the Allocation Rules are unchanged).

reclamation and minimizing releases of certain hydrofluorocarbons (HFCs), those which are designated as regulated substances under the Act. Subsection (h)(1) of the AIM Act authorizes EPA to establish regulations to control, where appropriate, practices, processes, or activities regarding the servicing, repair, disposal, or installation of equipment, for purposes of maximizing the reclamation and minimizing the release of HFCs from equipment and ensuring the safety of technicians and consumers. This rule implements the purposes of this statutory provision and is designed to serve the purposes identified in it of maximizing reclamation and minimizing releases of HFCs from equipment, as well as ensuring the safety of technicians and consumers. The requirements in this rule will also support the domestic phasedown of HFCs and the overall implementation of the AIM Act.

Among other things, subsection (h) also provides for the Agency to consider options to increase opportunities for reclaiming HFCs used as refrigerants and provides that the Agency may coordinate regulations carrying out subsection (h) of the AIM Act with similar EPA regulations. Those regulations could, for example, include those implementing the refrigerant management program established under Title VI of the Clean Air Act (CAA).

1.2 Summary of Regulatory Requirements

Pursuant to subsection (h) of the AIM Act, EPA is requiring the following:

- Applying a suite of leak repair requirements to refrigerant-containing appliances, including comfort cooling (CC) [6], commercial refrigeration (CR), and industrial process refrigeration (IPR) appliances, containing 15 or more pounds of a refrigerant containing a hydrofluorocarbon (HFCs) or a substitute for an HFC with a global warming potential (GWP) above 53 (e.g., would not apply to carbon dioxide (CO_2), ammonia, certain hydrofluoroolefins (HFOs), and other substitutes for HFCs with a GWP of 53 or below).[7] This includes:
    - Requiring annual leak inspection for all CR and IPR appliances containing 15 pounds up to 500 pounds of such refrigerant upon discovering the applicable leak rate threshold (20% per year and 30% per year for CR and IPR appliances, respectively) is exceeded.

[6] EPA is exempting from the suite of leak repair requirements under subsection (h) any refrigerant-containing appliance used for the residential and light commercial air conditioning and heat pumps subsector.

[7] For brevity, unless otherwise stated, in this document we use the term “refrigerant” to include regulated HFCs and substitutes for HFCs with a GWP greater than 53.

  - Requiring annual leak inspection for all CC and other appliances containing 15 pounds of such refrigerant upon discovering the applicable leak rate threshold (10% per year) is exceeded.
  - Requiring quarterly leak inspection for all CR and IPR appliances that contain 500 pounds or more of such refrigerant upon discovering the applicable leak rate threshold is exceeded (unless ALD equipment meeting certain requirements is used for compliance).
  - Requiring repair of leaks and initial and follow-up verification tests on the repairs for all appliances containing 15 or more pounds of such refrigerant (i.e., CC, CR, and IPR) when the applicable leak rate threshold is exceeded.
  - Allowing owners/operators of all CC, CR, and IPR appliances containing 15 or more pounds of such refrigerant to request extensions to the leak repair and retrofit timeline.
  - Applying recordkeeping and reporting requirements associated with leak inspection and leak repair to appliances containing 15 pounds or more of such refrigerant.
- Installation and use of ALD systems for CR and IPR appliances containing 1,500 pounds or more of a refrigerant for new appliances installed on or after January 1, 2026, and for existing appliances installed on or after January 1, 2017, and before January 1, 2026, as of January 1, 2027.
- The servicing and/or repair of refrigerant-containing equipment to be done to with reclaimed HFC refrigerants as of January 1, 2029, in the following RACHP subsectors: supermarket systems, refrigerated transport, and automatic commercial ice makers.
- For the servicing, repair, disposal, or installation of fire suppression equipment that contains HFC, the servicing and/or repair of fire suppression equipment with recycled HFCs as of January 1, 2026, and the initial installation of fire suppression equipment with recycled HFCs as of January 1, 2030.
- Requiring as of January 1, 2028, that disposable cylinders that have been used for the servicing, repair, or installation of refrigerant-containing equipment be transported to an entity in the supply and disposal chain (e.g., a distributor, wholesaler, refrigerant repackager, an EPA-certified reclaimer, or a landfill or metal-recovery operator) and that such entities remove or ensure removal (e.g., by forwarding to an EPA-certified reclaimer) of all HFCs from disposable cylinders prior to discarding the cylinder.
- Requiring that disposable cylinders that have been used for the servicing, repair, or installation of fire suppression equipment be transported to a fire suppressant recycler and

that fire suppressant recyclers remove all HFCs from disposable cylinders prior to discarding the cylinder.

- Finally, EPA is establishing alternative Resource Recovery and Conservation Act (RCRA) standards for ignitable spent refrigerants when recycled for reuse, as the term is to be defined under RCRA. EPA is stipulating that the 40 CFR part 266 Subpart Q RCRA alternative standards apply to HFCs and their substitutes that are lower flammability ignitable spent refrigerants.

1.3 Regulated Community

The HFC industry is composed of several types of entities. As noted in the RIA for the Allocation Framework Rule, entities potentially affected by this previous action include those that produce, import, export, destroy, use as a feedstock, reclaim, package, or otherwise distribute bulk HFCs. This analysis—which serves as an addendum to the above-mentioned Allocation Framework RIA—assesses a final rule under subsection (h) of the AIM Act that regulates certain practices, processes, or activities regarding the servicing, repair, disposal, or installation of equipment, for purposes of maximizing the reclamation and minimizing the release of HFCs from equipment and ensuring the safety of technicians and consumers. This rule affects certain entities who own, operate, service, repair, recycle, dispose, or install equipment containing HFCs or their substitutes, as well as those who recover, recycle, or reclaim HFCs or their substitutes. Manufacturers or sellers of equipment containing HFCs, or their substitutes may also be potentially affected. A detailed list of industries potentially affected by this rule can be found in Appendix H.

Chapter 2. Overview of the Analysis

2.1 Introduction

The purpose of this RIA addendum is to provide the public with information on the relevant costs and benefits of this action, as finalized, and to comply with executive orders. The document contains results of a costs and benefits assessment to help EPA and the public evaluate the impact of this final rulemaking across the affected businesses. Costs and benefits presented in this analysis include compliance costs (including recordkeeping and reporting costs), climate benefits, and combined net benefits.

Given that the rule establishes an emissions reduction and reclamation program for the management of HFCs, which are subject to previously finalized rulemakings under the AIM Act, EPA relied on previous analyses conducted for the Allocation Framework Rule (86 FR 55116; October 5, 2021), the 2024 Allocation Rule (88 FR 46836; July 20, 2023), and 2023 Technology Transitions Rule (88 FR

73098; October 24, 2023) as a starting point for the assessment of costs and benefits of this rule. We then evaluated how the provisions contained in this final rulemaking would yield potential incremental impacts.

In addition to a cost and benefits analysis, EPA conducted an environmental justice analysis evaluating facilities and surrounding communities that may be impacted by this rule. Following the analytical approach used in the Allocation Framework Rule RIA, the 2024 Allocation Rule RIA Addendum, and 2023 Technology Transitions Rule RIA Addendum, EPA has provided demographic data and the cancer and respiratory risks to surrounding communities.

2.2 Organization of the Analysis

The analysis contained in this document is organized as follows:

Chapter 3 summarizes key methodological assumptions relied upon for this analysis, including discussion of EPA's approach for evaluating incremental impacts relative to previous rulemakings and the marginal abatement cost (MAC) approach used for modeling the impact of regulatory requirements in this rule. Chapter 3 also summarizes assumptions and underlying data regarding the types of equipment affected by this rule. This includes equipment that relies on HFCs in the fire suppression, commercial refrigeration, industrial process refrigeration, and comfort cooling sectors. Using data from EPA's Vintaging Model, equipment is broken out by estimated average charge size (in pounds of refrigerant) and assumed leak rate.

Chapter 4 provides an assessment of the anticipated compliance costs resulting from the requirements contained in the final rule, including results from the MAC modeling approach. Estimated incremental costs are relative to those previously estimated by EPA for the Allocation and 2023 Technology Transitions Rules.

Chapter 5 provides an assessment of the anticipated environmental benefits resulting from the requirements contained in the final rule. As with results in chapter 4, estimated incremental benefits are relative to those previously estimated by EPA for the Allocation and 2023 Technology Transitions Rules. This chapter also provides details on the methodology used to calculate the social cost of HFCs (SC-HFCs).

Chapter 6 combines the compliance costs and climate benefit estimates from the preceding chapters to provide an assessment of total net benefits associated with the rule.

Chapter 7 covers the environmental justice analysis conducted for the rule. This analysis builds on the environmental justice analysis conducted for the Allocation and 2023 Technology Transitions Rules and evaluates the demographic characteristics and baseline exposure of the communities near facilities that reclaim HFCs.

Appendices A and B provide details on underlying data and assumptions used to estimate the costs and benefits of leak repair and inspection provisions contained in the final rule and the specific leak rate assumptions derived from EPA's Vintaging Model.

Appendix C provides detailed cost estimates by equipment category for the leak repair and inspection provisions contained in the final rule. These estimates were used to model abatement costs on a dollar-per-carbon dioxide equivalent (CO_2e)-ton basis for the MAC methodology.

Appendix D provides estimates of the servicing demand for equipment affected by reclamation provisions contained in the final rule, by HFC gas.

Appendix E provides additional details on assumptions made in order to model requirements contained in the final rule on a dollar-per-CO_2e-ton basis for the MAC methodology and a summary of mitigation options modeled and estimated costs.

Appendix F provides results under an alternative reference case scenario in which industry is assumed to undertake more leak repair and recovery activity in the reference case (i.e., in the absence of this rulemaking), thus illustrating a lower bound of the potential incremental benefits of this rule.

Appendix G provides a Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996 analysis of estimated impact to small entities, including small businesses and small governments, associated with establishing the leak repair and inspection provisions and ALD requirements to HFC and substitutes for HFCs.

Appendix H lists the industries that might be affected by this rule.

Appendix I provides annual SC-HFC estimates used to estimate the climate benefits of this rule. These values are consistent with the SC-HFC estimates used in the proposal RIA and in previous analysis conducted for the Allocation and 2023 Technology Transitions Rules.

Appendix J provides estimated climate benefits of this rule using updated SC-HFC estimates. These values were calculated following the methodology set forth in the *EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances.*

Appendix K provides a sensitivity analysis based on the assumed cost of reclaimed refrigerant vis a vis virgin refrigerant.

Appendix L provides a sensitivity analysis based on alternative ALD installation requirements considered for the final rule.

Appendix M provides additional details on the evaluation of potential costs and benefits of the requirement that disposable cylinders that contain HFCs and that have been used in the service, repair or installation of refrigerant-containing equipment be sent to an EPA-certified reclaimer or another final processor in the supply chain, as well as sensitivity analyses related to these costs and benefits.

2.3 Years of Analysis

This analysis estimates the costs and benefits of compliance with provisions contained in the final rule. The earliest required compliance year is 2026, and—consistent with prior analyses conducted for the Allocation and 2023 Technology Transitions Rules—EPA has evaluated cumulative costs and benefits through the year 2050. For the purposes of this analysis, we have assumed that full compliance will be reached for each provision contained in the final rule by the first year in which the requirement starts, and that compliance continues through 2050 (the final year included in this analysis).

2.4 Factors Analyzed

This RIA addendum takes into consideration the compliance costs of meeting the requirements of this rule as finalized as well as the associated the environmental benefits of the consequent reduction in HFC emissions and the associated avoided global warming. Consistent with the Allocation Rules RIA and the 2023 Technology Transitions RIA Addendum, specific factors evaluated in this assessment include capital costs, operations and maintenance (O&M) costs, recordkeeping and reporting costs, anticipated refrigerant savings (e.g., from early leak detection and repair and heel recovery), and benefits resulting from the avoided release of HFCs into the atmosphere. This analysis does not consider certain factors that could potentially further reduce compliance costs, such as potential decreases in costs over time resulting from economies of scale or the energy savings from reduced cooling demand as a result of avoided global warming.

2.5 Vintaging Model

EPA uses the Vintaging Model to forecast the use and emissions of HFCs and other substances, by sector and subsector, under a business as usual (BAU) scenario and under various policy compliance scenarios. This analysis uses a version of the model intended to represent compliance with the AIM Act HFC Phasedown and 2023 Technology Transitions Rule as a starting point and makes adjustments to various subsectors of affected equipment and end uses as needed to align with the requirements of the final ER&R Rule. The resulting consumption and emissions are compared against the analysis developed for the Allocation and 2023 Technology Transitions Rules to evaluate incremental impacts.

The model tracks the use and emissions of regulated substances separately for each generation or "vintage" of equipment. The Vintaging Model is used to produce the estimates of GHG emissions in the official U.S. GHG Inventory and is updated and enhanced annually. Information on the version of the model used for this analysis, the various assumptions used, and HFC emissions may be found in EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014. A more detailed explanation of the Vintaging Model is also found in Section 3.2.1 of the Allocation Framework RIA.

2.6 Regulatory Option

The primary costs/benefits analysis conducted for this RIA addendum is based on the estimated compliance costs and benefits of the requirements contained in the final rule. In our analysis of the proposed rule, we investigated the potential costs and benefits of alternative regulatory scenarios, including alternative equipment charge size threshold for the leak repair requirements. In this updated RIA Addendum for the final ER&R Rule, EPA is providing additional costs and benefits scenarios for alternative options considered for the final rule. These include:

- Alternative cutoff years for the final rule's ALD installation requirements for existing equipment, including scenarios where the requirements would have covered systems installed within 5 years of the compliance deadline or where the requirements would have covered all existing equipment (i.e., no cutoff date). See Appendix L for these results.
- Alternative compliance start years for the rule's provisions related to the management of disposable cylinders. See Appendix M for these results.

Importantly, the statutory direction for this final rule is not dependent on the analysis of costs and benefits, but rather the rule is designed to serve the purposes identified in subsection (h) of the Act of "maximizing reclaiming and minimizing the release of a regulated substance from equipment and ensuring the safety of technicians and consumers." We refer the reader to the final rule for further explanation of the requirements finalized therein.

2.7 Uncertainty

Throughout this RIA Addendum, EPA has included a number of sensitivity analyses on particular modeling parameters and assumptions relied upon for this analysis. These include:

- Assumed cost of reclaimed HFCs vis-a-vis virgin manufactured HFCs (see Appendix K)

- Assumed industry behavior including improvements to leak repair and recovery that would occur in the reference case for this analysis (i.e., in the absence of this rulemaking) and resulting incremental benefits (see Appendix F)
- The number of disposable refrigerant cylinders in circulation in the United States, the average volume of heel gas remaining in disposable cylinders, and the average rate of venting of heel gas versus removal (see Appendix M)

Uncertainty regarding the social cost of HFC (SC-HFC) methodology utilized in this RIA Addendum is also discussed in **Error! Reference source not found.**.

Chapter 3. Methodology

3.1 Reference Case and Relationship to Prior Analyses

Background

Through the Allocation Framework Rule (86 FR 55116, October 5, 2021) as well as an update to that rule, 2024 Allocation Rule (88 FR 46836, July 20, 2023), EPA has established a consumption baseline for the phasedown of HFCs.[8] The consumption baseline was established using the average annual quantity of all regulated substances consumed in the United States from January 1, 2011, through December 31, 2013, and additional quantities of past chlorofluorocarbon (CFC) and hydrochlorofluorocarbon (HCFC) consumption. More details on the methodology used to establish this baseline can be found in the Allocation Framework Rule.[9] The baseline serves as the starting point from which statutorily mandated percentage reductions are taken to implement the AIM Act HFC phasedown.

Following the finalization of these rules, EPA furthered the implementation of the AIM Act by finalizing the 2023 Technology Transitions Rule (88 FR 73098, October 24, 2023). The rule includes restrictions on the use of certain hydrofluorocarbons (HFCs) above a certain global warming potential (GWP) whether neat or used in a blend, and restrictions on certain HFCs and certain blends containing HFCs, in specific sectors or subsectors where HFCs are used.

EPA has previously estimated costs and benefits of the HFC phasedown, which are detailed in the Allocation Framework RIA and 2024 Allocation Rule RIA Addendum, and for the 2023 Technology Transitions Rule, which are updated in the 2023 Technology Transitions Rule RIA Addendum. The final ER&R Rule focuses on statutory provisions under the AIM Act that are separate from those addressed in the Allocation Rules and 2023 Technology Transitions Rule. However, in order to avoid double counting

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[8] The shorthand "Allocation Rules" is used throughout this document to refer to these rules together.
[9] *https://www.federalregister.gov/documents/2021/10/05/2021-21030/phasedown-of-hydrofluorocarbons-establishing-the-allowance-allocation-and-trading-program-under-the*.

or overestimating of costs and benefits of this rule, for the purposes of this analysis the estimated economic and environmental impacts of these prior rules are assumed to be the status quo or "reference case"[10] from which incremental impacts may be calculated.

As detailed in the Allocation Framework Rule RIA, 2024 Allocation Rule RIA Addendum, and 2023 Technology Transitions Rule RIA Addendum, EPA relied upon a MACC approach in order to estimate the full set of industry transitions and associated compliance costs required to meet statutory requirements. Emissions benefits were estimated based on the difference between HFC emissions in the compliance pathway and HFC emissions under a BAU scenario without the statutory requirements in place. Analysis for this rule builds on this previously used methodology by adding on additional measures required by the final ER&R Rule and evaluating their incremental impact.

HFC Consumption under BAU and Reference Case Projection

Under the previously modeled compliance pathways for the Allocation and 2023 Technology Transitions Rules, HFC consumption and emissions over time for appliances across all major sectors (including fire suppression, CC, IPR, and CR) are significantly lower (in CO_2e terms) than they otherwise would be under a BAU scenario. Since this analysis assumes these transitions occur in the reference case, the estimated avoided emissions from some of the provisions contained in this final rule are less than what they would be if a BAU scenario were used that does not assume these transitions and improved service activities occur.

Table 3-1 below shows the consumption-based BAU originally used to quantify benefits in the Allocation Rule analyses, as well as estimated consumption under the reference case used for this analysis that also incorporates impacts from the 2023 Technology Transitions Rule. The latter is used to quantify incremental benefits in this analysis.

Table 3-1: HFC Consumption under original BAU and reference case (MMTEVe)[11]

Year	***HFC Consumption under BAU (i.e., no AIM Act)***	***HFC Consumption under ER&R Rule reference case (i.e., with Allocation and 2023 Technology Transitions Rules)***
2025	315	126
2030	317	60

[10] As a disambiguation, throughout this document we refer to the Allocation and 2023 Technology Transitions Rules estimates as the "reference case" rather than "baseline," to avoid confusion with the statutory baseline for the Allocation Rules.
[11] In this document, units for consumption and emission reductions are presented in Million Metric Tons Exchange Value Equivalent (MMTEVe) or Metric Tons Exchange Value Equivalent (MTEVe). As explained in the Allocation Framework Rule, a metric ton of exchange value equivalent is numerically equal to a metric ton of carbon dioxide equivalent ($MTCO_2e$) and we use these terms interchangeably throughout this document.

2035	324	16
2040	337	27
2045	352	30
2050	366	33

Approach for Estimating Incremental Impacts

Results from this analysis indicate that the final ER&R Rule will yield incremental HFC consumption and emissions reductions relative to the previously modeled compliance pathways.[12] However, the extent of these incremental benefits depends in part on whether some of the HFC consumption- and emissions-reducing activities required by this final rule (such as improvements to detect and repair leaks) would have already been undertaken by industry in order to comply with, or otherwise address market outcomes from, the Allocation and 2023 Technology Transitions Rules.

As detailed in the 2023 Technology Transitions RIA Addendum, the precise set of transitions that will be undertaken by industry to meet compliance is uncertain, leading to a range in potential incremental benefits. The 2023 Technology Transitions RIA Addendum included two primary compliance scenarios illustrating this uncertainty:

> a) a base case scenario where compliance options not explicitly required by the rule but envisioned under the Allocation Rules were excluded, thus yielding benefits (i.e., greater reductions in HFC consumption and emissions) for certain subsectors but also disbenefits (i.e., lower reductions in HFC consumption and emissions) for other subsectors, relative to the Allocation Rule results.
>
> b) an upper-bound scenario of incremental benefits where compliance options from the Allocation Rules were assumed to occur even though not explicitly required by the 2023 Technology Transitions Rule, including actions taken in the fire protection subsector, improved leak repair, and additional recovery at disposal.[13]

To evaluate the incremental impacts of the ER&R Rule relative to the policy status quo, the former, base case scenario from the 2023 Technology Transitions RIA Addendum is used as the primary

[12] However, the schedule for the production and consumption phasedown is not made more stringent than the schedule under subsection (e)(2)(C) of the AIM Act (i.e., the production and consumption caps contained in the Allocation Rules are unchanged).

[13] The 2023 Technology Transitions rule was finalized in October 2023. Restrictions apply to the use of certain high GWP HFCs in aerosols, foams, and refrigeration, air conditioning, and heat pump products and equipment. Beginning January 1, 2025 (or model year 2025, but no earlier than one year after publication of the final rule, for some motor vehicle air conditioners), certain technologies will need to restrict use of higher-GWP HFCs or HFC blends. Compliance deadlines and GWP limits vary based on sector and subsector.

reference case from which additional costs and benefits are evaluated in this analysis. In this way, all measures found to be required to meet compliance with the Allocation and 2023 Technology Transitions Rules, based EPA's prior analyses, are assumed to occur in the reference case. Additional measures from the above-mentioned upper-bound scenario, which are not required to meet compliance with the Allocation and 2023 Technology Transitions rules (namely, enhanced recovery, leak repair, and transitions in the fire protection sector), are not assumed to occur in the reference case.

Given the uncertainty regarding whether industry may undertake these measures in the absence of explicit requirements, in Appendix F EPA has also provided an alternative scenario where we assume that the above-mentioned improvements to leak repair and recovery would occur even in the absence of this rule and they are therefore included in the reference case. This alternative scenario effectively illustrates a lower-bound of the incremental benefits of the final ER&R rule.

EPA notes that the above assumptions are made to 1) explore potential uncertainties around plausible scenarios and outcomes and 2) avoid double counting of benefits.

Moreover, there are potential additional benefits associated with provisions contained in the final rule that are not quantified in the incremental benefits presented in this document. These include, but are not limited to:

- the life-cycle cost savings associated with the use of reclaimed HFCs and substitutes for HFCs as opposed to virgin HFCs and substitutes for HFCs;[14]
- the moderation of future spikes in the cost of HFCs due to increased availability of reclaimed HFCs;
- the freeing up of available virgin HFCs for applications where reclaimed HFCs have not been proven effective for use; and
- avoided supply shortages of HFCs that are still needed for servicing certain appliances, by maximizing the supply of reclaimed refrigerant;
- thus, protecting the cold chain needed to deliver food and vaccines.

3.2 Equipment Characterization

In order to evaluate costs and benefits, EPA relied on the Vintaging Model (described in section 2.5 above) to construct an inventory of equipment and appliances potentially affected by specific provisions contained in the final rule as well as associated use and disposition of regulated substances over time.

[14] For example, see Yasaka et al. (2023), which discusses additional life-cycle benefits from the use of reclaimed HFCs.

This section provides a description of assumptions made to determine the universe of equipment and appliances affected. Qualitative descriptions of the broad categories of affected equipment and appliances are also provided.

Equipment in the Fire Suppression Sector

Fire suppression equipment covered by this final rule fall into two categories, and both types of equipment may contain HFCs that would be discharged in the event of a fire. Total flooding systems are designed to automatically discharge a fire extinguishing agent by detection and related controls (or manually by a system operator) and achieve a specified minimum agent concentration throughout a confined space (i.e., volume percent of the agent in air) that is sufficient to suppress development of a fire. Streaming applications use portable fire extinguishers that can be manually manipulated to discharge an agent in a specific direction and release a specific quantity of extinguishing agent at the fire. Table 3 summarizes reference case stock and emissions in 2025 for both end-uses within the Fire Suppression sector.

Table 3-2: Estimated Installed Stock (MT) and Emissions (MT) by Equipment Type (2025)

Equipment Type	***Installed Stock (MT)***	***% of Total Installed Stock***	***Leak Emissions (MT)***	***% of Total Leak Emissions***
Total Flooding Systems	14,976	89%	374	85%
Streaming Units	1,872	11%	66	15%
Total	**16,849**		**440**	

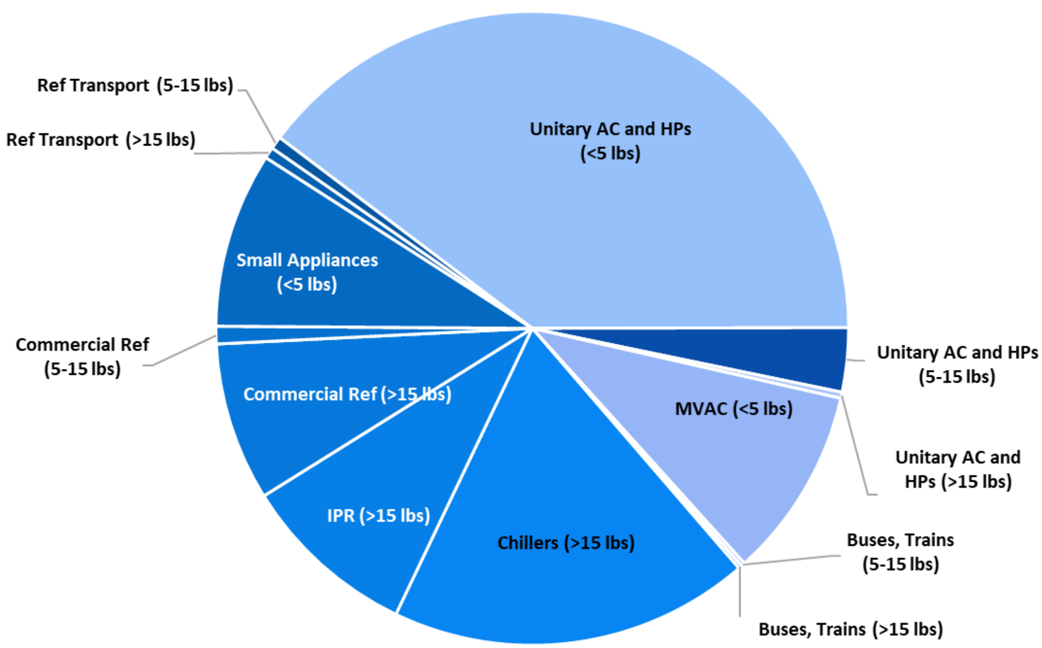
Refrigeration and Comfort Cooling Appliances

A variety of Refrigeration, Air Conditioning, and Heat Pump (RACHP) appliances used in the United States contain refrigerants, and these appliances can be organized into charge size groups such as the following: 1) appliances containing five or fewer pounds of a refrigerant containing an HFC or substitute for an HFC, 2) appliances containing between five and 15 pounds of such refrigerant, and 3) appliances containing more than 15 pounds of such refrigerant. For this analysis, affected equipment is considered to be refrigeration and air conditioning (AC) appliances containing 15 pounds or more of a refrigerant containing an HFC or substitute for an HFC with a GWP greater than 53.[15]

[15] For brevity, unless otherwise stated, in this document we use the term “refrigerant” to include regulated HFCs and substitutes for HFCs with a GWP greater than 53.

Figure 3-1 shows the projected installed stock of HFC refrigerant by RACHP appliance type across all equipment sizes in the United States in 2025, as modeled in EPA's Vintaging Model (EPA 2023f)[16] and Figure 3-2 shows estimated annual leak emissions (exclusive of loss during disposal) by appliance type in 2025. These appliances contain approximately 0.85 million MT (1.9 billion pounds) of HFC refrigerant and are estimated to release approximately 71,600 MT (157 million pounds) of HFC refrigerant in 2025 (an aggregate average leak rate of 8.4%) in the absence of control measures required by this rule. Table 3 summarizes stock and leak emissions in 2025 for each appliance type.

Figure 3-1: Projected Installed Stock (MT) of HFC Refrigerant by RACHP Appliance Type and Charge Size (2025)



[16] As explained in the RIA to the Allocation Framework Rule and associated addenda to that RIA, the Vintaging Model estimates the consumption and emissions from subsectors that traditionally relied on ODS and are transitioning to HFCs and other alternatives. The EPA 2023f version of the model (VM IO file_v4.4_02.04.16_Final TT Rule 2023 High Addition.xls) incorporates the transitions and practices anticipated to occur under the 2023 Technology Transitions RIA Addendum High Additionality Case, which in turn incorporates provisions of that rule and other actions anticipated under the 2024 Allocation Rule not otherwise adjusted based on the 2023 Technology Transitions Rule.

Figure 3-2: Estimated Leak Emissions (MT) of HFC Refrigerant by RACHP Appliance Type and Charge Size (2025)

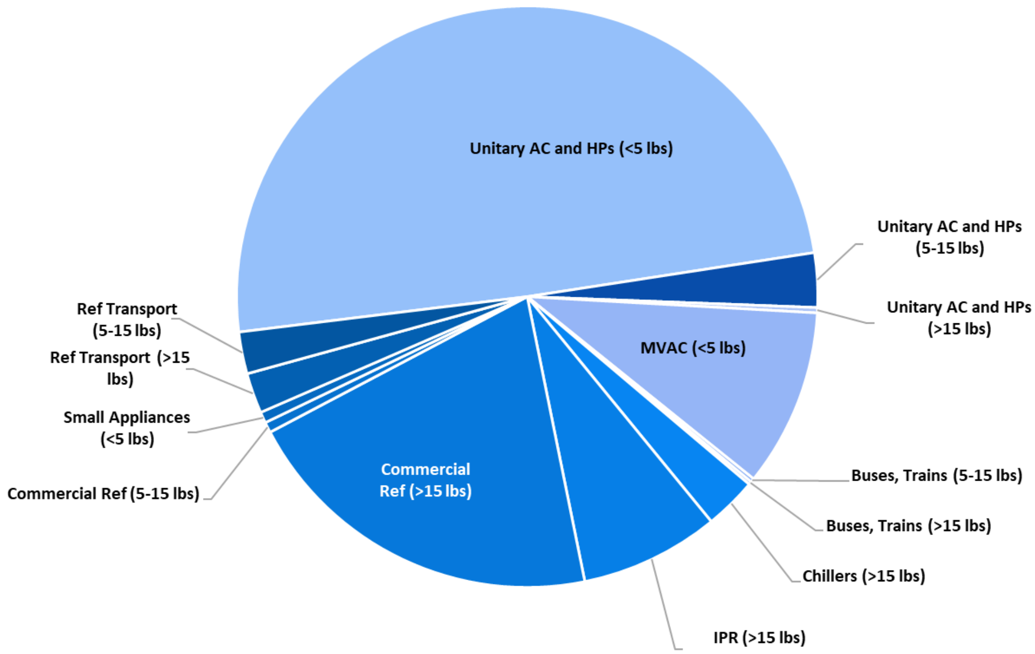


Table 3-3: Estimated Installed Stock (MT) and Leak Emissions (MT) by Equipment Type (2025)

Equipment Type	***Installed Stock (MT)***	***% of Total Installed Stock***	***Leak Emissions (MT)***	***% of Total Leak Emissions***
Motor Vehicle Air Conditioning (<5 lbs)	83,200	10%	7,100	10%
Unitary AC and Heat Pumps (<5 lbs)	338,600	40%	35,400	50%
Small Appliances (<5 lbs)	76,400	9%	400	0.6%
<5 lbs total	**498,200**		**42,900**	
Buses, Trains (5-15 lbs)	1,600	0.2%	200	0.3%
Ref Transport (5-15 lbs)	5,500	1%	1,700	2%
Commercial Ref (5-15 lbs)	7,600	1%	400	1%
Unitary AC and Heat Pumps (5-15 lbs)	27,900	3%	2,200	3%
5-15 lbs total	**42,600**		**4,500**	
Buses, Trains (>15 lbs)	1,500	0.2%	100	0.1%
Chillers (>15 lbs)	157,200	18%	2,100	3%
IPR (>15 lbs)	77,100	9%	5,500	8%
Commercial Ref (>15 lbs)	69,000	8%	14,600	20%
Ref Transport (>15 lbs)	4,900	1%	1,600	2%
Unitary AC and Heat Pumps (>15 lbs)	2,700	0.3%	200	0.3%
>15 lbs Total	**312,400**		**24,100**	
Total	**853,200**		**71,500**	

The ER&R Rule covers three broad categories of RACHP appliances, which can be summarized as follows:

- **Commercial refrigeration (CR)** equipment are the refrigerant-containing appliances used in the retail food and cold storage warehouse sectors and refrigerated transport systems. Retail food appliances include the refrigeration equipment found in supermarkets, convenience stores, restaurants, and other food service establishments and include multiplex rack systems and condensing unit systems. Cold storage appliances include the equipment used to store meat, produce, dairy products, and other perishable goods. Refrigerated transport appliances include the equipment to move perishable goods (e.g., food) and pharmaceutical products by various modes of transportation, including rail and ships.
- **Industrial Process Refrigeration (IPR)** equipment are complex, customized refrigerant-containing appliances used in the chemical, pharmaceutical, petrochemical, and manufacturing industries. These appliances are directly linked to the industrial process. This sector also includes industrial ice machines, refrigerant-containing appliances used directly in the generation of electricity, and ice rinks.
- **Comfort Cooling (CC)** equipment includes stationary refrigerant-containing appliances that provide cooling in order to control temperature and/or humidity in occupied facilities, such as office buildings and commercial buildings, and mobile AC equipment. Comfort cooling appliances include building chillers (which can be further broken down by compressor type) and mobile AC for transit, school, and tour buses and passenger trains.

Additional description of the Vintaging Model end-uses within each sector and equipment category is provided in Appendix B.

Equipment Affected by Leak Repair and Inspection Provisions

The leak repair and inspection provisions contained in the final rule affect refrigerant-containing appliances with a charge size (i.e., amount of refrigerant in a given independent circuit) of 15 pounds or more. CR, CC, and IPR appliances containing 15 pounds or more of HFC refrigerant[17] were identified using EPA's Vintaging Model, which models equipment using average charge sizes. To provide additional variation in potential costs and benefits for larger refrigerant-containing appliances where a more significant range of possible charge sizes is likely such that at least some portion of the appliances

[17] Although the final rule also covers substitutes for an HFC, this analysis focuses on HFCs and HFC-containing blends, including HFC-containing substitutes, noting that most other HFC substitutes modeled have small to zero GWPs (e.g., hydrocarbons, hydrofluoroolefins, carbon dioxide, and ammonia).

are addressed by this rule, end-uses were distributed into “low” (i.e., 50 percent of the modeled average charge size), “average” (i.e., the modeled average charge size), and “high” (i.e., 150 percent of the modeled average charge size) groups. Each group was assigned one-third of the total units, and the charge size distributions equal the weighted average charge size modeled in the Vintaging Model. Each end-use/charge size group was then categorized as sub-small (containing between 15 and 50 pounds of refrigerant), small (containing between 51 and 199 pounds of refrigerant), medium (containing between 200 and 1,999 pounds of refrigerant), and large (containing greater than 2,000 pounds of refrigerant). The categorization is done because provisions in the rule vary by charge size. Table 3-3 provides a mapping of end-uses into these three charge size groups and categorization. A more detailed version showing each end-use separately is available in Appendix A.

Table 3-4: Apportionment of Appliance Types by Refrigerant Charge Size

Appliance Sector	*Appliance Type* [a,b]	*Average Charge Size (lbs)* [c]	*Distributed Charge Size Group*	*Charge Size Analyzed (lbs)*	*Equipment Size*
Comfort Cooling	School & Tour Bus AC	13	Low	5	N/A
			Average	11	N/A
			High	16	Sub-small
	Transit Bus AC	16	Low	8	N/A
			Average	16	Sub-small
			High	24	Sub-small
	Passenger Train AC	41	Low	20	Sub-small
			Average	41	Sub-small
			High	61	Small
	Chillers	1,105	Low	265 – 929	Medium
			Average	529 – 1,857	Medium
			High	794 – 2,786	Medium – Large
Commercial Refrigeration	Modern Rail Transport	17	Low	8	N/A
			Average	17	Sub-small
			High	25	Sub-small
	Vintage Rail Transport	33	Low	17	Sub-small
			Average	33	Sub-small
			High	50	Sub-small
	Condensing Unit	47	Low	23	Sub-small
			Average	47	Sub-small
			High	70	Small
	Marine Transport	1,021	Low	194 – 827	Small – Medium
			Average	388 – 1,653	Medium
			High	582 – 2,480	Medium – Large
	Rack	2,038	Low	1,019	Medium
			Average	2,038	Large
			High	3,057	Large

	Cold Storage	24,755	Low	12,110 – 12,716	Large
			Average	24,220 – 25,431	Large
			High	36,331 – 38,147	Large
Industrial Process Refrigeration	IPR	6,633	Low	972 – 7,939	Medium – Large
			Average	1,945 – 15,877	Medium – Large
			High	2,917 – 23,816	Large

[a] Only end-uses within appliance sectors CC, CR, and IPR are shown.
[b] End-uses with charge sizes less than 10 pounds are not shown as even under the "high" charge size group, they will not be affected by the leak inspection and repair provisions of the rule.
[c] For some appliance types, the Vintaging Model simulates multiple subsectors that are distinguished by size, original ozone-depleting substances (ODS) refrigerant type, or technology. In those cases, a range is provided.

Refrigerant-containing appliances with a charge size greater than or equal to 15 pounds must also exceed specified annual leak thresholds to trigger the leak repair and inspection requirements contained in the final rule, and CR and IPR appliances with refrigerant charge sizes of 1,500 pounds or more must use an ALD system.[18] The proportion of refrigerant-containing appliances above the applicable leak rate thresholds was based on appliance stock estimated in the Vintaging Model. Because the Vintaging Model models appliances using average leak rates,[19] appliance stock was distributed into quintiles, each containing 20 percent of units, where the leak rate distributions equal the weighted average leak rate modeled in the Vintaging Model for each appliance type. Based on this approach, it is assumed that each subsector has at least 20 percent of its stock (i.e., one quintile) above the threshold leak rate. By distributing leak rates in this way, we estimate the percentage of each end-use that leaks above the threshold rates over which actions are required by this rule.[20] As an example, Transit Bus AC has an average leak rate of 10% per year (ICF International 2005). We divide the end-use into five quintiles, with annual leak rates of 5%, 7.5%, 10%, 12.5%, and 15%. Therefore, we calculate that 40% of the

[18] Owners and operators of refrigerant-containing appliances that are not required to install an ALD system (e.g., those with a charge size of less than 1,500 pounds) may voluntarily choose to install an ALD system as a compliance option for leak repair requirements in lieu of the applicable requirements for periodic leak inspections and certain recordkeeping and reporting requirements. However, leak inspections are required to be performed for the portions of the appliance where the ALD system is not monitoring for leaks.
[19] Under the base case scenario in this document, for chillers, large retail food (rack systems), cold storage, and industrial process refrigeration systems, the leak rate distributions were applied to the average leak rate modeled in the Vintaging Model as of 2026 with a 40 percent leak rate reduction, which is consistent with the assumption that larger refrigeration and AC equipment will experience enhanced leak recovery under the 2024 Allocation Rule as explained in the RIA to the Allocation Framework Rule and associated addenda to that RIA.
[20] The threshold leak rates are the same as those established under 40 CFR, part 82, subpart F; namely, 30% per year for CR appliances, 20% per year for IPR appliances, and 10% per year for CC and all other refrigerant-containing appliances.

appliances (those in the last two quintiles), exceed the threshold leak rate of 10% per year, See Appendix B for more detail.

Table 3-5 presents the assumptions made for this analysis regarding the proportion of affected refrigerant-containing appliances experiencing leaks above the threshold.

Table 3-5: Affected Refrigerant-Containing Appliance Assumptions by Appliance Sector, Type, and Size

Appliance Sector	***Appliance Type***	***Appliance Size***	***Average Charge Size (lbs)***[a]	***Percentage of Appliances Experiencing Leaks Above the Threshold Rate***
Comfort Cooling	School & Tour Bus AC[b]	Sub-small	16	13%
	Transit Bus AC	Sub-small	16	40%
	Passenger Train AC	Sub-small	41	20%
	Chiller	Medium	265 – 1,985	20%
		Large	2,084 – 2,786	20%
Commercial Refrigeration	Modern Rail Transport[c]	Sub-small	17	80%
	Vintage Rail Transport[c]	Sub-small	33	80%
	Condensing Unit	Sub-small	47	20%
	Marine Transport	Small	194	80%
		Medium	388 – 1,653	60% – 80%
		Large	2,480	60%
	Rack	Medium	986–1,972	20%
		Large	2,959	20%
	Cold Storage	Large	10,655 – 38,147	20%
Industrial Process Refrigeration	IPR	Medium	1,049 – 1,059	20%
		Large	2,099 – 23,816	20%

[a] For some equipment types, the Vintaging Model models multiple subsectors which are distinguished by size, original ozone-depleting substances (ODS) refrigerant type, or technology. In those cases, a range is provided.
[b] 66 percent of School & Tour Bus AC units have charge sizes below the charge size threshold of 15 lbs. and therefore are not included as affected appliances (EPA 2023f).
[c] The Vintaging Model models two subsectors for refrigerated rail car transport: vintage and modern. Modern rail refrigeration systems are considered to be easily replaceable units previously developed for road transport and adapted for rail use, have a lifetime of approximately 9 years, and a refrigerant charge size less than 20 pounds. Older or vintage units were typically developed specifically for rail use and operate for the whole lifetime of the railcar itself (i.e., 40 years) and have larger charge sizes than modern systems (EPA 2023f).

Equipment Affected by the Automatic Leak Detection Provisions

Refrigerant-containing appliances within the CC and IPR sectors are required to install an ALD system if the normal charge size is equal to 1,500 pounds or more. Some refrigerant-containing appliances are assumed to already have an ALD system installed. For instance, some refrigerant-containing appliances are provided with an ALD system, or have an option to include such. In this analysis, we assume 10 percent of affected refrigerant-containing appliances already have an ALD system installed in the reference case, and hence do not yield costs or benefits based on this rule.

In addition, the State of California requires the use of an ALD system if the refrigerant charge size exceeds 2,000 pounds. California comprises ~12 percent of the total population of the United States. Thus, we assume 12 percent of appliances with refrigerant charge sizes exceeding 2,000 pounds have an ALD system installed, in addition to the 10 percent reference case assumption. Combining these, and assuming a portion of the 10 percent reference case is in California, we estimate that 20.8 percent of appliances with refrigerant charge sizes over 2,000 pounds already have an ALD system installed.

For appliances between 1,500 and 2,000 pounds of refrigerant, we assume that an additional seven percent of affected appliances will already have an ALD system installed. This is the approximate percent of supermarkets represented under EPA's GreenChill voluntary program. As above, combining these two factors yields the assumption that 16.3 percent of affected appliances with refrigerant charge sizes between 1,500 and 2,000 pounds already have an ALD system installed.

Equipment Affected by Reclamation Provisions

The final ER&R Rule also requires the servicing and/or repair of existing refrigerant-containing equipment to be done with reclaimed HFCs in specific RACHP subsectors. The servicing and/or repair of refrigerant-containing equipment in the supermarket systems, refrigerated transport, and automatic commercial ice makers subsectors must be done with reclaimed refrigerants containing HFCs when refrigerant containing HFCs is needed to service and/or repair the equipment. The universe of refrigerant-containing equipment affected by these provisions and corresponding refrigerant demand was estimated using EPA's Vintaging Model (EPA 2023f). In 2029 (the first compliance year for these provisions), accounting for the leak repair provisions in the final rule, total reclaimed refrigerant demand is estimated to be approximately 12,168 MT as shown in Table 3-6: below. Note that these totals only reflect the AIM-listed HFCs, including those that are incorporated in blends; for example, HFOs, whether neat or in a blend with HFCs, are not included because the requirement to use reclaimed refrigerants for service applies only to the regulated HFCs.

Appendix D provides additional, detailed tables showing estimated servicing demand by specific HFC gas for refrigerant-containing equipment affected by these provisions.

Table 3-6: Service Demand of HFCs for Applicable RACHP Subsectors in 2029

Subsector	***Refrigerant-Containing Equipment Type***	***Service Demand (MT)***
Supermarket Systems		8,660
Refrigerated Transport	Road	1,405
	Vintage	10
	Modern Rail	9
	Intermodal Containers	304
	Marine	1,705
Automatic Commercial Ice Makers		75
Total		**12,168**

Reclamation of HFCs and refrigerants in general has been practiced for many years. While the requirements for servicing and/or repair of equipment with reclaimed HFCs in the above-listed subsectors may direct more reclaimed refrigerant thereto, it is likely that reclaimed refrigerants, to the extent available, will still be used in other subsectors. Recently reported total annual reclaim levels (4,115 MT in 2023) fall short of the above estimated demand for 2029, indicating that industry would have to make strides to increase reclamation totals in the coming years. This can be expected and has been seen in past refrigerant phaseouts. For instance, production of HCFC-22 for service ceased in 2020, yet numerous equipment continues to operate and continues to be serviced with reclaimed HCFC-22. Indeed, HCFC-22 has been the substance reclaimed the most (by mass) since at least the year 2000 (EPA, 2023e). To provide a perspective on recent reclaimed HFC levels, Table 3-7 below displays the amount of reclaim, in MT and million MT of CO_2e (MMTCO_2e), compared to consumption.

Table 3-7: Summary of HFC reclaim and consumption

Year	***Reclaimed HFCs (MT)[a]***	***Reclaimed HFCs (MMTCO_2e)[a]***	***Consumption (MMTCO_2e)[b]***
2017	2,309	4.9	290
2018	2,382	5.1	306
2019	2,749	5.5	314
2020	2,445	5.0	309
2021	2,455	5.0	462
2022	3,450	7.2	253
2023	4,115	8.8	Not Available

[a] (EPA, 2024d)
[b] Years 2017-2021 from EPA's Greenhouse Gas Reporting Program (EPA, 2024b); 2022 from EPA's HFC Data Hub (EPA, 2024c).

These data indicate that there remains a wide gap between consumption of virgin regulated substances versus the amount that is reclaimed each year (a ratio of over 40 to 1 in 2022), and that significant increases in recovery and reclamation rates are possible. According to estimates from EPA's Vintaging Model, the amount of HFCs available for recovery at disposal (i.e., as equipment reaches the end of its useful life) in the coming years significantly exceeds the amount of demand from the subsectors required by the rule to use reclaimed refrigerant and shown in Table 3-6 above and Table 3-8 below.

Reference case rates of recovery at disposal are derived from EPA's vintaging model BAU and correspond to equipment end-of-life loss rates of 5 to 65 percent of remaining refrigerant depending on equipment type.[21] At these rates, EPA estimates total annual recovery of HFCs from refrigerant-containing equipment of 35,458 MT in 2029, or almost three times the demand required by the final ER&R Rule's servicing reclaim provisions, and well more than three times if 15 percent of the demand for reclaim shown above were met with virgin HFCs. Table 3-8 below provides assumed recovery and demand for HFCs estimated to be necessary to meet servicing requirements in 2029.

Table 3-8: Modeled Recovery and Service Demand for HFCs in 2029 (RACHP only)

Gas	***Estimated Reference Case Recovery in 2029 (MT)***	***Estimated Demand Resulting from ER&R Servicing Reclaim Provisions in 2029 (MT)***	***Estimated Demand Resulting from ER&R Servicing Reclaim Provisions in 2029 - 85% (MT)[a,b]***
HFC-125	11,153	5,110	4,344
HFC-134a	13,376	3,381	2,874
HFC-143a	1,700	2,259	1,920
HFC-32	9,229	1,417	1,204

[a] Assumes 15% of reclaim demand will be met with virgin HFCs, consistent with regulatory requirements, thus reducing overall required demand for reclaimed HFCs.
[b] For blends, the assumed 15% reduction in demand shown in this table is applied proportionally across constituent HFCs. However, actual mix of virgin versus reclaimed of HFCs may vary. For example, a hypothetical 15/85 blend of HFC-143a and HFC-125 could comprise entirely virgin HFC-143a (a gas with shorter supply of estimated recovery in the above table), so long as the HFC-125 share (a gas with greater supply of estimated recovery in the above table) came entirely from reclaimed HFCs.

The values in *Table 3*-8 do not take into account industry's ability to leverage existing stocks and inventory of reclaimed material (provided they conform with the rule's requirement), which are likely to contribute to meeting the requirements of the rule, since reclaimed HFCs used to meet the requirements of the rule may have been recovered in prior years. In addition, the above values are inclusive of recovery and demand of specific blends, broken out by constituent HFCs. For example, a large share of the estimated recovery of HFC-125 and HFC-32 shown in Table 3-8 is driven by modeled recovery of R-410A (a 50/50 by weight blend of these two gases). These gases may then presumably be available to meet demand for blends such as R-452B (11% HFC-32 and 59% HFC-125), which drives a significant share of the estimated demand for these gases in Table 3-8. These dynamics may also indicate a need for

[21] The Vintaging Model assumes disposal recovery from equipment reaching end-of-life in a particular year is recovered and used, possibly after reclamation, to meet consumption demand for the same subsector and substance (i.e., new chemical demand plus servicing demand) in the same year.

continued industry capacity to reconstitute the component HFCs of recovered blends as demand changes in response to the 2023 Technology Transitions and ER&R Rules.

3.3 Marginal Abatement Cost Model

To generate cost estimates for the leak repair and inspection, fire suppression, and reclamation requirements of the final ER&R Rule, EPA relied on a marginal abatement cost (MAC) methodology consistent with the approach used in the Allocation Framework RIA (see Section 3.2 of the Allocation Framework RIA) and the 2023 Technology Transitions RIA Addendum. As before, consumption- and emissions-reducing measures that meet compliance with the rule were modeled in terms of their costs on a dollars-per-ton of CO2e avoided basis and added to an integrated MAC curve of abatement measures required to meet compliance with existing regulatory requirements. The amount of regulated substance "available" to be avoided through measures required by the final rule was determined using EPA's Vintaging Model and refrigerant-containing equipment characterization assumptions detailed in section 3.2 above. Additional details on these assumptions as well as cost assumptions can be found in Appendices A, B, and C of this RIA Addendum.

The use of a MAC approach allows for consistency and comparability with EPA's prior results and for assessment of the costs of the final rule within the context of EPA's previously finalized regulations under the AIM Act. Similar to the approach taken for the 2023 Technology Transitions Rule, all abatement activities required to achieve compliance with the rule are assumed to occur in the compliance pathway. This differs from the approach originally used for the Allocation Framework Rule, which is agnostic in terms of the specific abatement measures that industry may take up in order to meet compliance with the statutory phasedown caps. Whereas for the Allocation Framework Rule a least-cost pathway was modeled which included only the level of abatement necessary to meet the statutory caps in each step-down year, the approach taken for the final ER&R Rule as well as the 2023 Technology Transitions Rule assumes a specific compliance pathway informed by the sector-, subsector, and/or end-use-specific requirements of the rule.

Abatement Measures Modeled

This analysis uses the full set of required industry transitions previously modeled in the 2023 Technology Transitions Rule RIA addendum as the starting point from which potential incremental costs may be evaluated (i.e., the "base case" from the 2023 Technology Transitions RIA addendum). As discussed in the Allocation Framework Rule RIA, abatement measures can stem from a variety of compliance strategies, including reducing the amount of HFCs used in a piece of equipment (e.g., lowering charge sizes) and transitioning from using HFCs to alternatives such as hydrocarbons, ammonia, and hydrofluoroolefins (HFOs), which are not covered by the provisions of this rule as long as their GWP is 53 or lower, or HFC/HFO blends, which are covered by this rule as they contain an HFC. To model specific requirements from the final ER&R Rule, EPA evaluated abatement measures falling into the following two general categories:

- Direct reduction in HFC losses from equipment (e.g., through leak repair)
- Use of reclaimed/recycled HFCs (e.g., to meet equipment servicing and/or repair or initial installation demand)

Table 3-9: below provides a summary of abatement measures modeled to evaluate the impact of specific ER&R Rule requirements. For each abatement option modeled, total net costs associated with the strategy (e.g., leak detection costs minus any anticipated savings from reduced refrigerant consumption) are divided by the total amount of avoided HFC consumption to derive a cost estimate on a dollars-per-ton CO2e basis. Based on this approach, the average dollar-per-ton "break-even" cost tends to be lower for larger appliances or subsectors with large charge sizes, as opposed to smaller pieces of equipment where the amount of tons avoided per dollar is lower and hence the break-even cost is higher. For example, leak repair of large IPR systems has an estimated consumption abatement cost of approximately $1 per ton, whereas leak repair of medium IPR systems has an estimated consumption abatement cost of approximately $38 per ton.[22] Appendix E contains additional details on all abatement options developed and modeled for the final rule as well as their assumed break-even abatement costs in dollars per ton. Specific factors included in overall dollar-per-ton costs include equipment capital costs (e.g., ALD systems), labor costs (e.g., for conducting inspections and repairs), and savings associated with the avoided purchase of HFCs for servicing. For details on the bottom-up approach taken to estimate these factors for all affected equipment, including underlying data and assumptions used, see Appendix A.

[22] Unless stated elsewise, monetary figures are in 2022 U.S. dollars.

Table 3-9: Summary of abatement measures modeled and key factors evaluated to derive MAC estimates

Type of abatement strategy modeled	***Corresponding ER&R Rule Requirements***	***Key Factors Evaluated to develop MAC abatement measure***
Direct reduction in HFC losses from equipment	• Leak detection and repair for appliances containing 15 lbs or more of refrigerant • Use of ALD systems for CR and IPR appliances containing 1,500 pounds or more of refrigerant • Minimize releases of HFCs during the servicing, repair, disposal, or installation of fire suppression equipment containing HFCs or during the use of such equipment for technician training	**Abatement:** avoided virgin HFC consumption required to meet servicing demand **Costs:** labor and equipment for conducting leak detection/ inspections and repairs; capital and O&M costs for ALD systems **Savings:** HFC savings associated with detecting and repairing refrigerant leaks earlier and avoiding refrigerant and fire suppression agent emissions
Use of reclaimed/ recycled HFCs	• Servicing and/or repair of refrigerant-containing equipment for specific RACHP subsectors with reclaimed HFCs • Initial installation of fire suppression equipment with recycled HFCs • Servicing and/or repair of existing fire suppression equipment with recycled HFCs	**Abatement:** avoided virgin HFC consumption required to meet demand for initial installation or servicing **Costs:** cost of reclaimed/recycled HFCs vis a vis virgin manufactured HFCs **Savings:** avoided purchase of virgin HFCs

Table 3-10 below shows which provisions of the final rule were modeled to apply to which end-uses within the RACHP sector, and which charge size groups of those end-uses.

Table 3-10: Applicability of Requirements by Appliance Sector and Equipment Type

Sector	***Equipment Type***	***Distributed Charge Size Group***	***Average Charge Size (lbs)***	***Provision (Start Date)***		
				Leak Inspection &Repair (2026)	***Use of ALD (2026/2027)[a]***	***Reclaimed Refrigerant Servicing (2029)***
Comfort Cooling	School & Tour Bus AC	Low	11			
		Average				
		High		√		
	Transit Bus AC	Low	16			
		Average		√		
		High		√		
	Passenger Train AC	Low	41	√		
		Average		√		
		High		√		

Sector	Equipment Type	Distributed Charge Size Group	Average Charge Size (lbs)	Provision (Start Date)		
				Leak Inspection &Repair (2026)	Use of ALD (2026/2027)[a]	Reclaimed Refrigerant Servicing (2029)
	CFC-11 Centrifugal Chillers	Low	1,504	√		
		Average		√	√	
		High		√	√	
	CFC-12 Centrifugal Chillers	Low	1,566	√		
		Average		√	√	
		High		√	√	
	R-500 Chillers	Low	2,012	√		
		Average		√	√	
		High		√	√	
	CFC-114 Chillers	Low	1,389	√		
		Average		√		
		High		√	√	
	Screw Chillers	Low	661	√		
		Average		√		
		High		√		
	Scroll Chillers	Low	529	√		
		Average		√		
		High		√		
	Reciprocating Chillers	Low	529	√		
		Average		√		
		High		√		
	Modern Rail Transport	Low	17			√
		Average		√		√
		High		√		√
	Vintage Rail Transport	Low	33	√		√
		Average		√		√
		High		√		√
	Condensing Unit	Low	47	√		
		Average		√		
		High		√		
	Road Transport[b]	Low	10			√
Commercial Refrigeration		Average				√
		High				√
	Intermodal Containers[b]	Low	10			√
		Average				√
		High				√
	Reefer Ships	Low	1,653	√		√
		Average		√	√	√
		High		√	√	√
	Merchant Fishing Transport	Low	388	√		√
		Average		√		√
		High		√		√
		Low	2,038	√		√
		Average		√	√	√

Sector	Equipment Type	Distributed Charge Size Group	Average Charge Size (lbs)	Provision (Start Date)		
				Leak Inspection &Repair (2026)	Use of ALD (2026/2027)[a]	Reclaimed Refrigerant Servicing (2029)
	CFC-12 Large Retail Food (supermarkets)	High		√	√	√
	R-502 Large Retail Food (supermarkets)	Low	2,038	√		√
		Average		√	√	√
		High		√	√	√
	CFC-12 Cold Storage	Low	25,431	√	√	
		Average		√	√	
		High		√	√	
	HCFC-22 Cold Storage	Low	24,220	√	√	
		Average		√	√	
		High		√	√	
	R-502 Cold Storage	Low	24,613	√	√	
		Average		√	√	
		High		√	√	
	Ice Makers[b]	Low	6			√
		Average				√
		High				√
Industrial Process Refrigeration	CFC-11 IPR	Low	1,945	√		
		Average		√	√	
		High		√	√	
	CFC-12 IPR	Low	2,078	√		
		Average		√	√	
		High		√	√	
	HCFC-22 IPR	Low	15,877	√	√	
		Average		√	√	
		High		√	√	

[a] Where required, refrigerant-containing appliances that were installed on or after January 1, 2017, and before January 1, 2026, must include an ALD system as of January 1, 2027. Refrigerant-containing appliances installed on or after January 1, 2026 must include an ALD system upon installation or within 30 days of installation of the refrigerant-containing appliance. As described above, a portion of equipment is assumed to have an ALD installed in the reference case and therefore does not incur capital costs attributable to this rule.
[b] Road Transport and Intermodal Containers average charge sizes are less than 10 pounds but shown as rounded values. Therefore, these appliance types (even under the "High" distributed charge size group) along with Ice Makers are not affected by the leak repair or ALD provisions but are affected by the reclaim provisions.

Model limitations and assumptions regarding the impact of reclaim requirements

The EPA Vintaging Model estimates HFC consumption and the resulting emissions without explicitly defining the mix of virgin vs. reclaimed or recycled gases that is used by end use category. Certain assumptions were necessary to determine the reduction in consumption and emissions attributable to reclamation activity as: (1) the ER&R Rule provisions pertaining to reclaimed HFCs allow for reclaimed HFCs to be mixed with up to 15 percent virgin HFCs; and (2) some reclamation activity would be expected to occur in the absence of this rule. To account for these factors, the modeled change in consumption for options requiring reclaimed HFCs is scaled to remove the proportion not attributable to the rule. Thus, for a particular measure requiring reclaim, the change in consumption is determined as,

$$\Delta C_r = \Delta C_0(1 - (p_b + p_v))$$

where $\boldsymbol{\Delta C_0}$ is the initially calculated change in consumption from the Vintaging Model (e.g., total demand for a given end use to be met using reclaimed HFCs), $\boldsymbol{p_b}$ is the proportion attributable to reclamation already assumed in the reference case, and $\boldsymbol{p_v}$ is the proportion coming from virgin HFCs (assumed to be 15%, i.e., the maximum share allowable).

Specific approaches for determining consumption and emission reductions resulting from ER&R Rule abatement measures are summarized as follows:

- For measures in which the required servicing and/or repair with recovered/reclaimed HFCs was modeled:
  - Consistent with the above formula, EPA first factored out share of demand already met by recovery and reclamation activity assumed in the reference case[23], and the 15% maximum share of virgin HFCs that may be included in "reclaimed" refrigerant per regulatory definitions was also factored out.
  - EPA conservatively assumed that the measure would not result in an additional reduction in emissions beyond the emissions reductions from recovery of HFCs and avoided venting at disposal and servicing already included in the reference case.
- For measures in which a direct reduction in HFC losses from equipment was modeled (e.g., due to leak repair or ALD requirements), and the affected equipment category was not covered by a requirement for servicing and/or repair with reclaimed HFCs, it was assumed the servicing demand would have been met using virgin HFCs. A reduction in consumption of virgin HFCs equivalent to total avoided emissions was assumed.
- For measures in which a direct reduction in HFC losses from equipment was modeled (e.g., due to leak repair or ALD requirements), and the affected equipment category was also covered by a requirement for servicing and/or repair with reclaimed HFCs, it was assumed the servicing demand would have been met through reclaimed HFCs. The full emission reduction associated with the leak repair activity was assumed. EPA then used the above methodology to convert from emissions reductions to consumption reductions attributable to the rule.

[23]A reference case share of demand met by recovery and reclamation of 26.5% was used, derived from the Vintaging Model BAU. For more details, see Appendix E.

For more details on these and other specific assumptions applied to the abatement measures modeled for this rule, see Appendix E.

Updated MAC Compliance Path

The leak repair, automatic leak detection, fire suppression, and reclaim provisions modeled as abatement measures each have a net cost or savings estimated per ton of CO_2 equivalent consumption or emissions avoided. To evaluate the incremental cost of these provisions relative to EPA's previous analysis, these options were integrated with the set of MAC options previously assumed to achieve compliance with the Allocation and 2023 Technology Transitions Rules. The result is an updated compliance path which combines ER&R Rule provisions' measures with those previously modeled.

For reference,

Figure 3-**3** below shows the consumption MAC curves associated with the Allocation Rules and 2023 Technology Transitions Rule compliance path. These curves illustrate all compliance measures modeled to be achieved as a result of implementation of these rules, with each point representing the dollar-per-ton cost associated with abatement at a given threshold when moving (left-to-right) from lowest-to-highest cost measures. The compliance path for these previous rules is the reference case for this analysis, and is shown for 2026 (the first compliance year for the ER&R Rule) and 2036 (the final step-down year under the Allocation Rules). These curves illustrate all measures assumed in the compliance path in each year from lowest-cost to highest-cost, with total consumption abatement reaching approximately 242.3 MMT CO2e in 2026 and 323.1 MMT CO2e in 2036.

*Figure 3-***3***: Marginal Abatement Cost Curves in 2026 and 2036 – Allocation and 2023 Technology Transitions Rule Reference Case*

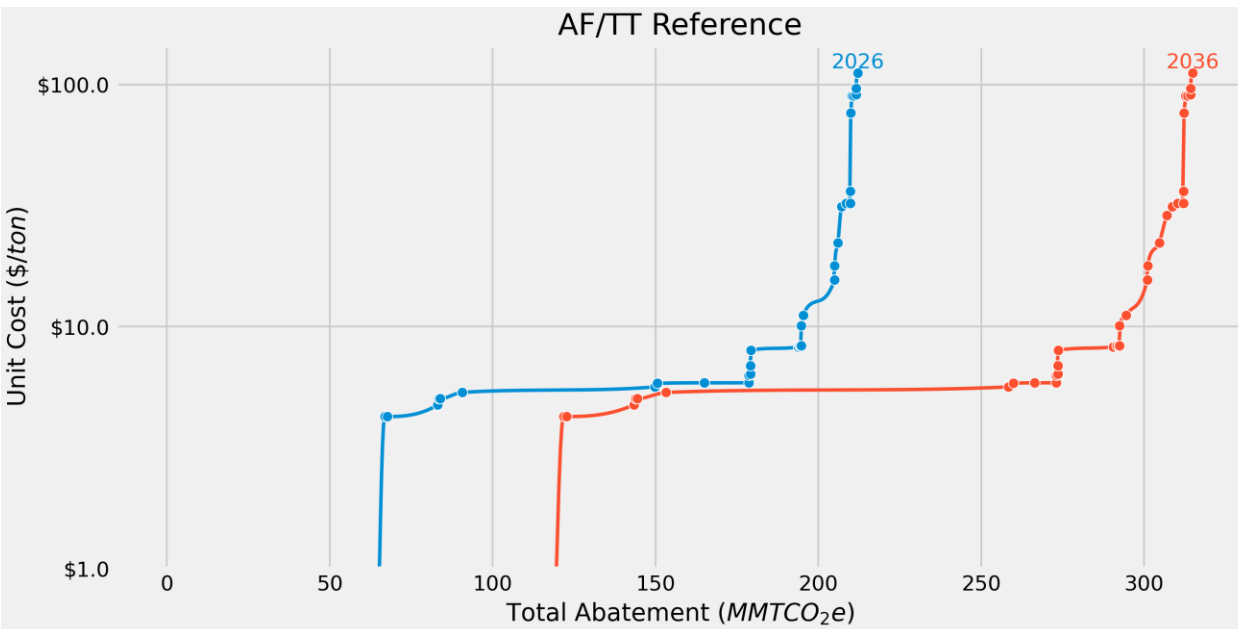
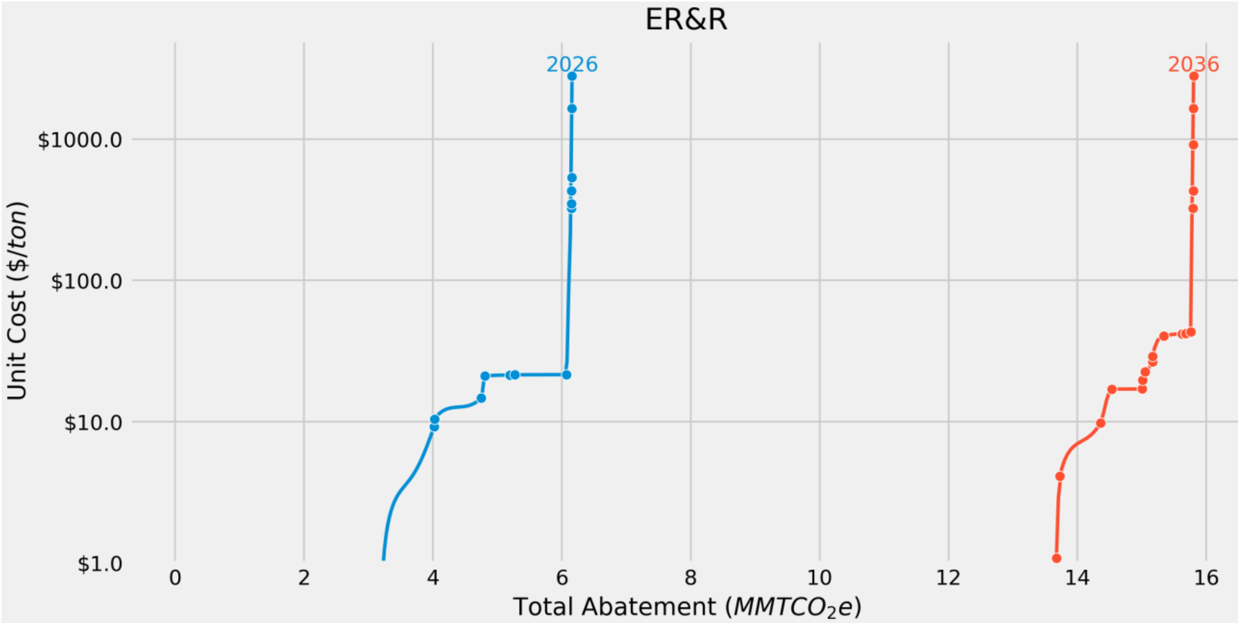


Figure 3-4 below then shows the additional abatement measures modeled for the final ER&R Rule described in the preceding sections. As shown, consumption abatement from these measures reaches an additional approximately 3.7 MMT CO2e in 2026 and 7.3 MMT CO2e in 2036.

*Figure 3-***4***: Marginal Abatement Cost Curves in 2026 and 2036 – Additional ER&R Rule Measures*

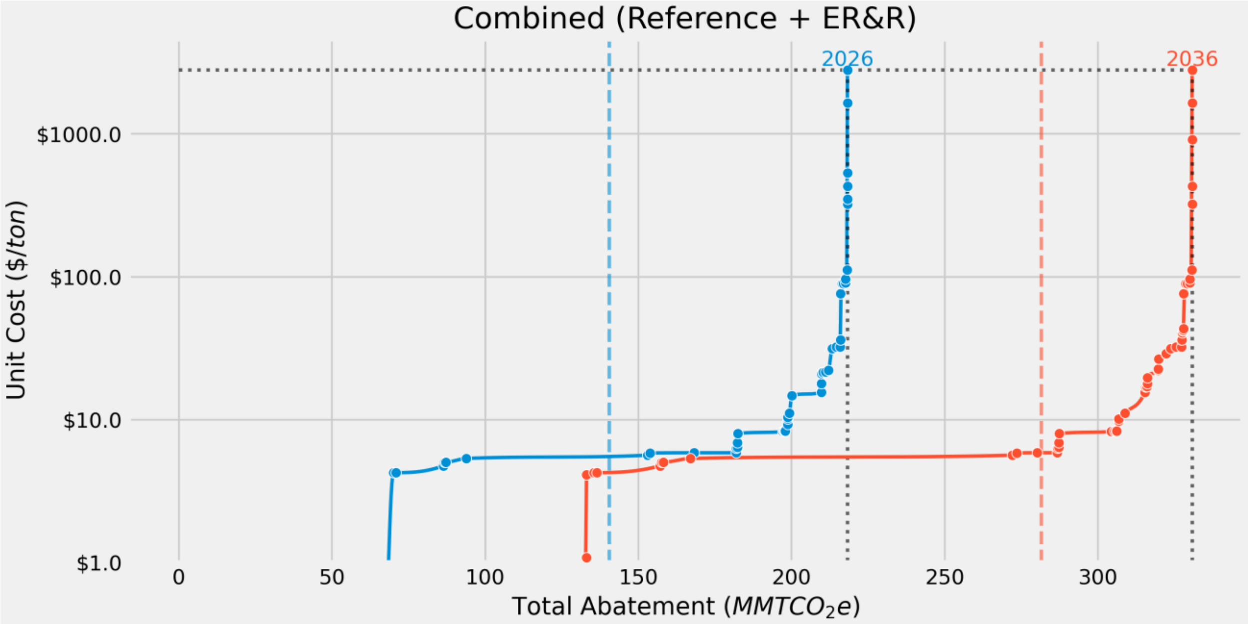


Finally,

below shows the integrated MAC curves reflecting both the reference case compliance measures assumed for the Allocation and 2023 Technology Transitions Rules as well as the updated measures evaluated for the final ER&R Rule. These curves illustrate total abatement assumed and assumed costs-per-abatement measure for the full suite of existing AIM Act regulations including the final ER&R Rule. A dashed vertical line showing the total amount of abatement required by the Allocation Rule (i.e., the abatement necessary to meet the HFC phasedown steps) in 2026 (blue) and 2036 (red) is provided for reference.[24]

*Figure 3-***5***: Revised Integrated Cost Curves in 2026 and 2036 –Allocation and 2023 Technology Transitions Rules with additional ER&R Rule measures*

[24]However, the schedule for the production and consumption phasedown is not made more stringent than the schedule under subsection (e)(2)(C) of the AIM Act (i.e., the production and consumption caps contained in the Allocation Rules are unchanged).



3.4 Other Costs from Rule Requirements

Certain requirements contained in the final rule were not modeled using a MACC approach described above, either because they do not directly impact HFC consumption and emissions or because they relate to HFC consumption and emissions sources that are exogenous to the Vintaging Model. For these measures, separate approaches were used to evaluate compliance costs and avoided consumption and/or emissions of HFCs, as detailed below. These measures include:

- Requirements pertaining to the management of disposable cylinders of refrigerants and fire suppressants
- Alternative Resource Conservation and Recovery Act (RCRA) standards for ignitable spent refrigerants being recycled for reuse
- Recordkeeping and reporting requirements

Disposable cylinder management requirements

The provisions of this Rule include requirements to remove the heel from used disposable cylinders before the cylinders are discarded; the requirement covers disposable cylinders used for servicing, repair, disposal, or installation of refrigerant-containing appliances. For analytical purposes, the Agency focused on anticipated additional reductions in HFC consumption and emissions as well as industry costs and the potential savings from avoided refrigerant loss.

To assess the impact of these provisions, EPA relied in part on the report, *Refrigerant Cylinders: Analysis of Use, Disposal, and Distribution of Refrigerants* (EPA 2024a), analyzing the costs and benefits of the requirement that disposable cylinders that have been used for the servicing, repair, or installation of refrigerant-containing equipment be transported to an EPA-certified reclaimer or another final processor within the supply and disposal chain (e.g., a distributor, repackager, wholesaler, landfill operator, or scrap metal recycler), and that these entities remove all HFCs (i.e., heel) from disposable cylinders prior to discarding the cylinder. If the heel is removed by a final processor or otherwise in the supply and disposal chain, the removed heels may be consolidated, but must be sent to an EPA-certified reclaimer or a fire suppressant recycler.

The report assesses the typical distribution of refrigerants in cylinders, including refrigerant changes expected under the Base Case; i.e., the scenario incorporating the 2023 Technology Transitions Rule. Based on the wide range of disposal practices currently employed and expected to continue in absence of this final rule, three scenarios were developed to estimate the emissions avoided: a low scenario (i.e., a lower heel left in the cylinder), a central scenario, and a high scenario.

The emissions avoided by removing such heels are dependent on the number of disposable cylinders in circulation and the average heel that would otherwise be emitted, and hence not available for reclaim, in absence of this rule. Based on the report cited above, we assume in the central scenario that there are approximately 4.5 million cylinders in circulation, of which 99 percent are disposable. Further, we estimate that the average heel is approximately 4 percent by weight of the nominal capacity (e.g., 0.96 pounds for a 24-pound cylinder).[25] Because of the other regulations in place, it is expected that the average GWP of the refrigerant in such cylinders will decrease. Other emissions associated with cylinders—for example, during transport and storage—are not expected to change based on this rule.

To account for the costs associated with the change in procedure for handling of cylinders (i.e., returning the cylinders for heels to be removed) we analyze possible ways a cylinder might travel before the heel is removed and the truly-empty cylinder is landfilled or recycled. This analysis assumes that some cylinders will be: (a) sent directly to the reclaimer; (b) returned to a wholesaler or distributor, who will ship disposable cylinders to a landfill or steel recycling facility, which would combine heels for shipment to a reclaimer; and (c) shipped directly from the end-user or technician to a landfill or steel recyling facility, which would combine heels for shipment to a reclaimer. For paths (b) and (c) above, we assume the landfill or steel recycling facility would reduce costs by combining 25 refrigerant heels (at 0.96 pounds as discussed above) of each HFC or blend containing an HFC (e.g., HFC/HFO blends) they

[25] R-404A is typically sold in a 24-pound cylinder. Cylinders for other HFC refrigerants are typically larger, from 25 to 50 pounds. We use 24 pounds as a conservative estimate here.

receive into individual 24-pound cylinders before sending those to a reclaimer. After recovering heels, reclaimers are assumed to send disposable cylinders to a landfill or steel recycler.

Neat HFOs, which are not regulated substances under this rulemaking but are used in some RACHP equipment, are not accounted for in the analysis. For HFCs and blends containing an HFC, we divide cylinders equally amongst the transportation paths described above. Thus, we assume one-third follow path (a), one-third follow path (b), and one-third follow path (c). Table 3-11 displays the estimated mileage for each leg of the paths taken compared to the business-as-usual (BAU) route.

Table 3-11: Estimated Distances for Disposable Cylinder Transportation Compared with BAU (Miles)[a]

Transportation Leg	***BAU***	***(a) End-user to Reclaimer to Landfill***	***(b) End-user to Distributor to Reclaimer***	***(c) End-user to Landfill***
Producer/Filler to Wholesale Distributor	1,000	1,000	1,000	1,000
Wholesale Distributor to End User/Technician	25	25	25	25
End User/Technician to Steel Recycler/Landfill	75	NA	NA	75
End User/Technician to Reclaimer	NA	50	NA	NA
End User/Technician to Wholesale Distributor	NA	NA	25	NA
Distributor or Reclaimer to Steel Recycler/Landfill	NA	75	75	NA
Landfill sending Recovered Refrigerant to Reclaimer[b]	NA	NA	75	75
Total Miles per Cylinder	**1,100**	**1,150**	**1,128**	**1,103**

[a] California Air Resources Board (CARB 2011)
[b] Each cylinder sent represents 25 cylinders received with heels.

The additional travel costs are influenced by how many cylinders fit on a truck, the fuel to drive the extra distances, and the incremental labor for such. By removing heels that would have otherwise been emitted and hence not available for reclaim, an additional supply is provided that would offset virgin production providing additional benefits based on the cost of refrigerant. These assumptions are shown in Table 3 below.

Table 3-1213: Additional Disposable Cylinder Cost Assumptions

Factor (units)	***Value***	***Source***	***Notes***
Cylinders per Truck	1,120	CARB (2011)	
Average Truck Speed (miles per hour)	50	CARB (2011)	
Truck Transport Labor Rate ($/hour)	$53.59	Bureau of Labor Statistics (BLS 2022)	May 2022 mean, including 110% overhead
Average Fuel Consumption (miles per gallon)	6.1	Geotab (2017)	Average across all states

Fuel cost ($/gallon)	$4.034	U.S. Energy Information Administration (EIA 2024)	Price of diesel as of March 25, 2024
Cost of HFC refrigerant ($/pound)	$4		Consistent with past AIM Act analyses

Accounting for the fuel and labor associated with the additional shipment of cylinders and the cost of refrigerants, we estimate costs and benefits, and hence the net benefits, as shown in Section 4.2 below and Appendix L.

Further details on the costs and benefits of the cylinder management requirements and a sensitivity analysis around some of the assumptions above are provided in Appendix L.

RCRA alternative standards

The final rule includes alternative RCRA (Resource Conservation and Recovery Act) standards for ignitable spent refrigerant. The purpose of these alternative standards is to help reduce emissions of ignitable spent refrigerants to the lowest achievable level by maximizing the recapture and safe reclamation/recycling of such refrigerants during the maintenance, service, repair, and disposal of refrigerant-containing appliances. The estimated compliance costs and savings resulting from these alternative standards are provided in this RIA Addendum for informational purposes. However, because they fall under a separate statutory authority from the AIM Act, they are not directly incorporated into the overall compliance costs and benefits estimates associated with this rulemaking and presented elsewhere in this document.

These alternative standards may incentivize additional reclamation of ignitable spent refrigerant over disposal, although EPA has not assumed they will result in additional recovery and reclamation consumption and emissions benefits beyond those already accounted for in response to other provisions contained in the final ER&R Rule. The alternative standards also are expected to result in an overall reduction in compliance costs for management of ignitable spent refrigerant under RCRA. Avoided costs include reduced transportation costs (hazardous waste manifest and transporter not required under the alternative standards), avoided compliance costs of complying with hazardous waste generator regulations for appliance owners and technicians, and avoided hazardous waste incineration costs for recovered ignitable spent refrigerant. Offsetting these avoided costs would be the cost to reclaimers for meeting the new standards for emergency preparedness and response, and for documenting that the ignitable spent refrigerant is not speculatively accumulated.

These cost estimates are heavily dependent on the future market for ignitable spent refrigerant sent for reclamation, which is difficult to predict with currently available data. In addition, because the alternative RCRA standards are voluntary, and regulated entities can always choose to dispose of ignitable spent refrigerant under the full RCRA standards if that is the economically preferred option, EPA anticipates that the RCRA alternative standards would either be economically neutral or result in an overall cost savings.

Reporting and Recordkeeping Requirements

The final rule includes provisions that are expected to result in additional recordkeeping and reporting costs for owners and operators of refrigerant-containing appliances related to leak repair and inspection. Additional recordkeeping and reporting costs are also anticipated for the requirement to include a certification that reclaimed refrigerant contains no more than 15 percent virgin HFC. For owners and operators of fire suppression systems, and entities that employ technicians who install or maintain fire suppression systems, additional reporting and recordkeeping requirements apply. All recordkeeping and reporting costs are calculated by multiplying the estimated burden (hours) times the average annual respondent hourly cost (labor plus overhead).

In deriving these costs, EPA identified applicable standard occupational classifications for each respondent and used the corresponding median hourly rate from the Bureau of Labor Statistics (BLS 2023).[26] The resulting costs outlined in Table 3-14: are the median hourly administrative cost of labor plus overhead for private firms (assumed to be 110 percent).

Table 3-14: Labor Rates

Respondent	***Bureau of Labor Statistics Information***			***Total***
	Standard Occupational Classification	***Occupational Title***	***Median Wage***	
Technicians	49-9021	Heating, Air-Conditioning, and Refrigeration Mechanics and Installers	$27.55	**$57.86**
Owners/ Operators	17-2111	Health and Safety Engineers	$49.85	**$104.69**

A brief summary of the specific approaches and assumptions applied for recordkeeping and reporting requirements is provided below. Additional details on assumptions and methods related to estimating recordkeeping and reporting costs can also be found in the Supporting Statement for the information collection request (ICR) prepared for this rulemaking (ICR Number 2778.02), which is contained in the docket for the final rule.

[26] Note figures here are in 2023 dollars.

Requests for extensions to the leak repair and retrofit timelines

Owners or operators of CC, CR, and IPR appliances normally containing 15 or more pounds of HFC refrigerant can apply to EPA for an extension to the leak repair and appliance retrofit timeframe. The total number of extension requests for CC, CR, and IPR HFC equipment was estimated by scaling the number of extension requests estimated for Ozone Depleting Substance (ODS)-containing equipment in the supporting ICR 1626.18[27] based on the proportion of total HFC equipment to ODS equipment modeled in EPA's Vintaging Model (EPA 2023f).

Installation records

Consistent with the ICR, this analysis assumes 1.5 minutes of burden time each time a refrigerant-containing appliance is installed.[28] Vintaging Model assumptions described in section 3.2 were used to identify the pool of affected appliances (i.e., new appliances with refrigerant charge sizes at or above 15 pounds) (EPA 2023f).

Purchase and service records

Consistent with the ICR, this analysis assumes 1.5 minutes of burden time each time a refrigerant-containing appliance that contains an HFC or a substitute for an HFC with a GWP greater than 53 is serviced.[29] Vintaging Model assumptions described in section 3.2 were used to identify the pool of affected appliances (i.e., all appliances with refrigerant charge sizes at or above 15 pounds) and the expected number of times that the affected appliances would be serviced. The total number of servicing events is assumed to be equal to the number of times that service technicians provide invoices (i.e., one time per year for all refrigerant-containing appliances with charge sizes at or above 15 pounds) (EPA 2023f).

Results of verification tests

The final rule includes leak repair regulations that require initial and follow-up verification tests on repairs made after the leak rate threshold is exceeded for a refrigerant-containing appliance. EPA's Vintaging Model was used to identify the affected pool of appliances (as described in section 3.2). For every occurrence of a refrigerant-containing appliance exceeding the applicable leak rate threshold, 1.5 minutes of burden time was assumed to maintain reports on the results of verification tests (EPA 2023f).

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[27] ICR 1626.18 was developed to estimate burden associated with reporting and recordkeeping of leak repair and inspection requirements for appliances containing more than 50 pounds of ODS refrigerant.

[28] This burden time is associated with writing the record and filing, not the time associated with filling or installing the system. This assumption is consistent with prior ODS and HFC ICRs.

[29] This assumption is premised on service technicians already needing to record information on services for invoicing, so the only incremental burden is in saving the data to a record file. For the significant percentage of service companies that record service information digitally in apps or other software, no additional time is needed to save logged data.

Leak inspections

The final rule requires that covered CR and IPR appliances with a refrigerant charge size less than 500 pounds or CC and other appliances with a refrigerant charge size of at least 15 pounds conduct a leak inspection once per calendar year until the owner or operator can demonstrate through leak detection calculations that the refrigerant-containing appliance has not leaked in excess of the applicable leak rate for one year. CR and IPR appliances with a refrigerant charge size from 500 pounds up to 1,500 pounds would be required to conduct a leak inspection quarterly (i.e., once per three-month period). Appliances, or portions of appliances, continuously monitored with an ALD system that is certified annually, including appliances with a refrigerant charge size of 1,500 or more pounds, would not be required to conduct an annual leak inspection. This analysis assumes that the recordkeeping time associated with maintaining leak inspection records is one minute. EPA's Vintaging Model was used to identify the affected pool of appliances (as described in section 3.2) (EPA 2023f).

Plans to retrofit appliances

The final rule requires that owners or operators of IPR, CC, and CR appliances normally containing 15 or more pounds of a refrigerant must develop and maintain a plan to retire or retrofit the appliance in the following cases after the applicable leak rate is exceeded: an owner or operator chooses to retrofit or retire rather than repair a leak, an owner or operator fails to take action to repair or identify a leak, or a refrigerant-containing appliance continues to leak above the applicable leak threshold after a repair attempt was made. The total number of retrofit requests for CC, CR, and IPR appliances containing 15 or more pounds of a refrigerant was estimated as 1 percent of all affected appliances leaking above the threshold (see section 3.2). For each retrofit plan, 8 hours of burden time was assumed.

Reports on systems that leak 125 percent or more

EPA is requiring owners/operators of refrigerant-containing appliances subject to the leak repair and inspection provisions to prepare and submit reports describing efforts to identify and repair leaks for appliances that leak 125 percent or more of the full charge in a calendar year. Using the assumptions in the ICR for ODS equipment and scaling proportionately based on the ratio of affected ODS and HFC appliances, this analysis estimates that approximately 388 appliances have an annual leak rate greater than 125 percent. For each refrigerant-containing appliance meeting or exceeding this leak rate threshold, 1 hour of burden time was assumed to prepare and submit a report for each occurrence.

Requests to cease a retrofit

The final rule allows owners/operators of appliances containing 15 or more pounds of refrigerant to submit a request to cease a retrofit if certain requirements are met, including an agreement to repair all identified leaks within one year of the retrofit plan's date. To estimate the costs for this reporting requirement, it was assumed that 5 percent of those that develop a retrofit plan will submit a request to cease their retrofit. Each request is assumed to take 30 minutes to complete.

Annual calibration of ALD system

The final rule requires owners/operators of refrigerant-containing appliances using ALD systems to maintain records regarding the annual calibration or audit of the ALD system. Records must be maintained each time an ALD system detects a leak, whether that be based on the applicable ppm threshold for a direct ALD system or the indicated loss of refrigerant measured in the ALD system. EPA assumes indirect ALD systems will collect and store this directly and no burden is assumed. For owners/operators of direct ALD systems, 1 minute of burden time is assumed.[30]

Labeling of reclaimed material with no more than 15% virgin material

It was assumed that reclaimers already label material and, therefore, will only need to modify labels to indicate the batch contains no more than 15% virgin material. The label modification was assumed to require 9 hours of both graphic design and administrative work.

Fire Suppression requirements

The final rule requires recordkeeping and reporting in the Fire Suppression sector. Those who first fill a fire suppression equipment with a regulated substance must report annually on the amount of such substances based on what is sold, recovered, recycled or virgin material and likewise on material sent for disposal. In addition, fire suppression technician employers must maintain records regarding the training used and documentation that the training was provided. Owners and operators of fire suppression equipment must also maintain records documenting that the regulated substances were recovered prior to sending the equipment for disposal. All records must be maintained for three years. EPA estimates that it will take 9.4 hours annually for the reporting, and an additional 40 hours annually for recordkeeping, per entity. We assume there will be 20 entities that will be required to perform the recordkeeping and reporting, including 15 reporters that already collect and share information under the voluntary HFC Emissions Estimating Program (HEEP).

3.5 Monetization of Emissions Benefits

The primary benefits of this final rule would derive from preventing the emissions of HFCs, thus reducing the damage from climate change that would have been induced by those emissions. The 18 HFCs and their isomers regulated under the AIM Act are GHGs that can trap much more heat per ton

[30] This burden time is associated with filing a record of the calibration of the ALD system, not the activity of calibrating the ALD system. Burden associated with ALD calibration is outside the ICR and is captured with the O&M compliance costs for the ALD systems. This assumption is consistent with prior ODS and HFC ICRs.

emitted than CO_2, a ratio shown in each chemical's GWP. The ratio of the amount of heat trapped by one ton of a chemical in the 100 years after it is emitted to the amount of heat trapped by one ton of CO_2 in 100 years after being emitted is the chemical's 100-year GWP, and the HFCs regulated under the phasedown have 100-year GWPs ranging from 53 to 14,800[31], with the vast majority of HFCs emitted having GWPs over 1,000. Prior to HFC regulation under the AIM Act, it was anticipated that HFC use and emissions would continue to rise, helping to drive global climate change. Thus, reducing the amount of HFCs that are used and emitted prevents climate damage and associated social costs that would have been induced by those HFC emissions. A more complete discussion of climate change damages and the social benefits of preventing them can be found in Sections 4.1 and 4.2 of the Allocation Framework Rule RIA.

While there may be other benefits to reducing emissions and increasing reclamation of HFCs, the benefits monetized in this analysis are limited to the climate benefits of reduced HFC emissions. More details on the social cost of HFCs (SC-HFC) methodology applied for this analysis and resulting monetized climate benefits can be found in **Error! Reference source not found.**.

3.6 Other Potential Benefits of this Rule

The estimated benefits of this rule that are quantified and presented in this analysis are the benefits of avoiding GHG emissions that would contribute to climate damages. There are, however, additional potential benefits that would follow from the provisions, some of which that are not quantified in this analysis.

The provisions that require leak inspections, the repair of leaks, and/or the installation of ALD systems for certain refrigerant-containing appliances are best practices for the maintenance and upkeep of such appliances. Following such best practices accrues benefits for the owner/operator of the appliance by reducing the loss of refrigerant, resulting in savings that are estimated in this analysis. Many unquantified benefits from such best practices also exist. A regular practice of inspecting refrigerant-containing appliances and repairing leaks when detected (rather than topping-up the appliance) also prevents such appliances from breaking down as often and can prolong the effective service life of the appliances (Barnish et al., 1997; Crippa et al., 2021). Fewer repairs of broken appliances and extending their service life directly benefits owner/operators, and in the case of refrigerant-containing appliances, reducing operation failures has the additional benefit of reducing the loss of refrigerated stock (Brush et al., 2011). The costs of a refrigerant-containing appliance at a retail store failing and thousands of pounds of

[31] EPA has determined that the exchange values included in subsection (c) of the AIM Act are identical to the 100-year GWPs included in IPCC (2007). In this context, EPA uses the terms "global warming potential" and "exchange value" interchangeably. One MTEVe is therefore equivalent to one $MTCO_2e$.

perishable stock being lost are considerable, and the aggregate costs of such food waste to the U.S. economy are also significant. In 2021, approximately 344,000 MT of food were lost due to refrigerant-containing equipment issues in the retail and food service sectors, with a value of $1.87 billion (ReFED, 2021).

The provisions of this rule designed to maximize reclaim would provide a number of additional benefits that are not quantified. As the HFC phasedown progresses, the supply of virgin HFCs will be reduced, but the demand for refrigerants, fire suppression agents, aerosol propellants, etc. may continue to grow. When complying with restrictions set by the 2023 Technology Transitions Rule, many uses of HFCs are expected to transition to using lower-GWP—and in some cases non-HFC—substitutes, but it is expected that demand for HFCs will continue, in part based on historic experience with the ODS phaseout. For example, although halons have not been produced or imported into the United States for decades, recycled halons are still used for the initial installation and servicing of certain fire suppression equipment. Reclaimed and recycled HFCs will be needed to meet the continuing demand and to meet certain requirements in the Rule.

By avoiding supply shortages of HFCs that are still needed for servicing certain appliances, maximizing reclaim avoids the economic disruption that might occur, including the stranding of equipment. A robust supply of reclaimed refrigerant would also protect the cold chain needed to deliver food and vaccines. Maximizing reclaim would also benefit sectors not directly covered by provisions of this rule, including certain specialized uses that cannot use reclaimed HFCs.

Chapter 4. Compliance Costs

Using the methodological approaches described chapter Chapter 3 of this RIA addendum, EPA has estimated the compliance costs associated with the provisions contained in the final ER&R Rule. Compliance costs also include all estimated savings (e.g., savings associated with avoided purchase of virgin refrigerant) and may therefore be net negative in certain cases.

The sections below summarize the estimated compliance costs for all relevant provisions contained in the final rule.

4.1 Leak repair and inspection, reclamation, and fire suppression requirements

As described in chapter Chapter 3, compliance costs for the leak repair and inspection, reclamation, and fire suppression requirements contained in the final rule for the affected equipment types shown in Table 3-10 were estimated using a marginal abatement cost (MAC) modeling approach. The additional

HFC consumption- and emissions-reducing measures required by the final rule and their associated costs were estimated on a cost-per-ton of CO_2e basis and integrated with the broader set of abatement measures previously assumed in the compliance path for the Allocation and 2023 Technology Transitions Rules. Results of the base case scenario from the 2023 Technology Transitions Rule RIA Addendum were used as the status quo from which the incremental costs stemming from the additional ER&R measures were evaluated.

Table 4-1 below shows the estimated incremental costs for a subset of model years included in the analysis by provision type.

Table 4-1: Incremental Annual Compliance Costs of MAC Abatement Measures (Millions 2022$)

Year	Leak Repair/ALD	Use of Reclaim for Servicing	Fire Suppression Requirements
2026	$79.5	$-	$0.2
2030	$88.3	$3.9	$0.8
2035	$75.0	$3.1	$0.9
2040	$57.5	$2.3	$0.9
2045	$43.4	$1.8	$1.0
2050	$43.3	$1.9	$1.0

The cost curves below illustrate an updated, integrated compliance path that includes the abatement measures assumed in for the Allocation and 2023 Technology Transitions Rules compliance pathway along with the additional abatement measures required by the ER&R Rule. The curves present rolling total compliance costs and U.S. HFC consumption in a given year as abatement measures are applied from lowest- to highest-cost measures (left to right). The curves help to show the relationship between total abatement and costs. Notably, and as illustrated in Table 4-1 above, for certain ER&R measures such as leak repair, annual abatement and costs decrease over time as HFCs in remaining stocks of equipment reduces. By contrast, abatement and costs (or savings) for the previously modeled 2023 Technology Transitions Rule build over time as the market penetration of HFC alternatives builds over time. The curves represent all options assumed to be undertaken to meet compliance, so the rightmost data point shows the resulting abatement and total cost in a given year (i.e., the rightmost points represent final abatement and net costs in each year after all required measures are applied).

Figure 4-1: Integrated Annual Abatement Pathways under AIM Rules

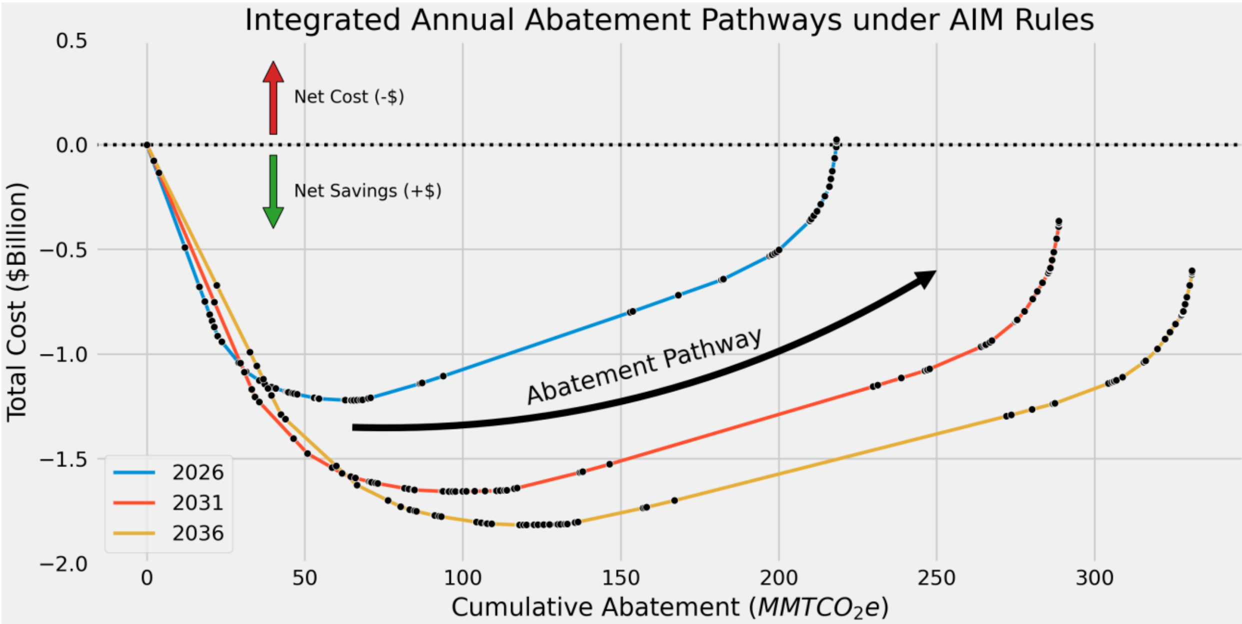

Figure Description: The curves above start with total costs incurred with the cheapest (or most cost-effective) abatement measures applied, with more expensive options added as the curve moves left to right. Points to the left of the low point on each curve represent measures with assumed net negative costs (or cost savings), while points to the right of the low point on each curve represent measures with assumed net positive costs. The rightmost point on each curve for a given year in each figure represents the final total net cost with all required abatement options being applied.

4.2 Disposable cylinder management requirements

To assess the impact of these provisions, EPA relied in part on the report, *Refrigerant Cylinders: Analysis of Use, Disposal, and Distribution of Refrigerants* (EPA 2024a). The report assesses the cost implications for the requirement for heel removal, accounting for the costs associated with the change in procedure for handling of cylinders (e.g., transporting the cylinders for heel removal prior to discarding the cylinder) and the potential savings from avoided refrigerant loss from heel emissions. Because neat HFOs, CO2, ammonia, and hydrocarbons are not regulated substances, these costs and benefits do not reflect possible handling of those refrigerants. For the cylinders containing HFCs (and blends containing HFCs), this analysis assumes that one third will be returned directly to a reclaimer, another third will be returned to a distributor, and the other third will be shipped directly to a landfill or scrap recycling center.

Table 4-2 below summarizes the estimated net costs of these requirements for a subset of model years from 2025-2050. Further detail including sensitivity analyses around some of the assumptions may be found in Appendix L.

Table 4-2: Estimated Compliance Costs for Cylinder Management Provisions (Millions 2022$)

Year	Transportation Costs	Refrigerant Savings	Net Costs
2028	$0.14	$12.9	-$12.8
2030	$0.14	$12.6	-$12.4
2035	$0.13	$11.7	-$11.6
2040	$0.12	$11.3	-$11.2
2045	$0.12	$11.1	-$10.9
2050	$0.12	$11.0	-$10.9

4.3 RCRA alternative standards

As described in Chapter 3, the amendments to RCRA standards for reclaimers are anticipated to be cost neutral or to provide some savings from reduced compliance burden on these entities. As documented in the ICR (ICR Number 2778.02), the average annual reduction in compliance burden is approximately $2,131,844. Taking this value as the net benefit of the amendments for each year from 2026 (the first year in which the avoided costs are estimated to accrue) through 2050 and discounting the savings to 2024, the present value of the savings benefits would be $21.7 million (7 percent discount rate), $35 million (3 percent), or $40 million (2 percent). As discussed in Chapter 3, due to uncertainty and the voluntary nature of the alternative standards, the net benefits may be lower and are shown in this document as a range from $0 to the discounted values above. In addition, these standards fall under a separate statutory authority from the AIM Act and are therefore not incorporated into the overall compliance costs and benefits estimates associated with this rulemaking presented elsewhere in this document.

4.4 Recordkeeping and reporting requirements

The final ER&R Rule contains several provisions that EPA has estimated will result in additional recordkeeping and reporting cost burden for affected industries. EPA has prepared an information collection request (ICR), ICR Number 2778.02, and a Supporting Statement which can be found in the docket.[32] The information collection requirements for recordkeeping, reporting, and labeling are not enforceable until OMB approves them. Among other things, EPA calculated the estimated time and financial burden over a three-year period (ICRs generally cover three-year time periods) for respondents to implement labeling practices and to electronically report data to the Agency on an annual basis. A summary of the respondent burden estimates follows. A summary of underlying assumptions and

[32] Docket ID: EPA-HQ-OAR-2022-0606

methods used can be found in section 3.4 of this document, and the full methodology for these calculations can be found in the docket.

For the three years covered in the ICR, the total respondent burden associated with information collection will average approximately 254 thousand hours per year and the respondent cost will average $19.2 million per year. This does not include over 31 thousand hours and $2.1 million avoided per year in RCRA reclamation reporting and recordkeeping (see section 4.3). The breakdown of the burden per year is provided in Table 4-3 in 2023 dollars, based on 2023 labor rates. The ICR will be subject to renewal after the three-year time period is over.

Table 4-3: Total Respondent Burden Costs Over the Three-year ICR Period (2023$s)

Year	***Total Responses***	***Total Hours***	***Total Labor Costs***	***Total O&M Costs***	***Total Costs***
Year 1 (2026)	4,445,381	141,372	$12,155,355.28	$0.00	$12,155,355
Year 2 (2027)	4,810,033	223,029	$17,580,430.39	$0.00	$17,580,430
Year 3 (2028)	5,115,220	396,447	$27,869,424.28	$0.00	$27,869,424
3yr ICR Annual Average	4,790,211	253,616	$19,201,736.65	$0.00	$19,201,737

For this analysis, these recordkeeping and reporting costs are also shown in 2022 dollars (based on 2022 labor rates) in Table 4-4 below.

Table 4-4: Total Respondent Burden Costs Over the Three-year ICR Period (2022$s)

Year	***Total Responses***	***Total Hours***	***Total Labor Costs***	***Total O&M Costs***	***Total Costs***
Year 1 (2026)	4,445,381	141,372	$12,155,855.96	$0.00	$12,155,856
Year 2 (2027)	4,810,033	223,029	$18,485,140.57	$0.00	$18,485,141
Year 3 (2028)	5,115,220	396,447	$28,854,376.49	$0.00	$28,854,376
3yr ICR Annual Average	4,790,211	253,616	$19,831,791.01	$0.00	$19,831,791

Chapter 5. Climate Benefits

5.1 Consumption and Emission Reductions

EPA’s Vintaging Model is used to estimate both consumption and emissions for each regulated substance for each generation or “vintage” of equipment in both a reference case scenario and policy compliance scenario. Reductions in consumption (in units of MMTEVe) are calculated for a given year by summing the total tons of virgin manufacture of HFCs avoided resulting from compliance with the rule across all end-uses. Emission reductions are similarly calculated by summing total HFC emissions avoided across end-uses in the compliance scenario. For many of the requirements contained in the final ER&R Rule, emissions reductions are assumed to occur in the same year as corresponding reductions in consumption and vice versa. For example, leak repair and inspection measures result in avoided emissions from equipment leaks and an equivalent amount of avoided demand (i.e., consumption) that would otherwise be required to "top off" the leaking equipment. In this case, both the emissions reduction and equivalent consumption reduction are modeled as occurring in the same year. As another example, measures that require increased recovery of HFCs from equipment at disposal also yield a reduction in emissions (since it is assumed the gas would otherwise be released), however the timing of when this recovered material will then be placed back onto the market as reclaimed refrigerant is uncertain and may well occur well after the material was recovered.

The reference case for this analysis includes baseline levels of recovery of HFCs and resulting avoided emissions, derived from the Vintaging Model BAU. While the requirements pertaining to servicing and/or repair of certain equipment with reclaimed HFCs contained in the final rule may yield further recovery of HFCs and resulting avoided emissions, EPA has conservatively assumed that these measures do not necessarily yield incremental HFC emissions reductions beyond these baseline levels.[33] EPA has further assumed that not all reclaimed HFCs utilized for the servicing and/or repair of certain refrigerant-containing equipment would be in direct response to this rule, and that some reclamation would occur in the absence of policy. In this way, EPA has conservatively estimated the amount of HFC recovery, re-use, and reclamation activity attributable to the rule's provisions versus the amount that would otherwise occur in the absence of the requirements. More details on these assumptions can be found in Chapter 3 as well as the appendices accompanying this document.

Due to these factors and assumptions, in the results presented below consumption and emission reductions resulting from the measures included in this analysis may not occur on a one-to-one basis in a given year and may also be less than the full amount of refrigerant demand affected by a particular provision. For more details on these assumptions, please see section 3.3 and Appendix E of this RIA Addendum.

[33] This assumption is made for technical analytic purposes and to avoid over-estimation of incremental benefits relative to the established model BAU relied upon for previous analyses including the Allocation Rules and 2023 Technology Transitions Rule RIA and RIA Addenda, and should not be interpreted as a reflection of the merits of any particular provision contained in the final rule.

Table 5-1 below shows the consumption reductions by year corresponding to the final ER&R Rule compliance scenario (base case) evaluated in this analysis. As discussed in Chapter 3 of this document, incremental benefits reflect reductions that are additional to the compliance scenario previously assessed by EPA in the 2023 Technology Transitions Rule RIA Addendum.

Table 5-1: Annual Incremental Consumption Reductions ($MMTCO_2e$) for ER&R Rule – Base Case Scenario

Year	Leak Repair and ALD	Fire Suppression	Use of Reclaim (Servicing)	Cylinder Management
2026	5.4	0.77	0.0	0.0
2030	4.7	4.1	12	2.1
2035	3.9	4.3	8.4	1.5
2040	2.6	4.5	5.7	1.1
2045	1.3	4.7	4.4	0.94
2050	0.68	4.9	4.5	0.90
Total (2026-2050)	**78**	**98**	**151**	**31**

Table 5-2 below shows the emissions reductions by year corresponding to the final ER&R Rule compliance scenario (base case) evaluated in this analysis. As discussed in Chapter 3 of this document, incremental benefits reflect reductions that are additional to the compliance scenario previously assessed by EPA in the 2023 Technology Transitions Rule RIA addendum.

Table 5-2: Annual Incremental Emissions Reductions ($MMTCO_2e$) for ER&R Rule – Base Case Scenario

Year	Leak Repair and ALD	Fire Suppression	Use of Reclaim (Servicing)	Cylinder Management
2026	5.4	0.01	-*	0.0
2030	5.6	0.01	-	2.1
2035	4.6	0.01	-	1.5
2040	3.0	0.01	-	1.1
2045	1.5	0.01	-	0.94
2050	0.92	0.01	-	0.90
Total (2026-2050)	**88**	**0.21**	**-**	**31**

*Reclaim requirements may lead to additional emissions reductions by inducing increased recovery of refrigerant at servicing and disposal that may otherwise be released or vented. In our base case scenario, EPA does not estimate an increase in these avoided emissions beyond reference case assumptions.

The mix and distribution of HFCs in refrigerant-containing appliances is anticipated to change significantly in the coming decades, resulting in different leak repair and inspection benefits for later years. As shown in Table 5-2 above, the annual GWP-weighted GHG emissions avoided from HFC refrigerants resulting from leak repair and ALD provisions in 2050 is less than half that of 2026. This is not due to decreased efficacy of leak repair or ALD systems or a decrease in use of refrigerant, but rather is a result of the reduction over time in the average GWP of the refrigerant contained in equipment that would otherwise leak.

5.2 Benefits of Reducing HFC Emissions

The primary benefits of this final rule are expected to derive from preventing the emissions of HFCs, thus reducing the damage from climate change that would have been induced by those emissions. The 18 HFCs and their isomers regulated under the AIM Act are GHGs that can trap much more heat per ton emitted than CO_2, a ratio shown in each chemical's GWP. The ratio of the amount of heat trapped by one ton of a chemical in the 100 years after it is emitted to the amount of heat trapped by one ton of CO_2 in 100 years after being emitted is the chemical's 100-year GWP, and the HFCs regulated under the phasedown have 100-year GWPs ranging from 53 to 14,800, with the vast majority of HFCs emitted having GWPs over 1,000. Prior to HFC regulation under the AIM Act, it was anticipated that HFC use and emissions would continue to rise, helping to drive global climate change. Thus, reducing the amount of HFCs that are used and emitted prevents climate damage and associated social costs that would have been induced by those HFC emissions. A more complete discussion of climate change damages and the social benefits of preventing them can be found in Sections 4.1 and 4.2 of the Allocation Framework Rule RIA.[34] While there may be other benefits to phasing down HFCs, the benefits monetized in this analysis are limited to the climate benefits of reduced HFC emissions.

While CO_2 is the most prevalent GHG emitted by humans, it is not the only GHG with climate impacts. The EPA Endangerment Finding (2009) defined a basket of six gases as the GHG air pollutant addressed in the finding, comprising CO_2, methane (CH_4), nitrous oxide (N_2O), HFCs, perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6). The climate impact of the emission of a molecule of each of these gases is generally a function of their lifetime in the atmosphere and the radiative efficiency of that molecule. We estimate the climate benefits for this rulemaking using estimates of the social cost of each HFC (collectively referred to as SC-HFC) that is affected by the rule. The SC-HFC is the monetary value of the net harm to society associated with a marginal increase in HFC emissions in a given year, or the benefit of avoiding that increase. In principle, SC-HFC includes the value of all climate change impacts,

[34] Available at: https://www.regulations.gov/document/EPA-HQ-OAR-2021-0044-0227

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-HFC, therefore, reflects the societal value of reducing emissions of the HFC in question by one metric ton. The SC-HFC is the theoretically appropriate value to use in conducting benefit-cost analyses of policies that affect HFC emissions.

The monetization of climate benefits in this analysis uses the same HFC-specific SC-HFC estimates as used in the proposal RIA and in the estimation of the benefits in the Allocation Framework Rule RIA. That is, for the primary benefits analysis in this final RIA, EPA uses SC-HFC estimates that are consistent with the methodology underlying the interim SC-GHG estimates presented in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG-SCGHG, 2021) that the Interagency Working Group (IWG) on the SC-GHG recommended for use until updated estimates that address the National Academies' recommendations are available. The SC-HFC estimates (shown in Appendix I) are presented in 2022 dollars per metric ton of HFC emitted by year. As explained in Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under E.O. 13990, it is appropriate for agencies to revert to the same set of four values drawn from the social cost of greenhouse gases (SC-GHG) distributions based on three discount rates as were used in regulatory analyses between 2010 and 2016 and subject to public comment (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, conditional on the 3 percent estimate of the discount rate. In that document it was also 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. For purposes of capturing uncertainty around the SC-HFC estimates in analyses, we emphasize the importance of considering all four values for each HFC affected by the rule. For each HFC, the SC-HFC estimate increases over time within the models—i.e., the societal harm from one metric ton emitted in 2030 is higher than the harm caused by one metric ton emitted in 2025—because future emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because gross domestic product (GDP) is growing over time and many damage categories are modeled as proportional to GDP. A more complete discussion of the development of these SC-HFC estimates can be found in section 4.1 of the Allocation Framework Rule RIA.

In addition to the climate benefits presented in Section 5.3 below, in Appendix J, EPA presents the monetized climate benefits of the final rule using a new set of SC-HFC estimates that 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 (NASEM, 2017). The methodology underlying these updated SC-HFC estimates is consistent with the SC-GHG estimates used in the EPA's 2023 RIA for the Final Oil and Gas New Source Performance Standards (NSPS)/Emissions Guidelines (EG) Rulemaking, "Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review". As EPA noted in the proposal RIA for this rulemaking, EPA solicited public comment on the methodology and use of these estimates in the RIA for the agency's December 2022 Oil and Gas NSPS/EG Supplemental Proposal (EPA 2022)[35] and has conducted an external peer review of these estimates, as described further below.

The EPA solicited public comment on the sensitivity analysis and the accompanying draft technical report, External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances, which explains the methodology underlying the new set of estimates, in the December 2022 Supplemental Oil and Gas Proposal. The response to comments document can be found in the docket for that action.

To ensure that the methodological updates adopted in the technical report are consistent with economic theory and reflect the latest science, the EPA also initiated an external peer review panel to conduct a high-quality review of the technical report, completed in May 2023 (EPA 2023c). The peer reviewers commended the agency on its development of the draft update, calling it a much-needed improvement in estimating the SC-GHG and a significant step towards addressing the National Academies' recommendations with defensible modeling choices based on current science. The peer reviewers provided numerous recommendations for refining the presentation and for future modeling improvements, especially with respect to climate change impacts and associated damages that are not currently included in the analysis. Additional discussion of omitted impacts and other updates have been incorporated in the technical report to address peer reviewer recommendations. Complete information about the external peer review, including the peer reviewer selection process, the final report with individual recommendations from peer reviewers, and the EPA's response to each recommendation is available on EPA's website.[36] Appendix J presents the climate benefits of the final rule using the updated

[35] EPA, 2022. Standard of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review. A Proposed Rule by the EPA on 12/06/22.
[36] https://www.epa.gov/environmental-economics/scghg

methodology set forth in EPA 2023d[37] for the calculation of SC-HFC. For more information on the updated SC-HFC estimates please also see the files included with this rule in the docket, titled GLOBAL_2023_AIM.

5.3 Monetized Climate Benefits Results

To monetize the climate benefits resulting from the final ER&R Rule provisions evaluated in this analysis, the HFC emission reductions in each year are multiplied by the corresponding SC-HFC for that HFC in that year.

Table 5-3 below shows the undiscounted monetized incremental climate benefits from all regulated HFCs under the base case. When the base case benefits are discounted to 2024 using a discount rate of 3 percent, the present value of the incremental benefits of the final rule provisions evaluated in this analysis are estimated to be $8.4 billion in 2022 dollars (under a 3% constant discount rate). This is equivalent to an annual incremental benefit of $0.5 billion per year over that timeframe.

Table 5-34: Undiscounted Monetized Climate Benefits 2026–2050 (2022$)[a,b,c,d]

Year	Base Case Incremental Climate Benefits (millions 2022$)			
	SC-HFC Discount Rate and Statistic			
	2.5% Average	3% Average	5% Average	3% 95th Percentile
2025	$0.00	$0.00	$0.00	$0.00
2026	$580.00	$430.00	$180.00	$1,100.00
2027	$670.00	$500.00	$210.00	$1,300.00
2028	$920.00	$690.00	$290.00	$1,800.00
2029	$910.00	$680.00	$290.00	$1,800.00
2030	$900.00	$680.00	$290.00	$1,800.00
2031	$890.00	$670.00	$290.00	$1,800.00
2032	$870.00	$660.00	$290.00	$1,800.00
2033	$860.00	$650.00	$290.00	$1,700.00
2034	$840.00	$640.00	$280.00	$1,700.00
2035	$800.00	$610.00	$270.00	$1,600.00
2036	$760.00	$590.00	$270.00	$1,600.00
2037	$730.00	$560.00	$250.00	$1,500.00
2038	$680.00	$530.00	$240.00	$1,400.00
2039	$640.00	$500.00	$230.00	$1,300.00
2040	$600.00	$470.00	$220.00	$1,300.00
2041	$570.00	$440.00	$210.00	$1,200.00
2042	$510.00	$400.00	$190.00	$1,100.00

[37] EPA, 2023d. Regulatory Impact Analysis of the Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review.

2043	$470.00	$360.00	$180.00	$980.00
2044	$430.00	$340.00	$170.00	$910.00
2045	$400.00	$320.00	$160.00	$850.00
2046	$380.00	$300.00	$150.00	$800.00
2047	$360.00	$280.00	$140.00	$760.00
2048	$340.00	$270.00	$140.00	$730.00
2049	$330.00	$260.00	$140.00	$710.00
2050	$330.00	$260.00	$140.00	$710.00
PV	12000.00	8400.00	3000.00	22000.00
EAV	630.00	480.00	210.000	1300.00

[a] Rows may not appear to add correctly due to rounding.
[b] Present values are calculated using end of year discounting.
[c] The equivalent annual values of benefits are calculated over a 25-year period.
[d] Climate benefits are based on changes in HFC emissions and are calculated using four different estimates of the SC-HFCs (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate).

Unlike many environmental problems where the causes and impacts are distributed more locally, GHG emissions are a global externality making climate change a true global challenge. GHG emissions contribute to damages around the world regardless of where they are emitted. Because of the distinctive global nature of climate change, in the RIA for this final rule the EPA centers attention on a global measure of climate benefits from the HFC emission reductions.

Consistent with all IWG recommended SC-GHG estimates to date, Table 5-3 presents the monetized global climate impacts of the HFC emission changes expected from the final rule. This approach is the same as that taken in EPA regulatory analyses from 2009 through 2016 and since 2021, including in the RIA for the proposal rule. It is also consistent with guidance in (OMB, 2003) (OMB, 2023) that recommends reporting of important international effects[38]. EPA also notes that EPA's cost estimates in

[38] The 2003 version of OMB Circular A-4 states when a regulation is likely to have international effects, "these effects should be reported"; while OMB Circular A-4 recommends that international effects we reported separately, the guidance also explains that "[d]ifferent regulations may call for different emphases in the analysis, depending on the nature and complexity of the regulatory issues." (OMB, 2003).
The 2023 update to Circular A-4 states that "In certain contexts, it may be particularly appropriate to include effects experienced by noncitizens residing abroad in your primary analysis. Such contexts include, for example, when:
• assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. citizens and residents that are difficult to otherwise estimate;
• assessing effects on noncitizens residing abroad provides a useful proxy for effects on U.S. national interests that are not otherwise fully captured by effects experienced by particular U.S. citizens and residents (e.g., national security interests, diplomatic interests, etc.);
• regulating an externality on the basis of its global effects supports a cooperative international approach to the regulation of the externality by potentially inducing other countries to follow suit or maintain existing efforts; or
• international or domestic legal obligations require or support a global calculation of regulatory effects" (OMB 2023). Due to the global nature of the climate change problem, the OMB recommendations of appropriate contexts for considering international effects are relevant to the HFC emission reductions expected from the final rule. For example, as discussed in this RIA, a global focus in evaluating the climate impacts of changes in HFC emissions supports a cooperative international approach to GHG mitigation by potentially inducing other countries to follow suit or maintain existing efforts, and the global SC-HFC estimates

RIAs, including the cost estimates contained in this RIA, regularly do not differentiate between the share of compliance costs expected to accrue to U.S. firms versus foreign interests, such as to foreign investors in regulated entities[39]. A global perspective on climate effects is therefore consistent with the approach EPA takes on costs. There are many reasons, as summarized in this section – and as articulated by OMB and in IWG assessments (IWG-SCC 2010; IWG-SCC 2013; IWG-SCGHG 2016a; IWG-SCGHG 2016b; IWG-SCGHG 2021), the 2015 Response to Comments (IWG-SSC 2015) and in detail in EPA (2023c) and in Appendix A of the Response to Comments document for the December 2023 Final Oil and Gas NSPS/EG Rulemaking – why the EPA focuses on the global value of climate change impacts when analyzing policies that affect GHG emissions.

International cooperation and reciprocity are essential to successfully addressing climate change, as the global nature of greenhouse gases means that a ton of GHGs emitted in any other country harms those in the U.S. just as much as a ton emitted within the territorial U.S. 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. This is a classic public goods problem because each country's reductions benefit everyone else, and no country can be excluded from enjoying the benefits of other countries' reductions. 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 and residents — is for all countries to base their policies on global estimates of damages. A wide range of scientific and economic experts have emphasized the issue of international cooperation and reciprocity as support for assessing global damages of GHG emission in domestic policy analysis. Using a global estimate of damages in U.S. analyses of regulatory actions allows the U.S. to continue to actively encourage other nations, including emerging major economies, to also assess global climate damages of their policies and to take steps to reduce emissions. Several recent studies have empirically examined the evidence on international GHG mitigation reciprocity, through both policy diffusion and technology diffusion effects. See EPA (2023d) for more discussion.

For all of these reasons, the EPA believes that a global metric is appropriate for assessing the climate impacts of GHG emissions in this final RIA. In addition, as emphasized in the (NASEM, 2017) recommendations, "[i]t is important to consider what constitutes a domestic impact in the case of a global

better capture effects on U.S. citizens and residents and U.S. national interests that are difficult to estimate and not otherwise fully captured.

[39] For example, in the RIA for the 2018 Proposed Reconsideration of the Oil and Natural Gas Sector Emission Standards for New, Reconstructed, and Modified Sources, the EPA acknowledged that some portion of regulatory costs will likely "accru[e] to entities outside U.S. borders" through foreign ownership, employment, or consumption. In general, a significant share of U.S. corporate debt and equities are foreign-owned, including in the oil and gas industry.

pollutant that could have international implications that impact the United States." The global nature of GHG pollution and its impacts means that U.S. interests are affected by climate change impacts through a multitude of pathways and these need to be considered when evaluating the benefits of GHG mitigation to U.S. citizens and residents. The increasing interconnectedness of global economy and populations means that impacts occuring outside of U.S. borders can have significant impacts on U.S. interests. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and 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. Those impacts point to the global nature of the climate change problem and are better captured within global measures of the social cost of greenhouse gases.

In the case of these global pollutants, for the reasons articulated in this section, the assessment of global net damages of GHG emissions allows EPA to fully disclose and contextualize the net climate benefits of HFC emission reductions expected from this final rule. The EPA disagrees with public comments received on the December 2022 Oil and Gas NSPS/EG Supplemental Proposal that suggested that the EPA can or should use a metric focused on benefits resulting solely from changes in climate impacts occurring within U.S. borders. The global models used in the SC-GHG modeling do not lend themselves to be disaggregated in a way that could provide comprehensive information about the distribution of the rule's climate impacts to citizens and residents of particular countries, or population groups across the globe and within the U.S. As discussed in the Allocation Framework Rule RIA, these estimates are only a partial accounting and do not capture all of the pathways through which climate change affects public health and welfare. Thus, they only cover a subset of potential climate change impacts. Furthermore, the estimates do not capture spillover or indirect effects whereby climate impacts in one country or region can affect the welfare of residents in other countries or regions— such as how economic and health conditions across countries will impact U.S. business, investments, and travel abroad.[40]

Additional modeling efforts can and have shed further light on some omitted damage categories. For example, the Framework for Evaluating Damages and Impacts (FrEDI) is an open-source modeling

[40]The limitations discussed in this paragraph also apply to the models used in the updated SC-HFC estimates used in Appendix J. For example, two of the models used to inform the updated methodology, the Greenhouse Gas Impact Value Estimator (GIVE) and Data-driven Spatial Climate Impact Model (DSCIM) models, have spatial resolution that allows for some geographic disaggregation of future climate impacts across the world. This permits the calculation of a partial GIVE and DSCIM-based SC-GHG measuring the damages from four or five climate impact categories projected to physically occur within the U.S., respectively, subject to caveats. As discussed at length in EPA (2023c), these damage modules are only a partial accounting and do not capture all of the pathways through which climate change affects public health and welfare. For example, this modeling omits most of the consequences of changes in precipitation, damages from extreme weather events (e.g., wildfires), the potential for nongradual damages from passing critical thresholds (e.g., tipping elements) in natural or socioeconomic systems, and non-climate mediated effects of GHG emissions other than CO_2 fertilization.

framework developed by EPA to facilitate the characterization of net annual climate change impacts in numerous impact categories within the contiguous United States (CONUS) (i.e., excluding Hawaii, Alaska, and U.S. territories) and monetize the associated distribution of modeled damages (Hartin et al., 2023; EPA, 2021).[41] The additional impact categories included in FrEDI reflect the availability of U.S.-specific data and research on climate change effects. Results from FrEDI show that annual damages resulting from climate change impacts within CONUS and for impact categories not represented in the latest global models are expected to be substantial. For example, applying U.S.-specific partial SC-HFC estimates derived from FrEDI to the HFC emission reductions expected under the final rule would yield substantial climate benefits. The present value of the climate benefits of the final rule as measured by FrEDI from climate change impacts in CONUS are estimated to be $2.98 billion (under a 2 percent near-term Ramsey discount rate)[42]. However, the numerous explicitly omitted damage categories and other modeling limitations discussed above and throughout EPA (2023d) make it likely that these estimates underestimate the climate benefits to U.S. citizens and residents of the HFC emission reductions from the final rule.[43] The limitations in developing a U.S.-specific estimate that accurately captures direct and spillover effects on U.S. citizens and residents further demonstrates that it is more appropriate to use a global measure of climate impacts from GHG emissions. The EPA will continue to review developments in the literature, including more robust methodologies for estimating the magnitude of the various damages to U.S. populations from climate impacts and reciprocal international mitigation activities, and explore ways to better inform the public of the full range of GHG impacts.

Chapter 6. Comparison of Costs and Benefits

This section summarizes the total incremental compliance costs (or savings) and the monetized incremental environmental benefits detailed in the sections above to provide an assessment of the total net incremental costs/benefits of requirements contained in the final rule. As described above, abatement costs for the ER&R Rule requirements were estimated using EPA's Vintaging Model and MACC

[41] The FrEDI framework and Technical Documentation have been subject to a public review comment period and an independent external peer review, following guidance in the EPA Peer-Review Handbook for Influential Scientific Information (ISI). Information on the FrEDI peer-review is available at the EPA Science Inventory (EPA Science Inventory, 2021).

[42] Please see the docket for the full calculation (FrEDI_2023_AIM.xlsx).. The inputs to the FrEDI modeling are consistent with the methodological advances reflected in the updated SC-HFCs using in Appendix J.

[43] Another method that has produced estimates of the effect of climate change on U.S.-specific outcomes uses a top-down approach to estimate aggregate damage functions. Published research using this approach include total-economy empirical studies that econometrically estimate the relationship between GDP and a climate variable, usually temperature. As discussed in EPA (2023c) the modeling framework used in the existing published studies using this approach differ in important ways from the inputs underlying the SC-GHG estimates described above (e.g., discounting, risk aversion, and scenario uncertainty) and focus solely on CO_2. Hence, we do not consider this line of evidence in the analysis for this RIA. Updating the framework of total-economy empirical damage functions to be consistent with the methods described in this RIA and EPA (2023c) would require new analysis. Finally, because total-economy empirical studies estimate market impacts, they do not include any non-market impacts of climate change (e.g., heat related mortality) and therefore are also only a partial estimate. EPA will continue to review developments in the literature and explore ways to better inform the public of the full range of GHG impacts.

methodology, while monetized climate benefits were estimated based on SC-HFC methodology consistent with the interim SC-GHG estimates recommended under E.O. 13990. The impact of additional final rule requirements not modeled using the MACC methodology—including cylinder management provisions and recordkeeping and reporting requirements—were then added on in order to estimate the combined costs, benefits, and net benefits of the final rule.

Table 6-1 below provides annual incremental costs, benefits, and net incremental costs of the final rule provisions. As shown, the present value of net incremental benefits is estimated to range from $6.9 billion to $7.5 billion in the base case scenario, using a 3% discount rate for climate benefits and either a 2%, 3%, or 7% discount rate for compliance costs.

Table 6-1: Summary of Annual Incremental Undiscounted Climate Benefits, Costs, and Net Benefits in Base Case Scenario for the 2026–2050 Timeframe (millions of 2022$)[a,b,c,d,e,f]

ER&R Final Rule Impacts – Base Case			
Year	***Incremental Climate Benefits***	***Annual Costs (savings)***	***Net Benefits***
2026	$428	$92	$336
2027	$498	$130	$368
2028	$688	$110	$579
2029	$683	$105	$579
2030	$676	$102	$574
2031	$670	$99	$571
2032	$662	$96	$565
2033	$653	$93	$560
2034	$640	$91	$549
2035	$613	$87	$526
2036	$586	$83	$503
2037	$557	$79	$478
2038	$527	$75	$452
2039	$497	$71	$426
2040	$466	$67	$399
2041	$440	$64	$376
2042	$400	$59	$341
2043	$364	$55	$309
2044	$337	$53	$284
2045	$315	$51	$264
2046	$298	$51	$246
2047	$283	$51	$232
2048	$271	$51	$220
2049	$264	$51	$213
2050	$263	$52	$211

Discount rate	3%	2%	3%	7%	2%	3%	7%
PV	$8,356	$1,499	$1,335	$884	$6,857	$7,021	$7,471
EAV	$480	$77	$77	$76	$403	$403	$404

[a] Benefits include only those related to climate. Climate benefits are based on changes (reductions) in HFC emissions and are calculated using four different estimates of the social cost of HFCs (SC-HFCs): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. For the presentational purposes of this table, we show the benefits associated with the average SC-HFC at a 3 percent discount rate.
[b] Rows may not appear to add correctly due to rounding.
[c] Present values are calculated using end of year discounting.
[d] The annualized present value of costs and benefits are calculated as if they occur over a 25-year period.
[e] The costs presented in this table are annual estimates.
[f] The PV for the net benefits column is found by taking the difference between the PV of climate benefits at 3 percent and the PV of costs discounted at 7 percent, 3 percent or 2 percent. Because the SC-HFC estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the social rate of return on capital (7 percent under OMB Circular A-4 (2003)) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-HFC. See Chapter 5 for more discussion.

Table 6-2 below provides the present value (discounted to 2024) of costs, benefits, and net incremental by type of provision contained in the final rule. Present value for climate benefits is calculated using a 3 percent discount rate, while present value for costs (or saving) is calculated using a 2, 3, and 7 percent discount rate.

Table 6-2: Present Value of Incremental Climate Benefits, Costs, and Net Benefits by type of rule provision in Base Case Scenario for the 2026–2050 Timeframe (millions of 2022$, discounted to 2024)[a,b,c,d]

Provision	Climate Benefits (3%)	Costs (Savings) (2%)	Costs (Savings) (3%)	Costs (Savings) (7%)	Net Benefits 3% Benefits, 2% Costs)	Net Benefits (3% Benefits, 3% Costs)	Net Benefits (3% Benefits, 7% Costs)
Leak Repair And ALD	$6,176	$1,285	$1,146	$760	$4,891	$5,031	$5,417
Fire Suppression	$14	$15	$13	$7	($1)	$1	$7
Cylinder Management	$2,165	($195)	($169)	($101)	$2,360	$2,335	$2,266
Use of Reclaimed HFCs for Servicing		$43	$38	$23	($43)	($38)	($23)
Recordkeeping & Reporting		$350	$308	$195	($350)	($308)	($195)

RCRA Amendments**	-	$0 to ($40)	$0 to ($35)	$0 to ($22)	$0 to $40	$0 to $35	$0 to $22

*Reclaim requirements may lead to additional emissions reductions by inducing increased recovery of refrigerant at servicing and disposal that may otherwise be released or vented. In our base case scenario, EPA does not estimate an increase in these avoided emissions beyond baseline assumptions.
** RCRA Amendments are not included in the total benefits of this final rule as presented in the text above but are included here for informational purposes.

Chapter 7. Environmental Justice

7.1 Introduction and Background

The environmental justice analyses that were conducted as part of the Allocation Framework Rule RIA and subsequent 2024 Allocation Framework Rule and 2023 Technology Transitions Rule RIA addenda addressed issues associated with the impacts of changes in the production of HFCs and certain substitutes of HFCs on communities near facilities identified as producers of these chemicals. EPA could not identify specific effects of the HFC phasedown or transitions on individual communities, but the Agency did identify ten specific facilities with emissions likely to be affected by these rules. EPA analyzed the demographic characteristics of the fence-line communities in the Census Block Groups within 1-, 3-, 5-, and 10-mile radii of the affected facilities. Please refer to Chapter 6 of the Allocation Framework Rule RIA for an extensive discussion of the environmental justice implications of HFC production and transition.

This chapter provides an analysis of the environmental justice (EJ) implications of this final rule under Subsection (h) of the AIM Act. The information provided in this section of this document is for informational purposes only; EPA is not relying on the information in this section as a record basis for the final action. This analysis is largely similar in approach to that used in the previous EJ analyses, in that it focuses on the baseline environmental conditions in communities proximate to known HFC reclamation facilities which EPA expects may be affected by the final rule.

As discussed in the preamble to this rule, the ER&R Rule establishes a program for the management of hydrofluorocarbons that includes requirements for: leak repair and use of automatic leak detectors for certain equipment containing HFC refrigerants; servicing and/or repair of refrigerant-containing equipment in certain sectors or subsectors with reclaimed HFCs; the servicing, repair, disposal, or installation of fire suppression equipment that contains HFCs; removal of HFCs from disposable cylinders before discarding; and recordkeeping, reporting, and labeling. EPA is also establishing alternative Resource Conservation and Recovery Act (RCRA) standards for ignitable spent refrigerants being recycled for reuse. The new standards require that ignitable spent refrigerant being recycled for reuse be sent to EPA-certified reclamation facilities.

7.2 Environmental Justice at EPA

Executive Order 14096, signed April 21, 2023, builds on the prior executive orders to further advance environmental justice (88 FR 25251), including Executive Order 12898 (59 FR 7629, February 16, 1994) and Executive Order 14008 (86 FR 7619, January 27, 2021) which establish federal executive policy on environmental justice. EPA defines[44] environmental justice as the "just treatment and meaningful involvement of all people, regardless of income, race, color, national origin, Tribal affiliation, or disability, in agency decision-making and other Federal activities that affect human health and the environment so that people: (i) are fully protected from disproportionate and adverse human health and environmental effects (including risks) and hazards, including those related to climate change, the cumulative impacts of environmental and other burdens, and the legacy of racism or other structural or systemic barriers; and (ii) have equitable access to a healthy, sustainable, and resilient environment in which to live, play, work, learn, grow, worship, and engage in cultural and subsistence practices."[45] EPA also released its "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis" (EPA 2016) to provide recommendations that encourage analysts to conduct the highest quality analysis feasible, recognizing that data limitations, time and resource constraints, and analytic challenges will vary by media and circumstance. See Section VII of the final rule for further discussion on the implications of this rule with respect to environmental justice.

As noted in the Allocation Framework Rule RIA, the production and consumption of HFCs is expected to result in changes in the emissions of chemicals which burden communities surrounding HFC production facilities. Because of the limited information regarding how much of each substitute would be produced, which substitutes would be used, and what other factors might affect production and emissions at those locations, it's unclear to what extent baseline risks from hazardous air toxics for communities living near HFC production facilities may be affected. We recognize that communities neighboring facilities that currently produce HFCs and HFC alternatives are often overburdened and disadvantaged. The Agency has a strong interest in mitigating undue burden on underserved communities.

EPA stated its intention in the Allocation Framework Rule to "continue to monitor the impacts of this program on HFC and substitute production, and emissions in neighboring communities, as we move

[44] EPA recognizes that Executive Order 14096 (88 FR 25251, April 21, 2023) provides a new terminology and a new definition for environmental justice. For additional information, see *https://www.federalregister.gov/documents/2023/04/26/2023-08955/revitalizing-our-nations-commitment-to-environmental-justice-for-all*.
[45] See, *e.g.*, Environmental Protection Agency. "*Environmental Justice*." Available at: *https://www.epa.gov/environmentaljustice*.

forward to implement this rule" (see 86 FR 55129). EPA will continue to work to address environmental justice and equity concerns for the communities near the facilities identified in this analysis.

7.3 Environmental Justice Analysis for this Rule

In the Allocation Framework Rule, EPA summarized the public health and welfare effects of GHG emissions (including HFCs), including findings that certain parts of the population may be especially vulnerable to climate change risks based on their characteristics or circumstances, including the poor, the elderly, the very young, those already in poor health, the disabled, those living alone, and/or indigenous populations dependent on one or limited resources due to factors including but not limited to geography, access, and mobility (86 FR 55124 – 55125). Potential impacts of climate change raise environmental justice issues. Low-income communities can be especially vulnerable to climate change impacts because they tend to have more limited capacity to bear the costs of adaptation and are more dependent on climate-sensitive resources such as local water and food supplies. In corollary, some communities of color, specifically populations defined jointly by both ethnic/racial characteristics and geographic location, may be uniquely vulnerable to climate change health impacts in the United States.

As discussed in more detail in the RIA for the Allocation Framework Rule, the environmental justice benefits of reducing climate change are significant. The ER&R Rule is expected to result in benefits in the form of reduced GHG emissions, including by reducing the rates of leakage of HFCs to the atmosphere from new and existing equipment. The analysis conducted for this rule also estimates that a portion of these benefits would be incremental to emissions reductions that were anticipated under the Allocation and 2023 Technology Transitions Rules, thus further reducing the risks of climate change.

HFCs are not a local pollutant and have low toxicity to humans. The final rule is expected to result in increased activity at HFC recovery and reclamation facilities. EPA does not anticipate that there are significant increased risks to human health in communities near these facilities due to the presence or potential leakage of the HFCs themselves. It is possible that other chemicals which are potential byproducts of HFC reclamation processes, such as petroleum-based lubricants and waste oils, may be released from these facilities. In addition, the RCRA provisions allow lower flammability spent refrigerants to be sent to HFC recovery and reclamation facilities, potentially increasing the potential for fires at the facilities. To help address the risks posed by fires, the standards include emergency preparedness and response requirements.

For the purposes of this rule, EPA assessed the characteristics of communities near facilities we expect to be affected by this rule (i.e., HFC reclamation facilities). EPA used data from reports required under Section 608 of the Clean Air Act,[46] EPA's Enforcement and Compliance History Online (ECHO) database[47] and information provided by company websites to identify facilities that are active HFC reclaimers. Once reclaim facility locations were identified, EPA retrieved the Facility Registry Service (FRS) IDs for each facility using the Agency's FRS national dataset.[48] EPA derived additional information on the communities surrounding the facilities included in this analysis using data from AirToxScreen 2019 (EPA 2023h) and the Census' American Community Survey 2019 (U.S. Census Bureau 2021). These steps were conducted to facilitate extracting 1) an environmental profile and 2) demographic information within 1, 3, 5 and 10 miles for each facility.

Fenceline communities may be impacted by emissions or chemical releases from facilities of the type identified here, although there is uncertainty about the nature and risks of potential emissions or chemical releases. This analysis notes several limits to our ability to assess the impact of this rule on the exposure that specific communities may face:

- The facilities that we identified are diverse, ranging in size from small, boutique facilities that recover and reclaim HFCs for small markets to large chemical production facilities that have several lines of business that may result in atmospheric emissions. EPA does not have information that allows us to distinguish possible fugitive emissions from HFC reclamation and other potential chemical processing or manufacture.
- Many of the communities near the facilities expected to be affected by this rule are also near other sources of toxic emissions which contribute to environmental justice concerns.
- The final rule, and other changes in the HFC reclamation market, would likely result in an overall increase in reclamation, but may result in increases or decreases in the activity at any given facility, or the construction of additional facilities.
- In regard to the effect of the RCRA alternative standards on flammable refrigerants, any potential increase in volumes sent to reclamation facilities would likely be offset by a decrease in volume sent to incineration facilities, or vented illegally.

Due to the limitations of the current data, we cannot make conclusions about the impact of this rule on individuals or specific communities. For the purposes of identifying environmental justice issues; however, it is important to understand the characteristics of the communities surrounding these facilities to better ensure that future actions, as more information becomes available, can improve outcomes.

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[46] EPA reviewed Section 608 annual reclamation reports to determine facilities that currently reclaim HFCs and may therefore be expected to continue to do so in the future.
[47] EPA's Enforcement and Compliance History Online (ECHO) database was used to verify locations of HFC reclamation facilities (EPA n.d.)
[48] FRS National Data Set available at https://www.epa.gov/frs/epa-frs-facilities-state-single-file-csv-download (EPA 2023h)

Following the format used for the Allocation Framework Rule RIA, this analysis focuses on information that is available on the demographics and baseline exposure of the communities near these facilities.

7.4 Aggregate Average Characteristics of Communities Near Potentially Affected Facilities

The RIA for the Allocation Framework Rule notes that a key issue for evaluating potential for environmental justice concerns is the extent to which an individual might be exposed to feedstock, catalyst, or byproduct emissions from production of HFCs or HFC alternatives. This final rule may result in increases in the numbers of individuals exposed to chemicals in the process of reclaiming and recycling HFCs.

EPA has not undertaken an analysis of how potential emissions from HFC reclamation affect nearby communities. However, a proximity-based approach can identify correlations between the location of these identified reclamation facilities and potential effects on nearby communities. Specifically, this approach assumes that individuals living within a specific distance of an HFC reclamation facility are more likely to be exposed to releases from the reclamation process. Those living further away are less likely to be exposed to these releases. Census block groups that are located within 1, 3, 5 and 10 miles of the facility are selected as potentially relevant distances to proxy for exposure. Socioeconomic and demographic data from the American Community Survey 5-year data release for 2019 is used to examine whether a greater percentage of population groups of concern live within a specific distance from a reclamation facility compared to the national average.

In addition, AirToxScreen data from 2019 for census tracts within and outside of a 1-, 3-, 5- and 10-mile distance are used to approximate the cumulative baseline cancer and respiratory risk due to air toxics exposure for communities near these reclamation facilities. The total cancer risk is reported as the risk per million people if exposed continuously to the specific concentration over an assumed lifetime. The total respiratory risk is reported as a hazard quotient, which is the exposure to a substance divided by the level at which no adverse effects are expected. Both total risk measures are the sum of the individual risk values for all the chemicals evaluated in the AirToxScreen database (EPA 2023h). Note that these risks are not necessarily only associated with a specific HFC reclamation facility. Industrial activity is often concentrated (i.e., multiple facilities located within the same geographic area).

Table 7-1 presents summary information for the demographic data and AirToxScreen risks averaged across the thirty-eight communities near the identified production facilities compared to the overall national average.

The values in the last four columns reflect population-weighted averages across the Census block groups within the specified distance of the facility. While it is not possible to disaggregate the risk information from AirToxScreen by race, ethnicity or income, the overall total cancer and total respiratory risk in communities within 1, 3, 5 or 10 miles of the facilities does appear to be elevated compared to national average.

Table 7-1: Overall Community Profile and 2019 AirToxScreen Risks for Communities Near Identified Facilities

	Overall National Average	***Within 1 mile of reclamation facilities***	***Within 3 miles of reclamation facilities***	***Within 5 miles of reclamation facilities***	***Within 10 miles of reclamation facilities***
% White (race)	72	65	63	62	62
% Black or African American (race)	13	15	16	16	17
% Other (race)	15	19	21	22	21
% Hispanic (ethnic origin)	18	29	29	28	26
Median Household Income (1k 2019$)	71	77	76	75	76
% Below Poverty Line	7.3	7.1	7.5	7.5	7.2
% Below Half the Poverty Line	5.8	5.5	5.7	5.9	5.7
Total Cancer Risk (per million)	26	28	28.6	29	29
Total Respiratory Risk (hazard quotient)	0.31	0.34	0.34	0.35	0.35

Notes: Demographic categories are as described in the 2019 American Community Survey (U.S. Census Bureau 2021). The “hazard quotient” is defined as the ratio of the potential exposure to a substance and the level at which no adverse effects are expected (calculated as the exposure divided by the appropriate chronic or acute value). A hazard quotient of 1 or lower means adverse noncancer effects are unlikely and, thus, can be considered to have negligible hazard. For HQs greater than one, the potential for adverse effects increases, but we do not know by how much. Total cancer and respiratory risk are drawn from the AirToxScreen database (2019) (EPA 2023h).

Looking across the thirty-eight facilities (Table 7-1), a higher percentage of non-white individuals live in the communities near HFC reclamation facilities compared to the national average. Within one mile of the facilities, the percentage of Black or African Americans is slightly higher than the national average, (15 percent compared to 13 percent) but the percentage increases to 16 percent and 17 percent for the 3 mile and 5 mile, and ten mile distances, respectively. For the communities near these facilities, there are more whose race is identified as “Other,” and whose ethnicity is “Hispanic” than the national average. In these communities, the percentage of White residents is higher within one mile of the facilities than farther away. Within one mile, 65 percent of the residents are white, which is lower than the national average of 72 percent.

Median income is generally higher for the communities near these facilities compared to the national average, with the highest median income within the 1-mile radius ($77,000 per year, compared to the national average of $71,000). These communities also generally have similar percentages of low-income households (below the poverty line) and very low-income households (with incomes less than half the poverty line) compared to the national average. The national percentage of households with incomes less than half of the poverty line is 5.8%. Within 1 mile of these specific facilities, the average percentage of households with incomes less than half of the poverty line 5.5 percent. At the 3- and 5-mile distances, the number rises to 5.7 percent and 5.9 percent—it is 5.7 percent in the average 10-mile radius.

For this analysis, we use the 2019 AirToxScreen data for total cancer risk and total respiratory risk. The overall national average total cancer risk using the newest data is 26 per million. The Total Respiratory Index average for the nation as a whole is 0.31. The average aggregate risks in communities near these facilities are generally higher than the national averages. The analysis also shows that Total Cancer Risk is higher for those within the 1-mile average radius and increase at the 3-, 5-, and 10-mile radii. While the Total Respiratory index for communities within one mile of these 38 facilities is 0.34 compared to the national average of 0.31) the risk for those closest to the facilities appears smaller than for those at greater distances. The analysis shows that 3-mile, 5-mile, and 10-mile Total Respiratory Risk averages are 0.34, 0.35, and 0.35 respectively.

7.5 Previous Violation and Enforcement Actions

Table 7-2 below provides summary data for facilities identified in the above analysis that are currently registered with one or more EPA compliance regimes under major statutes including CAA, RCRA, and the Clean Water Act (CWA). The table also provides a count of the number of facilities identified within a Native American tribal boundary or located within Census block groups in the 80th or higher national percentile of one of the primary EJ indexes of EJSCREEN, EPA's screening tool for EJ concerns. These data were obtained from EPA's ECHO. Notably, of the 38 facilities included in the above analysis, EPA identified 19 that are currently registered under CAA, RCRA, the National Pollutant Discharge Elimination System (NPDES), and/or CWA compliance regimes.

Table 7-2: Number of facilities falling under one or more environmental compliance regime

Variable	*Description of Variable*	*Count of Identified HFC Reclaim Facilities*
AIR_FLAG	Facility has an Air Facility System (AFS) ID	7
NPDES_FLAG	Facility has a Clean Water Act NPDES ID	5
SDWIS_FLAG	Facility has a Safe Drinking Water Information System (SDWIS) ID	0

RCRA_FLAG	Facility has a Resource Conservation and Recovery Act Information System (RCRAInfo) ID	12
TRI_FLAG	Facility has a Toxics Release Inventory (TRI) ID (most recent reporting year)	2
GHG_FLAG	Facility has a Greenhouse Gas (E-GGRT) ID	0
FAC_INDIAN_CNTRY_FLG	FRS Tribal Code Flag – a Y/N flag indicating whether or not an associated EPA program reported the facility as being within a Native American tribal boundary.	0
FAC_MAJOR_FLAG	Determines if the facility is a designated as a major.	0
FAC_ACTIVE_FLAG	A Y/N flag indicating if any of the associated ICIS-Air, ICIS-NPDES, RCRA or SDWA permits are in an active status.	18
EJSCREEN_FLAG_US	Indicates facilities located in Census block groups in the 80th or higher national percentile of one of the primary environmental justice (EJ) indexes of EJSCREEN, EPA's screening tool for EJ concerns.	7

Source: EPA's Enforcement and Compliance History Online (ECHO). Note: While EPA places a high priority on ensuring the integrity of the national enforcement and compliance databases, some incorrect data may be present due to the large amount of information compiled across multiple streams of data from state, local, and tribal agencies. Known data quality problems are discussed at https://echo.epa.gov/resources/echo-data/known-data-problems (EPA n.d.).

Table 7-3, Table 7-4, and Table 7-5 below provide further information on formal and informal enforcement actions which have occurred at identified facilities within the last 5 years. Out of the registered facilities, five are registered under CWA, 12 under RCRA, and seven under CAA. Two facilities have recent CWA enforcement violations, as shown in Table 7-3. None of the identified facilities have recent RCRA or CAA enforcement violations.

Table 7-3: Clean Water Act Compliance Status and Recent Enforcement History by Facility

Facility Name	***CWA NPDES Registration***	***CWA Compliance Status***	***Informal Enforcement Actions (last 5 years)***	***Formal Enforcement Actions (last 5 years)***
RECLAIM PA N DELAWARE AVE FAC	Y	Failure to Report DMR - Not Received	4	3
PERFECT SCORE TOO, LTD	Y	No Violation Identified		
REFRIGERANT RECYCLING INC	Y	No Violation Identified		
A-GAS US	Y	No Violation Identified		
NATIONAL REFRIGERANTS INC	Y	Violation Identified		

Source: EPA's Enforcement and Compliance History Online (ECHO). Note: While EPA places a high priority on ensuring the integrity of the national enforcement and compliance databases, some incorrect data may be present due to the large amount of information compiled across multiple streams of data from state, local, and tribal agencies. Known data quality problems are discussed at https://echo.epa.gov/resources/echo-data/known-data-problems (EPA n.d.).

Table 7-4: Resource Recovery and Conservation Act (RCRA) Compliance Status and Recent Enforcement History by Facility

Facility Name	***RCRA Registration***	***RCRA Compliance Status***
CERTIFIED REFRIGERANT SERVICES INC	Y	No Violation Identified
NEWCOMB MECHANICAL INC	Y	No Violation Identified
CHILLER SERVICES	Y	No Violation Identified
J.R.'S APPLIANCE DISPOSAL INC.	Y	No Violation Identified
RECLAIM PA N DELAWARE AVE FAC	Y	No Violation Identified
ACS RECLAMATION & RECOVERY INC	Y	No Violation Identified
REFRIGERANT HANDLING INC	Y	No Violation Identified
C & M ENTERPRISE OF CHRISTMAS FLORIDA	Y	No Violation Identified
CJG LLC DBA GOLDEN REFRIGERANT	Y	No Violation Identified
RECLAMATION TECHNOLOGIES INC	Y	No Violation Identified
SUMMIT REFRIGERANTS	Y	No Violation Identified
HUDSON TECHNOLOGIES CO	Y	No Violation Identified

Source: EPA's Enforcement and Compliance History Online (ECHO). Note: While EPA places a high priority on ensuring the integrity of the national enforcement and compliance databases, some incorrect data may be present due to the large amount of information compiled across multiple streams of data from state, local, and tribal agencies. Known data quality problems are discussed at https://echo.epa.gov/resources/echo-data/known-data-problems (EPA n.d.).

Table 7-5: Clean Air Act (CAA) Compliance Status and Recent Enforcement History by Facility

Facility Name	***CAA Air Facility System (AFS) Registration***	***CAA Compliance Status***
ADVANCED REFRIGERANT TECHNOLOGIES, LLC	Y	No Violation Identified
INSOLUTION KOOL DUCT FABRICATOR	Y	No Violation Identified
J.R.'S APPLIANCE DISPOSAL INC.	Y	No Violation Identified
RECLAMATION TECHNOLOGIES INC	Y	No Violation Identified
SUMMIT REFRIGERANTS	Y	No Violation Identified
HUDSON TECHNOLOGIES CO	Y	No Violation Identified
TRADEWATER EGV	Y	No Violation Identified

Source: EPA's Enforcement and Compliance History Online (ECHO). Note: While EPA places a high priority on ensuring the integrity of the national enforcement and compliance databases, some incorrect data may be present due to the large amount of information compiled across multiple streams of data from state, local, and tribal agencies. Known data quality problems are discussed at https://echo.epa.gov/resources/echo-data/known-data-problems (EPA n.d.)

7.6 Conclusion

The provisions in this final rule are expected to result in benefits in the form of reduced GHG emissions. The analysis conducted for the rule also estimates that a portion of these benefits would be incremental to emissions reductions that were anticipated under the Allocation and 2023 Technology Transitions rules, thus further reducing the risks of climate change.

While providing additional overall climate benefits, this rule may also result in changes in emissions of air pollutants or other chemicals which are potential byproducts of HFC reclamation processes at affected facilities. The market for reclaimed HFCs could drive changes in potential risk for communities living near these facilities. However, the nature and location of the emission changes are uncertain. Moreover, there is insufficient information at this time about which facilities will change reclamation processes. The proximity analysis of these communities demonstrates that:

- Total baseline cancer risk and total respiratory risk from air toxics (not all of which stem from HFC reclamation) is generally higher within 1-10 miles of an HFC reclamation facility;
- Generally, higher percentages of Black or African American individuals live near these facilities;
- Higher percentages of individuals whose race is identified as "Other" live near these facilities;
- Higher percentages of individuals of Hispanic ethnicity live near these facilities;
- It is not clear the extent to which these baseline risks are directly related to HFC reclamation; and,
- continued analysis of HFC reclamation facilities and associated environmental justice concerns is appropriate.

Given limited information at this time, it is unclear to what extent this rule will have disproportionate adverse effects on communities living near HFC reclamation facilities.[49] The Agency will continue to evaluate the impacts of this final rulemaking on affected communities, including communities with environmental justice concerns and consider further action, as appropriate, to protect health in communities affected by HFC reclamation.

References

[49] Statements made in this chapter on the environmental justice concerns of the AIM Act draw support from the following citations: Banzhaf, Spencer, Lala Ma, and Christopher Timmins. 2019. Environmental justice: The economics of race, place, and pollution. Journal of Public Economics; Hernandez-Cortes, D. and Meng, K.C., 2023. Do environmental markets cause environmental injustice? Evidence from California's carbon market (No. w27205). NBER; Hu, L., Montzka, S.A., Miller, B.R., Andrews, A.E., Miller, J.B., Lehman, S.J., Sweeney, C., Miller, S.M., Thoning, K., Siso, C. and Atlas, E.L., 2016. Continued emissions of carbon tetrachloride from the United States nearly two decades after its phaseout for dispersive uses. Proceedings of the National Academy of Sciences; Mansur, E. and Sheriff, G., 2021. On the measurement of environmental inequality: Ranking emissions distributions generated by different policy instruments.; EPA. 2011. Plan EJ 2014. Washington, DC: U.S. EPA, Office of Environmental Justice.; EPA. 2015. Guidance on Considering Environmental Justice During the Development of Regulatory Actions. May 2015.; USGCRP. 2016. The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. U.S. Global Change Research Program, Washington, DC.

Abt Associates (Abt). (2024). Supplemental information on automatic leak detection systems. Prepared for U.S. EPA Stratospheric Protection Division.

American Public Transportation Association (APTA). (2023). 2022 Public Transportation Fact Book. https://www.apta.com/wp-content/uploads/APTA-2022-Public-Transportation-Fact-Book.pdf.

Banzhaf, S., Ma, L., &Timmins, C. (2019). Environmental Justice: The Economics of Race, Place, and Pollution. Journal of Economic Perspectives, 33, no. (1), 185-208. https://doi.org/10.1257/jep.33.1.185.

Barnish, T. J., Muller, M. R., & Kasten, D. J. (1997). Motor maintenance: a survey of techniques and results. Proceedings of the 1997 ACEEE Summer Study on Energy Efficiency in Industry.

Brush, A., Masanet, E., &Worrell, E. (2011). Energy Efficiency Improvement and Cost Saving Opportunities for the Dairy Processing Industry (LBNL-6261E). Lawrence Berkeley National Laboratory, https://doi.org/10.2172/1171534.

Bureau of Labor Statistics (BLS), U.S. Department of Labor. (2022, May). Occupational Employment and Wage Statistics. www.bls.gov/oes/.

Bureau of Labor Statistics (BLS), U.S. Department of Labor. (2023, May). Occupational Employment and Wage Statistics. www.bls.gov/oes/.

Burrows, M., Burd, C., & McKenzie, B. (2021). Commuting by Public Transportation in the United States: 2019 (ACS-48; American Community Survey Reports). U.S. Census Bureau. https://www.census.gov/content/dam/Census/library/publications/2021/acs/acs-48.pdf.

California Air Resources Board (CARB). (2011). Lifecycle Analysis of High-Global Warming Potential Greenhouse Gas Destruction prepared for The California Air Resources Board. Prepared by ICF International. https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/07-330.pdf.

California Air Resources Board. (2009). Initial Statement of Reasons for Proposed Regulation for the Management of High Global Warming Potential Refrigerants for Stationary

Crippa, M., Solazzo, E., Guizzardi, D., Monforti-Ferrario, F., Tubiello, F. N., &Leip, A. (2021). Food systems are responsible for a third of global anthropogenic GHG emissions. Nature Food, 2(3), 198–209. https://doi.org/10.1038/s43016-021-00225-9.

Environmental Investigation Agency (EIA). (2018). Tip of The Iceberg: Implications of Illegal CFC Production and Use (30th Meeting of the Parties to the Montreal Protocol). https://static.us.eia.org/pdfs/EIA_US_CFC11_MOP30.pdf.

Executive Order. No. 12898. (1994). In 3 C.F.R. (p. 276). https://www.govinfo.gov/content/pkg/WCPD-1994-02-14/pdf/WCPD-1994-02-14-Pg276.pdf.

Executive Order. No. 14008. (2021). In 3 C.F.R. (p. 477). https://www.govinfo.gov/content/pkg/DCPD-202100095/pdf/DCPD-202100095.pdf.

Federal Highway Administration (FHWA). (2017). 2017 National Household Travel Survey. U.S. Department of Transportation. https://nhts.ornl.gov/.

Geotab. (2017). The State of Fuel Economy in Trucking. Geotab. https://www.geotab.com/truck-mpg-benchmark/.

Government Finance Officers Associations (GFOA). (n.d.) Local Government Revenue Sources – Cities. https://www.gfoa.org/revenue-dashboard-cities.

Hernandez-Cortes, D., & Meng, K. C. (2023). Do environnemental markets cause environnemental injustice? Evidence from California's carbon market. Journal of Public Economics, 217, 104786. https://doi.org/10.1016/j.jpubeco.2022.104786.

Hu, L., Montzka, S. A., Millera, B. R., Andrews, A. E., Miller, J. B., Lehman, S. J., Sweeney, C., Miller, S. M., Thoning, K., Siso, C., Atlas, E. L., Blake, D. R., de Gouw, J., Gilman, J. B., Dutton, G., Elkins, J. W., Hall, B., Chen, H., Fischer, M. L., Mountain, M. E., Nehrkorn, T., Biraud, S. C., Moore, F. L., & Tans, P. (2016). Continued emissions of carbon tetrachloride from the United States nearly two decades after its phaseout for dispersive uses. Proceedings of the National Academy of Sciences, 113, (11), 2880–2885. https://doi.org/10.1073/pnas.1522284113.

ICF International (ICF). (2005, September 12). Research Conclusions: Buses and Trains Comfort Cooling End Uses for the Vintaging Model [Memorandum].

Interagency Working Group on Social Cost of Greenhouse Gases (IWG-SCGHG). (2021, February). Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide: Interim Estimates under Executive Order 13990. https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.

Interagency Working Group on Social Cost of Greenhouse Gases (IWG-SCGHG). (2016a, August). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/sc_co2_tsd_august_2016.pdf.

Interagency Working Group on Social Cost of Greenhouse Gases (IWG-SCGHG). (2016b, August). Addendum to Technical Support Document on Social Cost of Carbon for Regulatory Impact Analysis under Executive Order 12866: Application of the Methodology to Estimate the Social Cost of Methane and the Social Cost of Nitrous Oxide. https://www.epa.gov/sites/default/files/2016-12/documents/addendum_to_sc-ghg_tsd_august_2016.pdf.

Interagency Working Group on Social Cost of Carbon (IWG-SCC). (2015, July). Response to Comments: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://obamawhitehouse.archives.gov/sites/default/files/omb/inforeg/scc-response-to-comments-final-july-2015.pdf

Interagency Working Group on Social Cost of Carbon (IWG-SCC). (2013, May). Technical Support Document: Technical Update of the Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://obamawhitehouse.archives.gov/sites/default/files/omb/assets/inforeg/technical-update-social-cost-of-carbon-for-regulator-impact-analysis.pdf.

Interagency Working Group on Social Cost of Carbon (IWG-SCC). (2010, February). Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866. https://www.epa.gov/sites/default/files/2016-12/documents/scc_tsd_2010.pdf.

IPCC. (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change. IPCC.

IPCC. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories. https://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

IPCC/TEAP. (2005). Safeguarding the Ozone Layer and the Global Climate System. https://www.ipcc.ch/site/assets/uploads/2018/03/sroc_full-1.pdf.

Mansur, E. T., & Sheriff, G. (2021). On the Measurement of Environmental Inequality: Ranking Emissions Distributions Generated by Different Policy Instruments. Journal of the Association of Environmental and Resource Economists, 8(4), 721–758. https://doi.org/10.1086/713113.

National Academies of Sciences, Engineering, and Medicine (NASEM). (2017). Valuing Climate Changes: Updating Estimation of the Social Cost of Carbon Dioxide (p. 24651). National Academies Press. https://doi.org/10.17226/24651.

Office of Management and Budget (OMB), Executive Office of the President. (2003). OMB Circular A-4, Regulatory Analysis.

Office of Management and Budget (OMB), Executive Office of the President. (2023). OMB Circular A-4, Regulatory Analysis.

Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years, 88 F.R. 46836 (codified at 40 C.F.R. 84) (2023). https://www.federalregister.gov/d/2023-14312.

Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act, 86 F.R. 55116 (codified at 40 C.F.R. §9 and 40 C.F.R. 84) 55116 (2021). https://www.federalregister.gov/d/2021-21030.

ReFED. (2021). Food Waste Monitor. https://insights-engine.refed.org/food-waste-monitor.

Regulatory Flexibility Act (RFA), Pub. L. No. 96–354, 5 U.S.C. § 601 et seq (1980). https://www.govinfo.gov/content/pkg/USCODE-2012-title5/pdf/USCODE-2012-title5-partI-chap6-sec601.pdf

Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review, 87 F.R. 74702 (to be codified at 40 C.F.R. 84) (2023). https://www.federalregister.gov/d/2022-24675.

Standards of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review, 86 F.R. 63110 (to be codified at 40 C.F.R. 60) 63110 (2021). https://www.federalregister.gov/d/2021-24202.

Stratus Consulting Inc. (Stratus). (2009). Screening Analysis to Examine the Economic Impact of Proposed Revisions to the Refrigerant Recycling and Emissions Rule. Prepared for U.S. Environmental Protection Agency.

Urban Institute. (2022). School Districts. Education Data Portal. https://educationdata.urban.org/documentation/.

U.S. Census Bureau. (2021). 2019 American Community Survey, 5-Year Estimates. https://www.census.gov/programs-surveys/acs.

U.S. Census Bureau. (2020). 2017 SUSB Annual Data Tables by Establishment Industry. https://www.census.gov/data/datasets/2017/econ/susb/2017-susb.html.

U.S. Energy Information Administration (U.S. EIA). (2024). Gasoline and Diesel Fuel Update. https://www.eia.gov/petroleum/gasdiesel/index.php.

U.S. Environmental Protection Agency (EPA). 2024. Refrigerant Cylinders: Analysis of Use, Disposal, and Distribution of Refrigerants, April 2024, 2024a.

U.S. Environmental Protection Agency (EPA). 2024. Suppliers of Industrial GHGs and Products Containing GHGs. Updated January 18, 2024, 2024b, https://www.epa.gov/ghgreporting/suppliers-industrial-ghgs-and-products-containing-ghgs.

U.S. Environmental Protection Agency (EPA). 2024. HFC Data Hub. Updated February 7, 2024, 2024c, https://www.epa.gov/climate-hfcs-reduction/hfc-data-hub.

U.S. Environmental Protection Agency (EPA). 2024. Analysis of the U.S. Hydrofluorocarbon Reclamation Market: Stakeholders, Drivers, and Practices. 2024d.

U.S. Environmental Protection Agency (EPA). *Addendum to the Regulatory Impact Analysis for the Phasedown of Hydrofluorocarbons. Notice of Final Rule – Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years*. Oct. 2023a, https://www.regulations.gov/document/EPA-HQ-OAR-2022-0430-0112.

U.S. Environmental Protection Agency (EPA). 2023. *Regulatory Impact Analysis Addendum: Impact of the Technology Transitions Rule.* Sept. 2023b. https://www.regulations.gov/document/EPA-HQ-OAR-2021-0643-0227.

U.S. Environmental Protection Agency (EPA). 2023. EPA's "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances." *Epa.gov*. 2023c. https://www.epa.gov/environmental-economics/scghg.

U.S. Environmental Protection Agency (EPA). 2023. Regulatory Impact Analysis of the Standard of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review. 2023d.

U.S. Environmental Protection Agency (EPA). 2023. Refrigerant Reclamation: Summary 2000-2022. November 28, 2023. 2023e. https://www.epa.gov/system/files/documents/2023-12/2022_reclamation_table.pdf.

U.S. Environmental Protection Agency (EPA). *EPA's Vintaging Model representing 2024 Allocation Rule and 2023 Technology Transitions Rule RIA Addenda. Version VM IO file_v4.4_02.04.16_Final TT Rule 2023 High Addition.xls*, 2023f.

U.S. Environmental Protection Agency (EPA). "Air Toxics Screening Assessment." *Epa.gov*, 2023g, https://www.epa.gov/AirToxScreen.

U.S. Environmental Protection Agency (EPA). *FRS National Data Set*, 2023h, https://www.epa.gov/frs/epa-frs-facilities-state-single-file-csv-download.

U.S. Environmental Protection Agency (EPA). "Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs)." *Regulations.gov*, 5 Oct. 2021, https://www.regulations.gov/document/EPA-HQ-OAR-2021-0044-0227.

U.S. Environmental Protection Agency (EPA). 2022. *Standard of Performance for New, Reconstructed, and Modified Sources and Emissions Guidelines for Existing Sources: Oil and Natural Gas Sector Climate Review.* 2022.

U.S. Environmental Protection Agency (EPA). *Technical Guidance for Assessing Environmental Justice in Regulatory Analysis.* June 2016, https://www.epa.gov/sites/default/files/2016-06/documents/ejtg_5_6_16_v5.1.pdf.

U.S. Environmental Protection Agency (EPA). *Guidance on Considering Environmental Justice During the Development of Regulatory Actions.* May 2015, https://www.epa.gov/sites/default/files/2015-06/documents/considering-ej-in-rulemaking-guide-final.pdf.

U.S. Environmental Protection Agency (EPA). (2011). Plan EJ 2014. Office of Environmental Justice. https://nepis.epa.gov/Exe/ZyPDF.cgi/P100DFCQ.PDF?Dockey=P100DFCQ.PDF

U.S. Environmental Protection Agency (EPA). (2009, December 7). Endangerment Finding. https://www.epa.gov/sites/default/files/2016-08/documents/endangermentfinding_legalbasis.pdf

U.S. Environmental Protection Agency (EPA). *Enforcement and Compliance History Online (ECHO) database.* N.d. https://echo.epa.gov/.

USGCRP. (2016). The Impacts of Climate Change on Human Health in the United States: A Scientific Assessment. Crimmins, A., J. Balbus, J.L. Gamble, C.B. Beard, J.E. Bell, D. Dodgen, R.J. Eisen, N. Fann, M.D. Hawkins, S.C. Herring, L. Jantarasami, D.M. Mills, S. Saha, M.C. Sarofim, J. Trtanj, and L. Ziska, Eds. U.S. Global Change Research Program. https://doi.org/10.7930/J0R49NQX.

Worthington Enterprises. (2023, December 18). Comments on the U.S. Environmental Protection Agency's Proposed Rule Regarding the Management of Certain Hydrofluorocarbons and Substitutes Under Subsection (h) of the American Innovation and Manufacturing Act of 2020. https://www.regulations.gov/comment/EPA-HQ-OAR-2022-0606-0143.

Yasaka, Y., Karkour, S., Shobatake, K., Itsubo, N., & Yakushiji, F. (2023). Life-Cycle Assessment of Refrigerants for Air Conditioners Considering Reclamation and Destruction. Sustainability, 15(1), Article 1. https://doi.org/10.3390/su15010473.

Appendices:

Appendix A. Underlying Data and Assumptions used to Estimate Costs and Benefits for Leak Repair and Inspection Provisions

The sections below describe the method and assumptions used to estimate aggregate incremental costs and benefits associated with the Agency's final regulations related to leak repair and inspection.

Refrigerant-Containing Equipment Mapping

To develop the scope of appliances affected by the leak inspection and repair requirements of the final rule, EPA utilizes the Vintaging Model. As explained in section 3.2, we divide each end-use within the model into three (low, average, and high) to estimate a range of charge sizes across any single end-use because the model only provides an average charge size. From that distribution, we determine appliance types that are not affected by the leak repair and inspection provisions of the final rule (charge size less than 15 pounds) and divide those that are affected into four groups: sub-small (15 to 50 pound charge size); small (51 to 199 pound charge size); medium (200 to 1,999 pound charge size); and large (2,000 pounds or greater charge size). This mapping for CC, CR, and IPR end-uses is shown in Table A-1.

Table A-1: Apportionment of Appliance Types by Charge Size

Appliance Sector	*Appliance Type* [a,b]	*Average Charge Size (lbs)*	*Distributed Charge Size Group*	*Charge Size Analyzed (lbs)*	*Equipment Size*
Comfort Cooling	School & Tour Bus AC	11	Low	5	N/A
			Average	11	N/A
			High	16	Sub-small
	Transit Bus AC	16	Low	8	N/A
			Average	16	Sub-small
			High	24	Sub-small
	Passenger Train AC	41	Low	20	Sub-small
			Average	41	Sub-small
			High	61	Small
	CFC-11 Centrifugal Chillers	1,504	Low	752	Medium
			Average	1,504	Medium
			High	2,255	Large
	CFC-12 Centrifugal Chillers	1,566	Low	783	Medium
			Average	1,566	Medium
			High	2,439	Large

	R-500 Chillers	2,012	Low	1,006	Medium
			Average	2,012	Large
			High	3,018	Large
	CFC-114 Chillers	1,389	Low	695	Medium
			Average	1,389	Medium
			High	2,084	Large
	Screw Chillers	661	Low	331	Medium
			Average	661	Medium
			High	992	Medium
	Scroll Chillers	529	Low	265	Medium
			Average	529	Medium
			High	794	Medium
	Reciprocating Chillers	529	Low	265	Medium
			Average	529	Medium
			High	794	Medium
Commercial Refrigeration	Ice Makers[c]	6	Low	3	N/A
			Average	6	N/A
			High	8	N/A
	Modern Rail Transport	17	Low	8	N/A
			Average	17	Sub-small
			High	25	Sub-small
	Vintage Rail Transport	33	Low	17	Sub-small
			Average	33	Sub-small
			High	50	Sub-small
	Road Transport[c]	10	Low	5	N/A
			Average	10	N/A
			High	15	N/A
	Intermodal Containers[c]	10	Low	5	N/A
			Average	10	N/A
			High	15	N/A
	Condensing Unit	47	Low	23	Sub-small
			Average	47	Sub-small
			High	70	Small
	Reefer Ships	1,653	Low	827	Medium
			Average	1,653	Medium
			High	2,480	Large
	Merchant Fishing Transport	388	Low	194	Small
			Average	388	Medium
			High	582	Medium
	CFC-12 Large Retail Food	2,038	Low	1,019	Medium
			Average	2,038	Large
			High	3,057	Large

	R-502 Large Retail Food	2,038	Low	1,019	Medium
			Average	2,038	Large
			High	3,057	Large
	CFC-12 Cold Storage	25,431	Low	12,716	Large
			Average	25,431	Large
			High	38,147	Large
	HCFC-22 Cold Storage	24,220	Low	12,110	Large
			Average	24,220	Large
			High	36,331	Large
	R-502 Cold Storage	24,613	Low	12,306	Large
			Average	24,613	Large
			High	36,919	Large
Industrial Process Refrigeration	CFC-11 Industrial Process Refrigeration	1,945	Low	972	Medium
			Average	1,945	Medium
			High	2,917	Large
	CFC-12 Industrial Process Refrigeration	2,078	Low	1,039	Medium
			Average	2,078	Large
			High	3,117	Large
	HCFC-22 Industrial Process Refrigeration	15,877	Low	7,939	Large
			Average	15,877	Large
			High	23,816	Large

[a] Only end-uses within appliance sectors CC, CR, and IPR are shown.
[b] End-uses with charge sizes less than 10 pounds are not shown as even under the "high" charge size group, they will not be affected by the leak inspection and repair provisions of the rule.
[c] Road Transport and Intermodal Containers average charge sizes are less than 10 pounds but shown as rounded values. Therefore, these appliance types along with Ice Makers are not affected by the leak repair or ALD provisions but are affected by the reclaim provisions.

Cost assumptions

The rule provisions associated with leak repair and inspection are expected to result in:

- **Incremental compliance costs** associated with conducting leak detection/inspections and repairs.
- **Refrigerant savings** associated with detecting and repairing leaks earlier.

Costs and savings were first estimated using a model equipment approach, and then were scaled up industry-wide based on the total number of affected refrigerant-containing appliances using EPA's Vintaging Model (EPA 2023f).

Leak Repair

The final regulation results in incremental compliance costs to owners and operators when leaks in appliances containing 15 or more pounds of refrigerant containing an HFC or a substitute for an HFC that has a GWP above 53 exceed the threshold leak rate. Owners and operators must repair leaks within 30 days, or, under certain circumstances, request an extension to conduct the repair. If leaks cannot be repaired, the appliance must be retrofitted or retired. These requirements are incremental for owners and operators of appliances containing 15 or more pounds of such refrigerant that exceeds the leak rate of 10 percent for CC, 20 percent for CR, or 30 percent for IPR equipment. When leaks are repaired, all appliances must also conduct initial and follow-up verification tests.

Leak repair outcomes. Extending leak rate thresholds to these refrigerant-containing appliances should result in leaks being identified and repaired sooner than previously assumed in the Allocation Rule Reference Case previously evaluated by EPA. This analysis assumes that leaks will be detected and repaired earlier across all CC, CR, and IPR appliances containing 15 pounds or more of HFC refrigerant. Specifically, the analysis assumed that HFC appliances that experience a leak event requiring repair realizes one of three outcomes:

- The **standard repair** outcome conservatively assumes that as a result of the leak rate threshold, repairs are conducted six weeks earlier than they would have been conducted when waiting for the system performance to noticeably change due to refrigerant loss. If the system is using ALD monitoring, repairs are assumed to be conducted ten weeks earlier.
- Under the **extension repair** outcome, owners/operators request an extension for conducting the repair. The analysis conservatively assumes that repairs are also conducted six weeks earlier as a result of the leak repair requirements (or ten weeks earlier if the system is using ALD monitoring). As mentioned above, the extension allows owners/operators additional time to repair an appliance if components cannot be delivered within the necessary time.
- The **retrofit** outcome assumes that systems that require retrofitting are retrofitted 5 years earlier than they would have been in the absence of the final regulations (i.e., five years were assumed to be remaining before normal end-of-life).

Table A-2below shows the proportion of affected appliances assumed to experience each outcome.

Table A-2: Leak Repair Outcomes and Proportions

Outcome	***HFC Systems***
Standard Repair	98%
Extension Repair	1%
Retrofit	1%

Frequency of repair. Data reported under California's Refrigerant Management Program (RMP) was reviewed to determine an appropriate assumption for the annual frequency of repair for refrigerant-containing appliances that use ALD monitoring systems or are inspected annually or quarterly and are leaking above the threshold annual leak rates in this final action. These data suggest that most appliances with refrigerant charge sizes greater than 50 pounds are repaired once per year, with the exception of larger (>500 pounds) cold storage systems, which are repaired about twice per year on average (CARB 2009).[50] This analysis assumes that there would be a similar relationship between appliances that are subject to this final rule (under subsection (h) of the AIM Act) as there is for the appliances subject to California's RMP.

Repair effectiveness and baseline leak rates. For all equipment types and sizes, post-repair leak rates reflect California Air Resources Board (CARB) (2009) estimates, which were based on EPA's Vintaging Model and Intergovernmental Panel on Climate Change (IPCC)/Technology and Economic Assessment Panel (TEAP) (2005) recommendations. The modeled leak rates represent an outcome in which a post-repair leak rate of zero is not achieved. This assumption therefore may be more conservative than what may be actually achieved once this rule is implemented (i.e., this may assume more post-repair leakage than actually occurs). This is because the GWP-weighted amount of emissions prevented by a given leak repair equals the number of weeks divided by 52 weeks per year, multiplied by the difference of the leak rate pre-repair and the leak rate post-repair) multiplied by the charge size multiplied by the GWP of the refrigerant leaking. A higher post-repair leak rate results in a lower change in leak rate, which results in a lower estimate of emissions prevented. On the other hand, some owners and operators may choose to repair the leak to the point where the leak rate does not trigger further leak repair, in which case the assumed non-zero post-repair leak rate may be more reflective of actual industry behavior.

Table A-3below presents the final leak rate assumptions by equipment sector, type, and size for refrigerant-containing appliances that are affected by the leak repair requirements (i.e., are expected to leak above the leak rate thresholds).[51] The percentage of each equipment type that is experiencing a qualifying leak was presented earlier in section 3.2 of this document.

[50] Cold storage systems that are repaired twice are assumed to follow a modified standard repair outcome. After the first leak is repaired, the system is assumed to leak for six weeks (without ALD) or 10 weeks (with ALD) at the post-repair leak rate. At that point, the system is assumed to experience a failure such that six weeks (without ALD) or 10 weeks (with ALD) after the original repair the system has leaked a qualifying amount of refrigerant to require a second repair.

[51] The average reference case annual leak rates shown in Table A-3 are based on actual leak rate data reported to the CARB RMP. For sub-small equipment, the annual post-repair leak rates are based on the average Vintaging Model leak rate (if lower than the leak rate threshold for the equipment type) or the quintile 1 or quintile 2 leak rate from the modeled leak rate distributions (see Appendix B for more information).

Table A-3: Leak Rate Assumptions by Equipment Sector, Type, and Size

Leak Rate Threshold	Appliance Sector	Equipment Type	Equipment Size	Baseline Annual Leak Rate (for Equipment Requiring Repair)	Annual Post-repair Leak Rate
10%	CC	School & Tour Bus AC	Sub-small	13%	10%
		Transit Bus AC	Sub-small	14%	8%
		Passenger Train AC	Sub-small	10%	2%
		Chiller	Medium	13% – 16%	2%
			Large	14% – 16%	2%
20%	CR	Modern Rail Transport	Sub-small	37%	19%
		Vintage Rail Transport	Sub-small	42%	15%
		Condensing Unit	Sub-small	22%	15%
		Marine Transport	Small	37%	10%
			Medium	29% – 37%	10%
			Large	29%	10%
		Rack	Medium	27%	10%
			Large	27%	10%
		Cold Storage	Large	30% – 34%	10%
30%	IPR	IPR	Medium	43% – 45%	7%
			Large	43% – 45%	7%

Source: EPA (2023f)

Leak Inspection

The final rule would result in incremental compliance costs to appliance owners and operators who would need to conduct leak inspections when leaks are identified that exceed the annual threshold leak rate (i.e., 10% for CC, 20% for CR, or 30% for IPR). For CR and IPR appliances with refrigerant charge sizes between 15 and 500 pounds and for CC and other appliances with charge sizes at or above 15 pounds, leak inspections are annual, and for CR and IPR appliances with refrigerant charge sizes between 500 and 1,500 pounds, leak inspections are quarterly. As a baseline, the cost analysis conservatively assumes that annual leak inspections are not currently performed. This assumption may overestimate compliance costs since some owners and operators have indicated they conduct regular leak inspections to ensure that systems continue to function properly, to avoid recurring refrigerant top-off costs, or they are required to do so based on state regulations. Although the cost analysis assumes no annual leak inspections in the baseline, when estimating baseline emissions, the real-world prevalence of ALD in each subsector is empirically captured in the average leak rates in the Vintaging Model (i.e., unlike costs, emissions are not conservatively estimated, nor are they overestimated due to this assumption). For CR and IPR appliances with refrigerant charge sizes above 1,500 pounds, ALD monitoring is required, so no additional inspections are assumed for these appliances. The incorporation of ALD in the model partially ameliorates the overestimation of costs for leak inspection but does not account for all overestimation due to current leak inspection practices.

Unit Cost and Savings Assumptions

Leak inspection. Leak inspections were assumed to require, on average, four hours per system per inspection for CR and IPR appliances, and two hours for CC appliances.

An hourly labor rate of $58.02 was assumed for leak repair and inspection, based on the mean hourly wage of $27.63 for the Heating, Air-conditioning, and Refrigeration Mechanics and Installers occupational group (49-9021) from the Bureau of Labor Statistics (BLS 2022), plus 110 percent to account for overhead ($30.39).

ALD systems. Direct and indirect ALD system costs include the capital expenditure to purchase the hardware (e.g., detector, sensors), plus installation costs and operations and maintenance (O&M) costs associated with annual system maintenance, certification, and data tracking/storage. These costs are assumed to vary by system size (e.g., number of zones and sensors) and are summarized in Table A-4, with direct ALD systems requiring higher material and installation costs than indirect systems because a separate monitoring device and zone sensors are required (see supplemental analysis [52] titled Supplemental Information on Automatic Leak Detection Systems for more information). For the purposes of this analysis, 50 percent of refrigerant-containing appliance owners were assumed to install direct ALD systems and 50 percent of refrigerant-containing appliance owners are assumed to install indirect ALD systems, which offer additional monitoring capabilities that automatically provide certain reporting and recordkeeping requirements. For new CR and IPR refrigerant-containing appliances containing 1,500 pounds or more of refrigerant and installed on or after January 1, 2026, owners or operators are required to purchase and install an ALD system upon installation or within 30 days of installation. By January 1, 2027 owners or operators with existing CR and IPR appliances containing 1,5000 pounds of refrigerant or more that were installed on or after January 1, 2017, and before January 1, 2026, and before January 1, 2026, are required to purchase and install an ALD system. This analysis assumes 10–21 percent of existing and new CR and IPR appliances would already have regularly calibrated ALD systems installed[53], which is assumed to last the full lifetime of the equipment. In subsequent years, new

[52] Abt 2024. Available in the docket (EPA-HQ-OAR-2022-0606) for this rulemaking at *https://www.regulations.gov*.

[53] This assumes that 10 percent of CR and IPR equipment under 1,500 pounds would have ALD already installed or would be expected to install ALD in the absence of this rulemaking, 16 percent of appliances 1,500–2,000 pounds, and that 21 percent of CR and IPR equipment have ALD as required in California (based on population of California relative to the United States) for appliances greater than 2,000 lb. For more details on these assumptions, see section 3.2.

refrigerant-containing appliances entering the market would also experience costs to purchase and install an ALD system. The upfront costs to purchase and install a direct ALD system were annualized over a 5-year period using a rate of 9.8 percent,[54] whereas indirect ALD system owners are not assumed to finance the material and installation costs. Owners and operators were also assumed to experience annual O&M costs throughout the life of the ALD system (Abt, 2024).

Table A-4: Unit Cost Assumptions for ALD Systems

System Size	***Material Cost***	***Labor Hours***	***Installation Cost***	***Equipment and Installation Cost***	***Annualized Equipment and Installation Cost (Years 1-5)***	***Annual O&M Cost***
Direct ALD System						
1,500–2,000	$9,000	16	$928	$9,928	$2,606	$1,250
2,000+	$9,850	20	$1,160	$11,010	$2,890	$1,440
Indirect ALD System						
1,500-2,000	$2,850	8	$464	$3,314	NA	$950
2,000+	$2,650	10	$580	$3,230	NA	$1,000

Source: (Abt, 2024)

Leak repair. Repair costs are calculated as the base cost of making the repair or retrofit, including labor, parts, refrigerant recovery, and verification tests.[55] These costs are assumed to vary by system size, where leak repairs on a sub-small or small refrigerant-containing appliances are assumed to be relatively simpler and less costly than repairs on medium and large refrigerant-containing appliances. The base costs associated with each outcome were estimated as described below.

- **Standard repair.** Leak repair costs for a "standard repair" are based on assumptions in CARB (2009). CARB surveyed RACHP service contractors and technicians to validate these cost assumptions. Although the CARB estimates did not cover appliances with charge sizes less than 50 pounds, repair costs for these smaller appliances were extrapolated from the CARB estimates.
- **Extension repair.** An "extension repair" is assumed to involve the repair of a major component such as a compressor and is based on costs presented in Stratus (2009).[56]

[54] Businesses are expected to treat ALD systems as capital assets and therefore it is assumed that businesses would be able to access financing for their purchase, if desired, for a loan tenure of five years. The discount rate used in this analysis is consistent with the RIA to the Allocation Framework Rule, which identified a weighted average cost of capital in this sector of 9.8 percent (EPA 2023a).

[55] Industry input suggested that verification tests are already conducted as standard practice during servicing events. Moreover, because initial and follow-up verification tests can both be conducted during the same service appointment, this requirement is not expected to result in additional servicing events. Time required to conduct the verification tests is included in the estimated time to conduct the repair.

[56] Stratus (2009) obtained estimates of retail prices for typical replacement compressors from a supplier (ThermaCom Ltd.).

- **Retrofit.** Retrofit costs were also based on Stratus (2009); this analysis assumed that the cost to retrofit an entire appliance was between two to three times the cost of the compressor or major component.

As noted above, lower leak rate thresholds will result in leaks being repaired sooner than under the current approach. The analysis assumes that repairs are conducted six or ten weeks earlier as a result of these requirements. Thus, the repair costs attributable to the rule are based on the time cost of conducting those repairs six or ten weeks earlier. The interest cost (at 7 percent, 3 percent, and 2 percent per year) of the base repair cost is attributed to the rule; this cost is referred to below as the "effective cost of repair."[57]

An "effective cost" approach was also taken for the cost of retrofitting. Refrigerant-containing appliances that are retrofitted as a result of the regulation are assumed to be retrofitted five years earlier than they would have been under current practices. Thus, the effective cost of retrofitting attributable to the rule is the cost of borrowing the funds for retrofitting for five years at 7 percent, 3 percent, or 2 percent per year.

Table *A-5*below presents the base and effective cost assumptions by repair, appliance charge size, and whether the appliance is using ALD. For retrofit outcomes, the base costs presented do not include the additional cost of replacing the entire refrigerant charge with virgin refrigerant. These costs can be sizable considering, for instance, charge sizes can exceed 10,000 pounds in some systems. For the standard and extension repair outcomes, the cost of refrigerant recharge is not included since it is assumed that the owner or operator would have topped off the system in the absence of the regulatory requirements.

Table A-5*: Unit Cost Assumptions for Leak Repair*[a,b,c]

Appliance Size	***Total Labor Hours***	***Parts***	***Refrigerant Recovery***	***Total Base Cost for Labor, Parts, and Recovery***	***Effective Cost of Early Repair / Retrofit (without ALD)***			***Effective Cost of Early Repair / Retrofit (with ALD)***		
					7% Discount Rate	***3% Discount Rate***	***2% Discount Rate***	***7% Discount Rate***	***3% Discount Rate***	***2% Discount Rate***
Standard Repair										
Sub-small, Small	8	$135	$269	$868	$7.6	$3.3	$2.2	-	-	-
Medium	12	$404	$471	$1,572	$13.8	$5.9	$3.9	$22.9	$9.8	$6.5
Large	16	$808	$876	$2,612	$22.9	$9.8	$6.5	$38.1	$32.7	10.9
Extension Repair										
Sub-small, Small	20.25	$3,501	$269	$4,945	$43.3	$18.5	$12.4	-	-	-
Medium	20.25	$12,768	$471	$14,415	$126	$54.1	$36.0	$210	$90.1	$60.1

[57] CARB used a similar approach—i.e., estimating the effective cost of repair—in developing its economic impact estimates for its High-Global Warming Potential Stationary Source Refrigerant Management Program (CARB 2009).

Large	20.25	$12,768	$876	$14,819	$130	$55.6	$37.0	$216	$92.6	$61.7
Retrofit[c]										
Sub-small, Small	20.25	$10,297	$269	$11,741	$2,616–$2,774	$1,278–$1,355	$881–$935	-	-	-
Medium	20.25	$27,459	$471	$29,105	$6,684–$7,837	$3,266–$3,829	$2,252–$2,641	$7,915–$8,173	$3,867–$3,993	$2,667–$2,754
Large	20.25	$27,459	$876	$29,509	$8,322–$9,214	$4,066–$4,502	$2,804–$3,104	$8,345–$40,352	$4,077–$19,715	$2,812–$13,596

Source: for Standard Repair Labor Hours, Parts, and Recovery Costs: CARB (2009); for Extension Repair and Retrofit: Stratus (2009).

[a] Assumptions for small appliances were proxied for sub-small equipment containing between 15 and 50 49 pounds of refrigerant.

[b] Total base cost is calculated by multiplying the total labor hours by the labor rate ($58.02) and adding the additional costs associated with parts and refrigerant recovery.

[c] Effective costs for repair and retrofit of appliances varies based on the charge size of the appliance replaced.

Refrigerant savings. By causing leaks to be repaired earlier, the regulations would result in refrigerant cost savings for system operators. Refrigerant cost savings are calculated based on the difference between the baseline and post-repair leak rates, multiplied by the charge size, over the six weeks earlier that each repair was conducted (or ten weeks earlier for appliances using an ALD system). An average price of $4 per pound was assumed for all refrigerants, based on the average price of HFC-134a, R-404A, R-407A and R-507 assumed in the RIA for Phasing Down Production and Consumption of HFCs (EPA 2021).

On a per system basis, effective refrigerant savings range from $0.20 for sub-small school bus AC up to $4,699 for large IPR systems.

Leak repair expected costs and savings. Expected costs and burden reductions per model appliance were estimated on a weighted basis, taking into account the proportion of appliances assumed to reach each leak repair outcome and the unit costs and savings associated with each outcome. Expected costs and savings were estimated in the Vintaging Model in a disaggregated manner, distinguishing between appliance sectors, types, sizes, and refrigerant type (EPA 2023f).

Abatement assumptions

Annual Benefits of Leak Repair and Inspection

Similar to the methodology for estimating costs and savings, benefits were estimated using a model equipment approach. For equipment with 15 or more pounds of refrigerant containing an HFC or a substitute for an HFC that has a GWP above 53, benefits were scaled up industry-wide based on the total number of affected equipment using EPA's Vintaging Model and the approach outlined in Section 3.2.

Benefits are calculated as the refrigerant emissions prevented by repairing or retrofitting a leaking system earlier than would have been done if waiting for the system performance to decline. EPA estimates this to be on average six weeks (or ten weeks if systems are using ALD monitoring). Avoided refrigerant emissions are calculated based on the difference between the baseline and post-repair leak rates (shown in Table A-3above), multiplied by the charge size, over the six weeks or ten weeks earlier that each repair was conducted. The amount of avoided refrigerant emissions is weighted by an average GWP. For all equipment types, weighted-average GWPs are based on average charge sizes, refrigerant type, and stock of affected equipment modeled in the Vintaging Model (EPA 2023f).

Table A-6: Average 2026 GWP Assumptions by Equipment Type, Size, and Refrigerant Type

Sector	***Equipment Type***	***Equipment Size***	***Weighted-Average GWP***
CC	School & Tour Bus AC	Sub-Small	1,430
	Transit Bus AC	Sub-small	1,430
	Passenger Train AC	Sub-small	1,602
	Chiller	Medium	1,279 – 1,794
		Large	1,279 – 1,388
CR	Modern Rail Transport	Sub-small	2,676
	Vintage Rail Transport	Sub-small	1,430
	Condensing Unit	Sub-small	3,937
	Marine Transport	Small	3,482
		Medium	2,708 – 3,482
		Large	2,708
	Rack	Medium	2,701
		Large	2,701
	Cold Storage	Large	3,937
IPR	IPR	Medium	1,400 – 1,663
		Large	1,400 – 3,157

Source: EPA (2023f)

The benefits for the extension repair are assumed to be equivalent to the benefits of a standard repair. This analysis does not take into account the additional 30 days (or longer) that the system is leaking between filing the extension and when the actual repair takes place, which could result in overestimating the avoided emissions as a result of the extension request. However, because refrigerant-containing appliances requiring an extension repair have typically more complicated or catastrophic leaks, an extension repair as a result of the regulations would still be taking place earlier than it would under the baseline scenario, and emissions would still be avoided.

Although emission benefits associated with retrofit are anticipated, none are calculated in this analysis. The benefits associated with retrofit fall outside of the one-year timeframe of this analysis (i.e., end users have 30 days to make the initial repair, 30 days to prepare and submit a retrofit plan, and then a full year to complete the retrofit and repair all additional leaks), and thus are not included. Furthermore, because this analysis only considers a one-year period, it does not include benefits from preventing a chronically leaking appliance from continued operation over a longer time period than one year.

On a per appliance basis, effective benefits range from 0.03 metric tons of carbon dioxide (CO_2) equivalent ($MTCO_2eq$) for sub-small school bus AC systems up to 2,503 $MTCO_2eq$ for very large cold storage refrigeration systems (EPA 2023f).

Model Equipment Expected Benefits.

Expected benefits per model equipment were estimated on a weighted basis, taking into account the proportion of appliances assumed to reach each leak repair outcome and the avoided refrigerant emissions associated with each outcome. Expected benefits were estimated in the model in a disaggregated manner, distinguishing between equipment sectors, types, sizes, and refrigerant type. The expected avoided refrigerant emissions per model equipment type (as described above) were multiplied by the number of each type of equipment assumed to experience leaks above the rule's threshold leak rates (see section 3.2). This yields aggregate benefits for the United States as a whole as shown in Table A-7below (EPA 2023f).

Table A-7: Expected Emissions Reductions in 2026 by Equipment Type and Size

Sector	***Equipment Type***	***Equipment Size***	***GHG Emissions Avoided ($MTCO_2eq$)***
CC	School & Tour Bus AC	Sub-small	3,100
	Transit Bus AC	Sub-small	1,900
	Passenger Train AC	Sub-small	1,100
	Chiller	Medium	724,200
		Large	27,500
CR	Modern Rail Transport	Sub-small	1,400
	Vintage Rail Transport	Sub-small	1,900
	Condensing Unit	Sub-small	77,800
	Marine Transport	Small	75,700
		Medium	386,300
		Large	8,300
	Rack	Medium	876,000
		Large	913,400
	Cold Storage	Large	163,700
IPR	IPR	Medium	59,500
		Large	2,065,800

Future Annual Benefits of Leak Repair and Inspection

The analysis described above estimates one-year benefits based on the current distribution of HFC appliances in use. However, because the use of HFCs will change over the next decade due to the phasedown of HFCs in accordance with the AIM Act 2024 Allocation Rule, benefits for the requirements of this rule will also change. Future benefits were estimated using a model equipment, facility, and entity approach. Benefits were then scaled up industry-wide based on the total number of affected appliances anticipated in 2030, 2040, and 2050.

Several assumptions were made to simplify the process of determining the number of affected appliances and the benefits of leak repair in 2030, 2040, and 2050:

- Appliances used in later years are assumed to have the same leak rates and refrigerant charge sizes as those in the 2026 baseline scenario.
- The same proportion of standard repairs, extension repairs, and retrofits are assumed for all years.
- The affected HFC appliances in 2026 are assumed to grow according to the growth rate, lifetime, and transitions in EPA's Vintaging Model—with the adjustments described below.

The growth in stock of HFC appliances was adjusted to account for the Allocation Framework rule, the 2024 Allocation Rule RIA addendum, and the 2023 Technology Transitions RIA addendum. Benefits from the transition away from HFCs were quantified and recently presented in the RIA addendum for the EPA final rulemaking, *Regulatory Impact Analysis Addendum: Impact of the Technology Transitions Rule* (EPA 2023b). To avoid double-counting benefits, this analysis assumes that HFC CR, CC, and IPR appliances begin transitioning away from HFCs in accordance with the transition scenario presented in the 2023 Technology Transitions RIA Addendum.[58]

Appliance-specific average GWP values were also updated to reflect the specific mix of HFC refrigerants assumed in 2030, 2040, and 2050, as shown in Table A-8. GWP values in 2030, 2040, and 2050 include HFCs and substitutes such as HFOs and HCFOs, but did not include other substitutes such as CO_2, ammonia, or hydrocarbons.[59] Affected equipment modeled in EPA's Vintaging Model, which was the basis for the RIA analysis for the AIM Allocation Framework Rule and the RIA Addendum for the 2024 Allocation Rule, were distributed into three size categories (as discussed in section 3.2) and therefore all size categories for some equipment types have the same weighted-average GWP.

Table A-8: Average GWP Assumptions by Equipment Type, Size, and Refrigerant Type for 2030, 2040, and 2050

Sector	***Equipment Type***	***Equipment Size***	***Weighted-Average GWP***		
			2030	***2040***	***2050***

[58] Different types of appliances are assumed to transition in different years as presented in the 2023 Technology Transitions Rule RIA Addendum (EPA 2023b).
[59] Given the GWPs of HFOs, HCFOs, CO_2, ammonia, and hydrocarbons are very low compared to regulated HFCs, the is not expected to affect the weighted-average GWP significantly.

CC	School & Tour Bus AC	Sub-small	1,430	1,430	1,430
	Transit Bus AC	Sub-small	1,430	1,430	1,430
	Passenger Train AC	Sub-small	1,602	1,602	1,602
	Unitary AC	Sub-small	1,717	836	730
	Chiller	Medium	1,122 – 1,832	716 – 1,887	0 – 698
		Large	1,122 – 1,182	716 – 896	618 – 625
CR	Modern Rail Transport	Sub-small	2,676	2,676	2,676
	Vintage Rail Transport	Sub-small	1,430	-	-
	Condensing Unit	Sub-small	3,937	3,937	-
	Marine Transport	Small	3,274	2,817	2,431
		Medium			
		Large	2,554 – 3,274	2,242 – 2,817	1,957 – 2,431
	Rack	Medium	2,554	2,242	1,957
		Large	2,510	2,417	-
	Cold Storage	Large	2510	2417	-
IPR	IPR	Medium	3,937	3,937	-
		Large	1,340 – 1,639	1,078 – 1,442	485 – 517

Benefits on a per-appliance basis were then calculated in the same manner outlined in above and were multiplied by the estimated affected appliances in 2030, 2040, and 2050 described above as shown in Table A-9.

Table A-9: Expected Emissions Reductions by Equipment Type, Size, and Refrigerant Type for 2030, 2040, and 2050

Sector	***Equipment Type***	***Equipment Size***	***MTCO2eq***		
			2030	***2040***	***2050***
CC	School & Tour Bus AC	Sub-small	3,300	3,800	4,100
	Transit Bus AC	Sub-small	2,000	2,300	2,500
	Passenger Train AC	Sub-small	1,200	1,300	1,400
	Chiller	Medium	678,200	324,200	197,700
		Large	25,200	19,500	14,700
CR	Modern Rail Transport	Sub-small	1,500	1,600	1,700
	Vintage Rail Transport	Sub-small	800	-	-
	Condensing Unit	Sub-small	64,700	19,900	-
	Marine Transport	Small	86,900	95,200	92,700
		Medium	445,500	488,800	476,100
		Large	12,400	14,900	14,600
	Rack	Medium	752,200	174,000	-
		Large	840,300	200,800	-
	Cold Storage	Large	197,900	82,700	-
IPR	IPR	Medium	52,200	26,800	3,500
		Large	2,463,100	1,559,000	111,100

Note: By 2040, there are no longer any HFC refrigerants assumed in vintage rail transport systems. By 2050, there are no longer any HFC refrigerants assumed in condensing units, cold storage, and rack systems.

Appendix B. Vintaging Model Leak Rate Distributions

The Vintaging Model simulates equipment emissions and consumption using average leak rates, consistent with *2006 IPCC Guidelines for National Greenhouse Gas Inventories* (IPCC 2006). These average leak rates represent the full spectrum of potential equipment leak events, in which equipment may experience negligible or more significant and/or catastrophic leaks. In order to simulate a more real-world distribution of leak rates, equipment stock was distributed into quintiles, each containing 20 percent of units, where the leak rate distributions equal the weighted average leak rate modeled in the Vintaging Model for each equipment type. The representative leak rate for each quintile was estimated such that each subsector has at least 20 percent of its stock (i.e., one quintile) above the threshold leak rate.

Table B-1 summarizes the leak rate distributions for equipment containing 15 or more pounds of refrigerant considered in the analysis.

For most subsectors, the quintiles were established in increments of 25% percent above or below the average leak rate (i.e., quintile 1 is 50 percent below, quintile 2 is 25 percent below, quintile 3 is the average, quintile 4 is 25 percent above, and quintile 5 is 50 percent above). However, for some subsectors, the average leak rate modeled in the Vintaging Model was significantly below the threshold leak rate, such that the upper quintile leak rate did not exceed the threshold leak rate. In those cases, the fifth quintile leak rate was set to be significantly higher than the average leak rate to ensure that each subsector had some portion of equipment stock above the leak rate threshold and therefore was affected by the final rulemaking. In those cases, the quintile 1 through 4 values were also manipulated such that the weighted average leak rate across all five quintiles still equaled the average leak rate (i.e., quintile 3).[60]

Table B-1: Leak Rate Distributions for Refrigerant-Containing Appliances

<table>
<tr><th rowspan="2">Sector</th><th rowspan="2">Equipment Type</th><th rowspan="2" colspan="2">Vintaging Model Subsector[a]</th><th colspan="5">Quintile</th><th rowspan="2">Average Leak Rate</th></tr>
<tr><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th></tr>
<tr><td colspan="10">Subsectors with charge sizes greater than 15 pounds</td></tr>
<tr><td rowspan="2">CC</td><td rowspan="2">Passenger Train AC</td><td rowspan="2">Passenger Train AC</td><td>% Relative to Average</td><td>0.88</td><td>1.1</td><td>1.4</td><td>1.6</td><td>495</td><td rowspan="2">2.1</td></tr>
<tr><td>Assumed Leak Rate (%)</td><td>0.018</td><td>0.023</td><td>0.029</td><td>0.034</td><td>10[b]</td></tr>
</table>

[60] Because the average Vintaging Model leak rate for certain subsectors (e.g., chillers, IPR) are significantly lower than the threshold leak rates of 10% for comfort cooling and 30% for IPR, it is not possible for the weighted average leak rate across the quintiles to equal the average leak rate using the percentages above.

CC	School & Tour Bus AC	School & Tour Bus AC[c]	% Relative to Average	50	75	100	125	150	10
			Assumed Leak Rate (%)	4.8	7.2	10	12	14	
CR	Rail Transport	Vintage Rail Transport	% Relative to Average	25	50	100	150	175	36
			Assumed Leak Rate (%)	15	24	36	48	57	
CR	Condensing Unit	HCFC-22 Large Condensing Units (Medium Retail Food)	% Relative to Average	50	75	100	125	150	15
			Assumed Leak Rate (%)	6.5	11	15	19	23	
CC	Transit Bus AC	Transit Bus AC	% Relative to Average	50	75	100	125	150	10
			Assumed Leak Rate (%)	5	7.5	10	12	15	
CR	Rail Transport	Modern Rail Transport	% Relative to Average	50	75	100	125	150	33
			Assumed Leak Rate (%)	17	25	33	41	50	
CC	Chiller	CFC-11 Centrifugal Chillers[d]	% Relative to Average	0	0	0	0	850	3.2
			Assumed Leak Rate (%)	0	0	0	0	16	
CC	Chiller	CFC-12 Centrifugal Chillers[d]	% Relative to Average	0	0	0	0	700	2.8
			Assumed Leak Rate (%)	0	0	0	0	14	
CC	Chiller	R-500 Chillers[d]	% Relative to Average	0	0	0	0	700	2.8
			Assumed Leak Rate (%)	0	0	0	0	14	
CC	Chiller	CFC-114 Chillers[d]	% Relative to Average	0	0	0	0	750	3.0
			Assumed Leak Rate (%)	0	0	0	0	15	
CC	Chiller	Screw Chillers[d]	% Relative to Average	0	0	0	0	1300	2.6
			Assumed Leak Rate (%)	0	0	0	0	13	
CC	Chiller	Scroll Chillers[d]	% Relative to Average	0	0	0	0	1300	2.6
			Assumed Leak Rate (%)	0	0	0	0	13	

CC	Chiller	Reciprocating Chillers[d]	% Relative to Average	0	0	0	0	850	2.6
			Assumed Leak Rate (%)	0	0	0	0	13	
IPR	IPR	CFC-11 Industrial Process Refrigeration[d]	% Relative to Average	0	0	0	0	850	8.5
			Assumed Leak Rate (%)	0	0	0	0	43	
IPR	IPR	CFC-12 Industrial Process Refrigeration[d]	% Relative to Average	0	0	0	0	1250	9.0
			Assumed Leak Rate (%)	0	0	0	0	45	
IPR	IPR	HCFC-22 Industrial Process Refrigeration	% Relative to Average	0	0	0	0	500	8.6
			Assumed Leak Rate (%)	0	0	0	0	43	
CR	Cold Storage	CFC-12 Cold Storage	% Relative to Average	0	50	75	100	275	12
			Assumed Leak Rate (%)	0	6.1	9.2	12	34	
CR	Cold Storage	HCFC-22 Cold Storage	% Relative to Average	0	50	75	100	275	11
			Assumed Leak Rate (%)	0	5.5	8.3	11	30	
CR	Cold Storage	R-502 Cold Storage	Assumed Leak Rate (%)	0	50	75	100	275	11
			% Relative to Average	0	5.6	8.4	11	31	
CR	Rack	CFC-12 Large Retail Food	Assumed Leak Rate (%)	50	75	100	125	150	22
			% Relative to Average	11	16	22	27	32	
CR	Rack	R-502 Large Retail Food	Assumed Leak Rate (%)	50	75	100	125	150	22
			Assumed Leak Rate (%)	11	16	22	27	32	
CR	Marine Transport	Merchant Fishing Transport	% Relative to Average	50	75	100	125	150	33
			Assumed Leak Rate (%)	17	25	33	41	50	
CR	Marine Transport	Reefer Ships	% Relative to Average	50	75	100	125	150	23

			Assumed Leak Rate (%)	12	17	23	29	35	

Note: Values may not sum due to independent rounding
[a] Vintaging Model subsectors are often defined by the ODS that was original used, as that affects the transition choices. This analysis does not consider the effects the final rule may have on ODS emissions.
[b] The assumed leak rate percentages for this equipment type quintile exceeds the 10 percent threshold rate for comfort cooling systems, but is shown as equal to 10 percent due to rounding.
[c] 33 percent of units in the School & Tour Bus AC sector are modeled with a charge size above 15 lbs.
[d] The average leak rate modeled does not equal the average leak rate for these subsectors in the Vintaging Model.

Althought the leak inspection and repair provisions only apply to refrigerant-containing appliances with a charge size of 15 pounds or greater, the requirement to use reclaimed refrierant applies to a few subsectors that have smaller charge sizes. The leak rate distribution for these subsectors are shown in Table B-2.

Table B-2: Leak Rate Distributions for Additional Refrigerant-Containing Appliances

Sector	***Equipment Type***	***Vintaging Model Subsector***		***Quintile***					***Average Leak Rate***
				1	***2***	***3***	***4***	***5***	
Subsectors with charge sizes less than 15 pounds									
IPR	Ice Makers	Ice Makers[a]	% Relative to Average	15	30	45	60	350	3.0
			Assumed Leak Rate (%)	0.45	0.90	1.4	1.8	11	
CR	Road Transport	Road Transport	% Relative to Average	50	75	100	125	150	33
			Assumed Leak Rate (%)	17	25	33	41	50	
CR	Intermodal Containers	Intermodal Containers	% Relative to Average	50	75	100	125	150	21
			Assumed Leak Rate (%)	10	16	21	26	31	

[a] The average leak rate modeled does not equal the average leak rate for these subsectors in the Vintaging Model.

Appendix C. Detailed Costs by Equipment – Leak Repair and Inspection

Table C-1: Total Annual Refrigerant Savings in 2030 (2022$) and Combined Annual Cost and Annual Savings with 7% and 3% Discount Rate by Equipment Type

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2030	2030	2030	2030	2030	2030	2030
Leak Repair			**-$20,873,100**	**$19,963,000**	**-$910,100**	**$9,509,100**	**-$11,364,000**	**$6,517,600**	**-$14355500**
CC	School & Tour Bus AC	Sub-Small	-$20,700	$2,400,800	$2,380,100	$1,139,800	$1,119,100	$780,600	$759,900
CC	Transit Bus AC	Sub-Small	-$12,400	$850,500	$838,100	$403,800	$391,400	$276,500	$264,100
CC	Train AC	Sub-Small	-$6,500	$132,700	$126,200	$63,000	$56,500	$43,200	$36,700
CC	Chiller	Medium	-$4,100,500	$7,985,200	$3,884,700	$3,817,700	-$282,800	$2,619,000	-$1,481,500
CC	Chiller	Large	-$192,000	$140,900	-$51,100	$67,000	-$125,000	$45,900	-$146,100
CR	Modern Rail Transport[a]	Sub-Small	-$5,400	$108,000	$102,600	$51,300	$45,900	$35,100	$29,700
CR	Condensing Unit	Sub-Small	-$146,400	$2,903,400	$2,757,000	$1,378,700	$1,232,300	$944,300	$797,900
CR	Vintage Rail Transport[a]	Sub-Small	-$5,600	$40,300	$34,700	$19,200	$13,600	$13,100	$7,500
CR	Rack[a]	Medium	-$2,936,100	$1,648,800	-$1,287,300	$782,300	-$2,153,800	$535,700	-$2,400,400
CR	Rack[a]	Large	-$3,280,300	$1,023,800	-$2,256,500	$483,900	-$2,796,400	$331,000	-$2,949,300
CR	Marine Transport[a]	Small	-$260,200	$318,800	$58,600	$151,500	-$108,700	$103,800	-$156,400
CR	Marine Transport[a]	Medium	-$1,342,500	$1,518,300	$175,800	$725,900	-$616,600	$498,000	-$844,500
CR	Marine Transport[a]	Large	-$47,600	$15,300	-$32,300	$7,200	-$40,400	$4,900	-$42,700
CR	Cold Storage	Large	-$233,500	$39,500	-$194,000	$18,800	-$214,700	$12,900	-$220,600
IPR	IPR	Medium	-$284,900	$127,300	-$157,600	$60,900	-$224,000	$41,800	-$243,100
IPR	IPR	Large	-$7,998,500	$709,400	-$7,289,100	$338,100	-$7,660,400	$231,800	-$7,766,700

Leak Inspection			**$0**	**$73,942,500**	**$73,942,500**	**$73,942,500**	**$73,942,500**	**$73,942,500**	**$73,942,500**
CC	School & Tour Bus AC	Sub-Small	$0	$8,195,200	$8,195,200	$8,195,200	$8,195,200	$8,195,200	$8,195,200
	Transit Bus AC	Sub-Small	$0	$2,903,400	$2,903,400	$2,903,400	$2,903,400	$2,903,400	$2,903,400
	Train AC	Sub-Small	$0	$450,200	$450,200	$450,200	$450,200	$450,200	$450,200
	Chiller	Medium	$0	$10,755,700	$10,755,700	$10,755,700	$10,755,700	$10,755,700	$10,755,700
	Chiller	Large	$0	$147,900	$147,900	$147,900	$147,900	$147,900	$147,900
CR	Modern Rail Transport[a]	Sub-Small	$0	$736,900	$736,900	$736,900	$736,900	$736,900	$736,900
	Condensing Unit	Sub-Small	$0	$19,665,500	$19,665,500	$19,665,500	$19,665,500	$19,665,500	$19,665,500
	Vintage Rail Transport[a]	Sub-Small	$0	$273,900	$273,900	$273,900	$273,900	$273,900	$273,900
	Rack[a]	Medium	$0	$10,881,300	$10,881,300	$10,881,300	$10,881,300	$10,881,300	$10,881,300
	Rack[a]	Large	$0	$3,545,700	$3,545,700	$3,545,700	$3,545,700	$3,545,700	$3,545,700
	Marine Transport[a]	Small	$0	$2,069,900	$2,069,900	$2,069,900	$2,069,900	$2,069,900	$2,069,900
	Marine Transport[a]	Medium	$0	$10,520,000	$10,520,000	$10,520,000	$10,520,000	$10,520,000	$10,520,000
	Marine Transport[a]	Large	$0	$50,500	$50,500	$50,500	$50,500	$50,500	$50,500
	Cold Storage	Large	$0	$35,800	$35,800	$35,800	$35,800	$35,800	$35,800
IPR	IPR	Medium	$0	$1,338,300	$1,338,300	$1,338,300	$1,338,300	$1,338,300	$1,338,300
	IPR	Large	$0	$2,372,300	$2,372,300	$2,372,300	$2,372,300	$2,372,300	$2,372,300
Automatic Leak Detection			**$0**	**$26,491,300**	**$26,491,300**	**$26,491,300**	**$26,491,300**	**$26,491,300**	**$26,491,300**
CC	School & Tour Bus AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Transit Bus AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Train AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Chiller	Medium	$0	$0	$0	$0	$0	$0	$0
	Chiller	Large	$0	$0	$0	$0	$0	$0	$0
CR	Modern Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Condensing Unit	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0

	Rack[a]	Medium	$0	$7,725,900	$7,725,900	$7,725,900	$7,725,900	$7,725,900	$7,725,900
	Rack[a]	Large	$0	$7,725,900	$7,725,900	$7,725,900	$7,725,900	$7,725,900	$7,725,900
	Marine Transport[a]	Small	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Medium	$0	$172,800	$172,800	$172,800	$172,800	$172,800	$172,800
	Marine Transport[a]	Large	$0	$188,300	$188,300	$188,300	$188,300	$188,300	$188,300
	Cold Storage	Large	$0	$447,700	$447,700	$447,700	$447,700	$447,700	$447,700
IPR	IPR	Medium	$0	$0	$0	$0	$0	$0	$0
	IPR	Large	$0	$10,230,700	$10,230,700	$10,230,700	$10,230,700	$10,230,700	$10,230,700
Reporting & Recordkeeping			**$0**	**$10,770,884**	**$10,770,884**	**$10,770,884**	**$10,770,884**	**$10,770,884**	**$10,770,884**
CC, CR, and IPR	CC and CR 15–50 lb.	15-50	$0	$6,115,317	$6,115,317	$6,115,317	$6,115,317	$6,115,317	$6,115,317
	CC, CR, and IPR ≥50 lb.	50+	$0	$4,655,567	$4,655,567	$4,655,567	$4,655,567	$4,655,567	$4,655,567
Total			**-$20,873,100**	**$131,167,684**	**$110,294,584**	**$120,713,784**	**$99,840,684**	**$117,722,284**	**$96,849,184**

Totals may not sum due to independent rounding.

[a] The costs and savings for Modern Rail Transport, Vintage Rail Transport, Rack, and Marine Transport reflect the requirements to use reclaimed material starting in 2029.

Table C-2: Total Annual Refrigerant Savings in 2040 (2022$) and Combined Annual Cost and Annual Savings with 7% and 3% Discount Rate by Equipment Type

Sector	***Equipment Type***		***Annual Refrigerant Savings***	***7% Discount Rate***		***3% Discount Rate***		***2% Discount Rate***	
				Incremental Compliance Costs	***Combined Annual Savings and Compliance Costs***	***Incremental Compliance Costs***	***Combined Annual Savings and Compliance Costs***	***Incremental Compliance Costs***	***Combined Annual Savings and Compliance Costs***
			2040	***2040***	***2040***	***2040***	***2040***	***2040***	***2040***
Leak Repair			**-$12,790,700**	**$13,708,900**	**$918,200**	**$6,531,600**	**-$6,259,100**	**$4,476,900**	**-$8,313,800**
CC	School & Tour Bus AC	Sub-Small	-$23,600	$2,731,800	$2,708,200	$1,296,900	$1,273,300	$888,200	$864,600
	Transit Bus AC	Sub-Small	-$14,100	$967,700	$953,600	$459,400	$445,300	$314,600	$300,500

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2040	2040	2040	2040	2040	2040	2040
	Train AC	Sub-Small	-$7,200	$145,400	$138,200	$69,100	$61,900	$47,300	$40,100
	Chiller	Medium	-$2,984,500	$5,210,500	$2,226,000	$2,490,600	-$493,900	$1,708,500	-$1,276,000
	Chiller	Large	-$204,000	$149,600	-$54,400	$71,200	-$132,800	$48,800	-$155,200
CR	Modern Rail Transport[a]	Sub-Small	-$5,700	$115,600	$109,900	$54,900	$49,200	$37,600	$31,900
	Condensing Unit	Sub-Small	-$45,100	$893,900	$848,800	$424,500	$379,400	$290,700	$245,600
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Medium	-$705,500	$366,600	-$338,900	$173,600	-$531,900	$118,800	-$586,700
	Rack[a]	Large	-$814,000	$230,800	-$583,200	$108,700	-$705,300	$74,300	-$739,700
	Marine Transport[a]	Small	-$331,200	$405,700	$74,500	$192,900	-$138,300	$132,100	-$199,100
	Marine Transport[a]	Medium	-$1,711,400	$1,932,200	$220,800	$923,800	-$787,600	$633,700	-$1,077,700
	Marine Transport[a]	Large	-$65,300	$19,800	-$45,500	$9,300	-$56,000	$6,400	-$58,900
	Cold Storage	Large	-$96,500	$16,500	-$80,000	$7,800	-$88,700	$5,400	-$91,100
IPR	IPR	Medium	-$167,100	$74,700	-$92,400	$35,800	-$131,300	$24,500	-$142,600
	IPR	Large	-$5,615,500	$448,100	-$5,167,400	$213,100	-$5,402,400	$146,000	-$5,469,500
Leak Inspection			**$0**	**$47,214,200**	**$47,214,200**	**$47,214,200**	**$47,214,200**	**$47,214,200**	**$47,214,200**
CC	School & Tour Bus AC	Sub-Small	$0	$9,325,000	$9,325,000	$9,325,000	$9,325,000	$9,325,000	$9,325,000
	Transit Bus AC	Sub-Small	$0	$3,303,700	$3,303,700	$3,303,700	$3,303,700	$3,303,700	$3,303,700
	Train AC	Sub-Small	$0	$493,300	$493,300	$493,300	$493,300	$493,300	$493,300
	Chiller	Medium	$0	$6,949,600	$6,949,600	$6,949,600	$6,949,600	$6,949,600	$6,949,600
	Chiller	Large	$0	$157,000	$157,000	$157,000	$157,000	$157,000	$157,000
CR	Modern Rail Transport[a]	Sub-Small	$0	$788,700	$788,700	$788,700	$788,700	$788,700	$788,700

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2040	2040	2040	2040	2040	2040	2040
	Condensing Unit	Sub-Small	$0	$6,054,800	$6,054,800	$6,054,800	$6,054,800	$6,054,800	$6,054,800
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Medium	$0	$1,992,300	$1,992,300	$1,992,300	$1,992,300	$1,992,300	$1,992,300
	Rack[a]	Large	$0	$398,500	$398,500	$398,500	$398,500	$398,500	$398,500
	Marine Transport[a]	Small	$0	$2,634,200	$2,634,200	$2,634,200	$2,634,200	$2,634,200	$2,634,200
	Marine Transport[a]	Medium	$0	$13,365,200	$13,365,200	$13,365,200	$13,365,200	$13,365,200	$13,365,200
	Marine Transport[a]	Large	$0	$41,900	$41,900	$41,900	$41,900	$41,900	$41,900
	Cold Storage	Large	$0	$13,100	$13,100	$13,100	$13,100	$13,100	$13,100
IPR	IPR	Medium	$0	$785,700	$785,700	$785,700	$785,700	$785,700	$785,700
	IPR	Large	$0	$911,200	$911,200	$911,200	$911,200	$911,200	$911,200
Automatic Leak Detection			**$0**	**$17,473,700**	**$17,473,700**	**$17,473,700**	**$17,473,700**	**$17,473,700**	**$17,473,700**
CC	School & Tour Bus	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Transit Bus AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Train AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Chiller	Medium	$0	$0	$0	$0	$0	$0	$0
	Chiller	Large	$0	$0	$0	$0	$0	$0	$0
CR	Modern Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Condensing Unit	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Medium	$0	$2,764,700	$2,764,700	$2,764,700	$2,764,700	$2,764,700	$2,764,700
	Rack[a]	Large	$0	$2,764,700	$2,764,700	$2,764,700	$2,764,700	$2,764,700	$2,764,700

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2040	2040	2040	2040	2040	2040	2040
	Marine Transport[a]	Small	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Medium	$0	$261,500	$261,500	$261,500	$261,500	$261,500	$261,500
	Marine Transport[a]	Large	$0	$290,700	$290,700	$290,700	$290,700	$290,700	$290,700
	Cold Storage	Large	$0	$202,300	$202,300	$202,300	$202,300	$202,300	$202,300
IPR	IPR	Medium	$0	$0	$0	$0	$0	$0	$0
	IPR	Large	$0	$11,189,800	$11,189,800	$11,189,800	$11,189,800	$11,189,800	$11,189,800
Reporting & Recordkeeping			**$0**	**$7,860,124**	**$7,860,124**	**$7,860,124**	**$7,860,124**	**$7,860,124**	**$7,860,124**
CC, CR, and IPR	CC and CR 15–50 lb.	15-50	$0	$4,629,656	$4,629,656	$4,629,656	$4,629,656	$4,629,656	$4,629,656
	CC, CR, and IPR ≥50 lb.	50+	$0	$3,230,469	$3,230,469	$3,230,469	$3,230,469	$3,230,469	$3,230,469
Total			**-$12,790,700**	**$86,256,924**	**$73,466,224**	**$79,079,624**	**$66,288,924**	**$77,024,924**	**$64,234,224**

Totals may not sum due to independent rounding.

[a] The costs and savings for Modern Rail Transport, Vintage Rail Transport, Rack, and Marine Transport reflect the requirements to use reclaimed material starting in 2029.

Table C-3: Total Annual Refrigerant Savings in 2050 (2022$) and Combined Annual Cost and Annual Savings with 7% and 3% Discount Rate by Equipment Type

Sector	Equipment Type	Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
			Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
		2050	2050	2050	2050	2050	2050	2050
Leak Repair		**-$7,068,700**	**$11,896,900**	**$4,828,200**	**$5,670,700**	**-$1,398,000**	**$3,887,400**	**-$3,181,300**

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2050	2050	2050	2050	2050	2050	2050
CC	School & Tour Bus AC	Sub-Small	-$25,600	$2,959,500	$2,933,900	$1,405,000	$1,379,400	$962,200	$936,600
	Transit Bus AC	Sub-Small	-$15,300	$1,048,400	$1,033,100	$497,700	$482,400	$340,900	$325,600
	Train AC	Sub-Small	-$7,800	$157,500	$149,700	$74,800	$67,000	$51,200	$43,400
	Chiller	Medium	-$2,709,700	$4,629,300	$1,919,600	$2,212,700	-$497,000	$1,517,900	-$1,191,800
	Chiller	Large	-$210,800	$154,700	-$56,100	$73,600	-$137,200	$50,400	-$160,400
CR	Modern Rail Transport[a]	Sub-Small	-$6,200	$125,200	$119,000	$59,400	$53,200	$40,700	$34,500
	Condensing Unit	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Medium	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Large	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Small	-$373,600	$457,700	$84,100	$217,600	-$156,000	$149,100	-$224,500
	Marine Transport[a]	Medium	-$1,931,300	$2,178,900	$247,600	$1,041,800	-$889,500	$714,700	-$1,216,600
	Marine Transport[a]	Large	-$72,900	$21,700	-$51,200	$10,200	-$62,700	$7,000	-$65,900
	Cold Storage	Large	$0	$0	$0	$0	$0	$0	$0
IPR	IPR	Medium	-$59,800	$26,800	-$33,000	$12,800	-$47,000	$8,800	-$51,000
	IPR	Large	-$1,655,700	$137,200	-$1,518,500	$65,100	-$1,590,600	$44,500	-$1,611,200
Leak Inspection			**$0**	**$39,939,300**	**$39,939,300**	**$39,939,300**	**$39,939,300**	**$39,939,300**	**$39,939,300**
CC	School & Tour Bus AC	Sub-Small	$0	$10,102,300	$10,102,300	$10,102,300	$10,102,300	$10,102,300	$10,102,300
	Transit Bus AC	Sub-Small	$0	$3,579,100	$3,579,100	$3,579,100	$3,579,100	$3,579,100	$3,579,100
	Train AC	Sub-Small	$0	$534,200	$534,200	$534,200	$534,200	$534,200	$534,200
	Chiller	Medium	$0	$6,161,900	$6,161,900	$6,161,900	$6,161,900	$6,161,900	$6,161,900
	Chiller	Large	$0	$162,500	$162,500	$162,500	$162,500	$162,500	$162,500

Sector	Equipment Type		Annual Refrigerant Savings	7% Discount Rate		3% Discount Rate		2% Discount Rate	
				Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs	Incremental Compliance Costs	Combined Annual Savings and Compliance Costs
			2050	2050	2050	2050	2050	2050	2050
CR	Modern Rail Transport[a]	Sub-Small	$0	$854,100	$854,100	$854,100	$854,100	$854,100	$854,100
	Condensing Unit	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Medium	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Large	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Small	$0	$2,971,800	$2,971,800	$2,971,800	$2,971,800	$2,971,800	$2,971,800
	Marine Transport[a]	Medium	$0	$15,054,600	$15,054,600	$15,054,600	$15,054,600	$15,054,600	$15,054,600
	Marine Transport[a]	Large	$0	$39,200	$39,200	$39,200	$39,200	$39,200	$39,200
	Cold Storage	Large	$0	$0	$0	$0	$0	$0	$0
IPR	IPR	Medium	$0	$281,900	$281,900	$281,900	$281,900	$281,900	$281,900
	IPR	Large	$0	$197,700	$197,700	$197,700	$197,700	$197,700	$197,700
Automatic Leak Detection			**$0**	**$5,713,900**	**$5,713,900**	**$5,713,900**	**$5,713,900**	**$5,713,900**	**$5,713,900**
CC	School & Tour AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Transit Bus AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Train AC	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Chiller	Medium	$0	$0	$0	$0	$0	$0	$0
	Chiller	Large	$0	$0	$0	$0	$0	$0	$0
CR	Modern Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Condensing Unit	Sub-Small	$0	$0	$0	$0	$0	$0	$0
	Vintage Rail Transport[a]	Sub-Small	$0	$0	$0	$0	$0	$0	$0

Sector	***Equipment Type***		***Annual Refrigerant Savings***	***7% Discount Rate***		***3% Discount Rate***		***2% Discount Rate***	
				Incremental Compliance Costs	***Combined Annual Savings and Compliance Costs***	***Incremental Compliance Costs***	***Combined Annual Savings and Compliance Costs***	***Incremental Compliance Costs***	***Combined Annual Savings and Compliance Costs***
			2050	***2050***	***2050***	***2050***	***2050***	***2050***	***2050***
	Rack[a]	Medium	$0	$0	$0	$0	$0	$0	$0
	Rack[a]	Large	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Small	$0	$0	$0	$0	$0	$0	$0
	Marine Transport[a]	Medium	$0	$327,100	$327,100	$327,100	$327,100	$327,100	$327,100
	Marine Transport[a]	Large	$0	$335,900	$335,900	$335,900	$335,900	$335,900	$335,900
	Cold Storage	Large	$0	$0	$0	$0	$0	$0	$0
IPR	IPR	Medium	$0	$0	$0	$0	$0	$0	$0
	IPR	Large	$0	$5,050,900	$5,050,900	$5,050,900	$5,050,900	$5,050,900	$5,050,900
Reporting & Recordkeeping			**$0**	**$7,361,138**	**$7,361,138**	**$7,361,138**	**$7,361,138**	**$7,361,138**	**$7,361,138**
CC, CR, and IPR	CC and CR 15-50 lbs.[a]	15-50	$0	$4,097,624	$4,097,624	$4,097,624	$4,097,624	$4,097,624	$4,097,624
	CC, CR, and IPR ≥50 lbs.	50+	$0	$3,263,514	$3,263,514	$3,263,514	$3,263,514	$3,263,514	$3,263,514
Total			**-$7,068,700**	**$64,911,238**	**$57,842,538**	**$58,685,038**	**$51,616,338**	**$56,901,738**	**$49,833,038**

Totals may not sum due to independent rounding.

[a] The costs and savings for Modern Rail Transport, Vintage Rail Transport, Rack, and Marine Transport reflect the requirements to use reclaimed material starting in 2029.

Appendix D. Modeled Servicing Demand for Equipment Affected by Reclamation Provisions, by HFC Gas

Projected reclaimed refrigerant demand, accounting for the leak repair provisions in the final rule, is shown by species and equipment type in the Table D-1 below. In 2029, when the requirement for servicing and/or repair of certain refrigerant-containing equipment with reclaimed HFCs take effect, the required reclaimed refrigerants for service in the subsectors specified are estimated to be 1,417 MT HFC-32, 5,110 MT HFC-125, 3,381 MT HFC-134a, and 2,259 MT HFC-143a.[61]

Table D-1: Service Demand of HFCs for Applicable Subsectors in 2029[a]

Sector	***Refrigerant-Containing Equipment Type***	***Service Demand (MT)***			
		HFC-32	***HFC-125***	***HFC-134a***	***HFC-143a***
Supermarket Systems		1,265	3,561	2,621	1,213
Refrigerated Transport	Road	82	730	191	402
	Vintage	0	0	10	0
	Modern Rail	0	2	5	2
	Intermodal Containers	0	3	298	3
	Marine	58	789	236	622
Automatic Commercial Ice Makers		11	25	22	16
Total		**1,417**	**5,110**	**3,381**	**2,259**

[a] Results by gas represent demand for HFCs both as neat gases and as constituent gases within specific blends. For example, a significant driver of demand for HFC-32, HFC-125, and HFC-134a in the above table is driven by estimated servicing demand for R-407A, a blend of these three gases.

From 2029 through 2050, the amount of reclaimed HFCs needed to service the applicable refrigerant-containing equipment types is expected to decrease, in both mass and CO_2e terms, as more refrigerant-containing equipment transitions to alternatives. Further, as refrigerant-containing equipment using higher-GWPs comes offline, the model assumes some of that can be recovered and reused, alleviating the need for reclaimed material. Tables D-2 and D-3 show the projected demand for servicing the designated refrigerant-containing equipment types in metric tons and $MMTCO_2$e.

[61] These values represent the full demand and do not incorporate the rule's allowance that up to 15 percent of the amount may be from virgin material.

Table D-2: Service Demand of HFCs for Applicable Subsectors, 2029-2050 (Metric Tons)

Year	***HFC-32***	***HFC-125***	***HFC-134a***	***HFC-143a***	***Total***
2029	1,417	5,110	3,381	2,259	12,168
2030	1,389	4,889	3,274	1,978	11,530
2031	1,348	4,685	3,147	1,747	10,927
2032	1,292	4,477	2,988	1,546	10,303
2033	1,223	4,292	2,808	1,402	9,725
2034	1,148	4,095	2,621	1,254	9,119
2035	1,077	3,915	2,440	1,117	8,548
2036	1,005	3,730	2,255	976	7,967
2037	919	3,524	2,072	897	7,411
2038	831	3,313	1,884	816	6,844
2039	742	3,097	1,693	733	6,266
2040	651	2,878	1,498	650	5,677
2041	558	2,653	1,300	565	5,076
2042	464	2,436	1,098	495	4,494
2043	404	2,300	964	439	4,106
2044	415	2,318	971	398	4,101
2045	425	2,349	978	372	4,124
2046	436	2,380	985	346	4,147
2047	446	2,411	992	319	4,168
2048	457	2,442	999	291	4,189
2049	468	2,472	1,006	263	4,209
2050	472	2,495	1,014	266	4,247

Table D-3: Service Demand of HFCs for Applicable Subsectors, 2029-2050 (MMTCO$_2$e)

Year	HFC-32	HFC-125	HFC-134a	HFC-143a	Total
2029	1.0	17.9	4.8	10.1	33.8
2030	0.9	17.1	4.7	8.8	31.6
2031	0.9	16.4	4.5	7.8	29.6
2032	0.9	15.7	4.3	6.9	27.7
2033	0.8	15.0	4.0	6.3	26.1
2034	0.8	14.3	3.7	5.6	24.5
2035	0.7	13.7	3.5	5.0	22.9
2036	0.7	13.1	3.2	4.4	21.3
2037	0.6	12.3	3.0	4.0	19.9
2038	0.6	11.6	2.7	3.6	18.5
2039	0.5	10.8	2.4	3.3	17.0
2040	0.4	10.1	2.1	2.9	15.6
2041	0.4	9.3	1.9	2.5	14.0
2042	0.3	8.5	1.6	2.2	12.6
2043	0.3	8.0	1.4	2.0	11.7
2044	0.3	8.1	1.4	1.8	11.6
2045	0.3	8.2	1.4	1.7	11.6
2046	0.3	8.3	1.4	1.5	11.6
2047	0.3	8.4	1.4	1.4	11.6
2048	0.3	8.5	1.4	1.3	11.6
2049	0.3	8.7	1.4	1.2	11.6
2050	0.3	8.7	1.5	1.2	11.7

Appendix E. Detailed Description of Mitigation Actions Modeled Specific to the ER&R Rule

For the MACC analysis used as the primary methodological tool, updated abatement options were calculated for leak repair, ALD, reclaimed refrigerant requirements, and fire suppression-related provisions contained in the final rule for each year of the analysis period (2026–2050). For calculating break-even costs, abatement potential was calculated on a consumption basis (i.e., cost per ton of carbon dioxide equivalent consumption abated), to be comparable to the abatement options presented in the Allocation Rules and 2023 Technology Transitions Rules analyses.

Leak repair of appliances

Abatement options for leak repair were calculated for the equipment types and sizes analyzed in this RIA Addendum, using the same approach for estimating costs and benefits. In these options, because equipment owners would eventually add refrigerant to maintain that equipment in working order, it was assumed that emission benefits are equivalent to consumption benefits (i.e., that all avoided refrigerant emissions associated with repairing leaks translate into avoided consumption).

Table E-1: Leak Repair abatement options added to MACC model for the ER&R Rule analysis in 2026

Abatement Option No.	Type	Equipment Type	Equipment Size	Breakeven Cost ($/mt$CO_2e$)
1	Leak repair	School & Tour Bus AC	Sub-small	$2,798.13
2	Leak repair	Transit Bus AC	Sub-small	$1,651.70
3	Leak repair	Passenger Train AC	Sub-small	$431.23
4	Leak repair	Chiller	Medium	$14.69
5	Leak repair		Large	$0.81
6	Leak repair	Modern Rail Transport	Sub-small	$534.15
7	Leak repair	Vintage Rail Transport	Sub-small	$349.47
8	Leak repair	Condensing Unit	Sub-small	$322.98
9	Leak repair	Marine Transport	Small	$21.46
10	Leak repair		Medium	$21.41

11	Leak repair		Large	$10.41
12	Leak repair	Rack	Medium	$21.56
13	Leak repair		Large	$9.24
14	Leak repair	Cold Storage	Large	-$0.22
15	Leak repair	IPR	Medium	$21.03
16	Leak repair		Large	-$0.62

Automatic leak detection systems

Abatement options for requiring ALD systems in existing and new systems were calculated for the equipment types and sizes shown in table A-4. The approach for estimating capital, installation, and O&M costs of ALD systems was based on the assumptions detailed in Appendix A of this RIA Addendum. The leak repair and inspection costs, refrigerant savings, and benefits of the ALD options were associated with repairs being conducted four weeks earlier (i.e., the incremental difference between the assumed six weeks earlier that repairs will be conducted without ALD and the 10 weeks earlier assumed for systems using ALD monitoring, as detailed in the draft RIA Addendum) and/or systems requiring fewer leak inspections (e.g., CR and IPR systems containing more than 1,500 pounds of refrigerant will switch from quarterly to annual inspections).

As with the added leak repair abatement options, it was assumed that emission benefits are equivalent to consumption benefits (i.e., that all avoided refrigerant emissions associated with repairing leaks translate into avoided consumption).

Table E-2: ALD abatement options added to MACC model for the ER&R Rule analysis in 2026

Option No.	***Type***	***Equipment Type***	***Equipment Size***	***Breakeven Cost ($/mtCO₂e)***
17	ALD	Marine Transport	Medium	-$2.13
18	ALD		Large	-$4.89
19	ALD	Rack	Medium	-$22.01

Option No.	*Type*	*Equipment Type*	*Equipment Size*	*Breakeven Cost ($/mtCO₂e)*
20	ALD		Large	-$15.78
21	ALD	Cold Storage	Large	-$2.09
22	ALD	IPR	Large	-$4.47

Servicing and/or repair of equipment with reclaimed HFCs starting January 1, 2029

To quantify costs and benefits, a baseline for the use of reclaimed HFCs in business-as-usual was first established. This baseline was derived from HFC reclamation totals modeled in the Vintaging Model[62] relative to modeled consumption for the RACHP and fire suppression sectors (i.e., new chemical demand and servicing demand) across the analysis period (2026-2050). The assumed percentage of demand met by reclaimed refrigerant in the baseline is 26.5 percent per year.

The costs and/or cost savings estimated for this activity included the refrigerant price difference in reclaimed refrigerant vs. virgin refrigerant. For the purposes of this analysis, it was assumed that the price of reclaimed refrigerant is 10 percent higher than virgin manufacture.[63] We provide a sensitivity analysis of this assumption in Appendix L.

The consumption benefits of this regulatory action needed to account for the proportion of virgin manufacture that the use of reclaimed refrigerant can offset. As discussed above, in our base case we assume there some recovery activity in the BAU model. In addition to accounting the BAU activity, we assume an additional offset stems from the final rule, which allows up to 15 percent virgin HFC material in reclaimed refrigerant.

This requirement was modeled as a series of abatement options that account for whether the equipment types for which reclaimed refrigerant must be used are covered or not covered by the leak repair requirements. For those equipment types covered by the leak repair requirements, the abatement options

[62] The Vintaging Model assumes disposal recovery from equipment reaching end-of-life in a particular year is used to meet consumption demand for the same subsector and substance (i.e., new chemical demand plus servicing demand) in the same year (i.e., reclamation). If disposal recovery is not sufficient to meet consumption demand, the remainder is assumed to be produced as virgin manufacture.
[63] This baseline amount of reclaim is not accounted for in the costs/benefits of the leak repair options above (e.g., the average refrigerant price is assumed to represent the cost of virgin refrigerant).

further distinguish between: a) leak repair above the leak threshold; and b) additional servicing and/or repair that would be conducted that is below the leak rate threshold.

- *Leak repair above the leak threshold, using reclaimed refrigerant, for marine transport, modern rail transport, vintage rail transport, and supermarket rack systems.*
    - To avoid double counting, these options supplant their equivalent, non-reclaim options listed above in Leak Repair and ALD (i.e., option numbers 6-7, 9-13, and 17-20), starting in 2029, when the requirement to use reclaim in servicing for the affected subsectors take effect. Costs and consumption benefits of leak repair using reclaimed refrigerant are calculated using the leak repair methods described in this RIA Addendum—but substituting the price of reclaimed refrigerant and applying the offsets for reclaim described above. EPA conservatively assumed that these measures would not result in an additional reduction in emissions beyond the emissions reductions from recovery of HFCs and avoided venting at disposal and servicing already included in the baseline.

Table E-3: Combined leak repair, ALD, and reclaim abatement options added to MACC model for the ER&R Rule analysis in 2029

Option No.	***Type***	***Equipment Type***	***Equipment Size***	***Breakeven Cost ($/mtCO₂e)***
23	Leak repair – reclaim	Modern Rail Transport	Sub-small	$912.53
24	Leak repair – reclaim	Vintage Rail Transport	Sub-small	$596.35
25	Leak repair – reclaim	Marine Transport	Small	$38.02
26	Leak repair – reclaim		Medium	$37.94
27	Leak repair – reclaim		Large	$18.06
28	Leak repair – reclaim	Rack	Medium	$38.43
29	Leak repair – reclaim		Large	$16.15
30	ALD – reclaim	Marine Transport	Medium	$36.72
31	ALD – reclaim		Large	$24.71
32	ALD – reclaim	Rack	Medium	$29.67
33	ALD – reclaim		Large	$17.59

- *Servicing and/or repair below the leak threshold using reclaimed refrigerant, for marine transport, modern rail transport, vintage rail transport, and supermarket rack systems.*
    - For these abatement options, the amount of servicing was based on the difference between the amount of refrigerant replaced in each year (2029–2050) in equipment leaking above the leak threshold and the baseline amount of servicing demand modeled for these equipment types in the Vintaging Model. As for other reclaim options, the assumed costs reflect the price of reclaimed refrigerant, and the consumption benefits apply offset factors for the continued use of virgin material (i.e., up to 15%) and the

baseline percentage of demand met by reclaim (i.e., 26.5%). There are no emission benefits associated with these options.

Table E-4: Servicing reclaim abatement options added to MACC model for the ER&R Rule analysis in 2029

Option No.	***Type***	***Equipment Type***	***Equipment Size***	***Breakeven Cost ($/mtCO₂e)***
34	Servicing – reclaim	Modern Rail Transport	Sub-small	$0.33
35	Servicing – reclaim	Vintage Rail Transport	Sub-small	$0.62
36	Servicing – reclaim		Small	$0.27
37	Servicing – reclaim	Marine Transport	Medium	$0.27
38	Servicing – reclaim		Large	$0.34
39	Servicing – reclaim	Rack	Medium	$0.34
40	Servicing – reclaim		Large	$0.34

- *All servicing and/or repair for equipment types covered by the reclaimed refrigerant requirement but not covered by the leak repair requirement.*
    - For these abatement options, servicing demand was derived from EPA's Vintaging Model. As with other reclaim options, the assumed costs reflect the price of reclaimed refrigerant and the consumption benefits apply offset factors for the continued use of virgin material (i.e., up to 15%) and the baseline percentage of demand met by reclaim (i.e., 26.5%). There are no emission benefits associated with these options.

Table E-5: Additional servicing reclaim abatement options added to MACC model for the ER&R Rule analysis in 2029

Option No.	***Type***	***Equipment Type***	***Breakeven Cost ($/mtCO₂e)***
41	Servicing other equipment types – reclaim	Road Transport	$0.30
42	Servicing other equipment types – reclaim	Intermodal Containers	$0.60
43	Servicing other equipment types – reclaim	Automatic Commercial Ice Makers	$0.38

Fire suppression equipment

An additional set of abatement options was run for rule provisions associated with restricting intentional releases (e.g., during installation, servicing, repairing, or disposal) of fire suppression equipment. Abatement options for total flooding fire suppression systems were calculated assuming a proportion of the annual leakage amount (assumed to be 0.5 percent) for total flooding systems estimated in the Vintaging Model is avoided through the venting restriction. Cost savings are assumed because losses during testing of new or existing systems would have been replaced before the unit enters or reenters service.[64]

Additionally, fire suppression equipment is required to use recycled fire suppression agent for both servicing existing equipment (beginning in 2026) and to install new equipment (beginning in 2030). Because the venting restriction and recycled agent requirement for servicing/repair of fire suppression equipment start in the same year (2026), the venting prohibition option assumes that intentional venting during testing would have been replaced with recycled agent, and therefore, as for other reclaim options in the RACHP sector, the assumed costs reflect the price of recycled agent and the benefits apply the offset factors for the continued use of virgin material (i.e., up to 15%) and the baseline percentage of demand met by reclaim (i.e., 26.5%).

In addition, options associated with the requirement to use recycled agent in servicing (i.e., for normal operating leaks and servicing) for total flooding systems and filling of new fire suppression equipment for total flooding and streaming were considered. Costs and benefits for these options were calculated using the same approach as that used for refrigeration and AC equipment. The venting prohibition option is estimated to have emission benefits analogous to 0.5 percent of leak emissions for total flooding fire suppression systems. There are no associated emission benefits for the use of recycled agent for servicing and initial installation in fire suppression equipment.

Table E-6: Fire suppression abatement options added to MACC model for the ER&R Rule analysis in 2026 or 2030

Option No.	***Type***	***Equipment Type***	***Breakeven Cost ($/mtCO₂e)***
44	Venting prohibition – recycled	Fire Extinguishing: Flooding Agents	$0.26

[64] An abatement option for the venting prohibition requirement is only applied to total flooding systems because streaming systems are not assumed to be serviced and therefore have no consumption benefits associated with avoiding leaks (i.e., losses from intentional venting are not replaced over the lifetime of the equipment). The potential emission benefits for streaming systems due to the venting prohibition are not calculated in this RIA addendum. Similarly, an abatement option for the servicing reclaim requirement is only applied to total flooding systems because streaming systems are not assumed to be serviced.

45	Servicing– recycled	Fire Extinguishing: Flooding Agents	$0.26
46	Initial installation – recycled	Fire Extinguishing: Streaming Agents	$0.09
47	Initial installation – recycled	Fire Extinguishing: Flooding Agents	$0.26

Appendix F. Analysis of Alternative Reference Case

As discussed in section 3.1 of this document, the incremental costs and benefits of the final ER&R Rule depend in part on the degree to which industry would have otherwise undertaken measures such as improved leak repair and recovery even in the absence of this regulation. Prior analyses conducted by EPA have illustrated multiple potential compliance pathways in response to existing AIM Act regulations, some of which included measures that would partially fulfill the requirements of the ER&R Rule. These include actions taken in the fire protection subsector, improved leak repair, and additional recovery at disposal.

As discussed in the 2023 Technology Transitions Rule RIA Addendum, these measures are not required to meet compliance with prior AIM Act regulations, and the degree to which industry would undertake them in the absence of explicit requirements is uncertain. Since these fire protection, leak repair, and enhanced recovery measures were not found to be required to meet compliance with the Allocation and 2023 Technology Transitions Rules, they are not included in the primary reference case for this analysis. However, as a bounding exercise, this appendix provides the resulting incremental benefits of the final ER&R Rule with an alternative reference case in which these measures are included. In other words, these measures are assumed to occur even in the absence of the ER&R Rule, thus illustrating a lower bound of the incremental climate benefits of the rule.

*Table F-*1 below provides a summary of the specific measures previously assumed as compliance options for the Allocation and 2023 Technology Transitions Rules RIA and RIA Addenda which are included in the reference case in the alternative scenario provided in this appendix. Transitions to lower-GWP options as assumed in the 2023 Technology Transitions Rule RIA remain as part of the reference case under this alternative scenario as they do in the primary reference case.

Table F-1: Reference Case Assumptions in ER&R Rule Base Case vs. Alternative Reference Case Scenario

Abatement Measure	***ER&R Alternative Reference Case Assumption***	***ER&R Base Case Assumption***
Leak Repair	Average leak rate for large RefAC equipment improves (i.e., is reduced) by 40% assumed in reference case. ER&R Rule reclaim requirements only result in incremental emission reductions insofar as they require additional or earlier leak repairs beyond these levels.	No improvement in average leak rate for large RefAC equipment included in reference case beyond Vintaging Model BAU assumptions.
Disposal Recovery and Emissions	Improvement in end-of-life emissions rate to 3-4% of remaining equipment charge for large and small RACHP equipment assumed in reference case. ER&R Rule reclaim requirements do not result in incremental emissions reductions and recovery rates beyond these levels.	No improvement in end-of-life emissions rate assumed in reference case beyond Vintaging Model BAU assumptions.
Fire Suppression	Fire suppression sector makes transitions away from HFCs to low-GWP alternatives in reference case. ER&R measures therefore affect smaller universe of fire suppression equipment.	Fire suppression sector does not make transitions away from HFCs to low-GWP alternatives in reference case. ER&R measures affect larger universe of fire suppression equipment still using HFCs.
RACHP, Foams, and Aerosol Transitions	All transitions in the 2023 Technology Transitions RIA Addendum Base Case are assumed in the reference case.	All transitions in the 2023 Technology Transitions RIA Addendum Base Case are assumed in the reference case.

Table F-2 and Table F-3 below provide the total MAC costs and emissions reductions in the ER&R Alternative Reference Case and Base Case Scenarios.

Table F-2: Incremental Annual Compliance Costs of MAC Abatement Measures under ER&R Alternative Reference Case and Base Case Scenarios (Millions 2022$)

	ER&R Alternative Reference Case Scenario			***ER&R Base Case***		
Year	Leak Repair	Reclamation	Fire Suppression	Leak Repair	Reclamation	Fire Suppression
2026	$69.5	$-	$0.1	$79.5	$-	$0.2
2030	$91.5	$2.2	$0.3	$88.3	$3.9	$0.8
2035	$78.8	$1.4	$0.2	$75.0	$3.1	$0.9
2040	$61.8	$1.6	$0.3	$57.5	$2.3	$0.9
2045	$45.2	$1.6	$0.4	$43.4	$1.8	$1.0
2050	$44.6	$2.1	$0.6	$43.3	$1.9	$1.0
PV (3% d.r.)	$1,183	$23	$5	$1,146	$38	$13

Table F-3: Incremental Annual Emissions Reductions from MAC Abatement Measures under ER&R Alternative Reference Case and Base Case Scenarios (MMTCO$_2$e)

	ER&R Alternative Reference Case Scenario			***ER&R Base Case***		
Year	Leak Repair	Reclamation	Fire Suppression	Leak Repair	Reclamation	Fire Suppression
2026	3.09	-*	0.01	5.39	-*	0.01
2030	3.41	-	0.01	5.63	-	0.01
2035	2.97	-	0.00	4.62	-	0.01
2040	2.16	-	0.00	3.01	-	0.01
2045	1.23	-	0.00	1.53	-	0.01
2050	0.83	-	0.00	0.92	-	0.01
Total	58.05	-	0.12	88.49	-	0.21

*Reclaim requirements may lead to additional emissions reductions by inducing increased recovery of refrigerant at servicing and disposal that may otherwise be released or vented. As described elsewhere in this RIA Addendum, EPA has conservatively assumed that these measures do not yield incremental HFC emissions reductions beyond model BAU levels.

Overall, these results indicate that there would be approximately 34% less reductions in emissions under the alternative reference case assumptions, while the present value of total costs would be approximately 1% higher than those of the ER&R base case.

For abatement measures corresponding to leak repair and ALD provisions, overall avoided emissions reductions decrease under the alternative reference case scenario, since average reference case equipment leak rates are lower (thus yielding lower “available” emissions reductions from repairs). However, because in most cases the overall scope of equipment with leak rates above the ER&R Rule leak rate threshold remains the same under either scenario, costs remain similar, albeit with small changes due to cases where additional equipment exceed the leak rate threshold or where the measure results in additional refrigerant savings attributable to the rule as a result of the alternative assumptions.

For abatement measures corresponding to Fire Suppression, the inclusion of transitions away from HFCs for the broader sector in the alternative the reference case results in a smaller universe of equipment affected by the rule’s venting and recycled HFCs provisions. As a result, both emissions reductions and costs decrease under the alternative reference case scenario, relative to the base case.

Table F-4 below provides the benefits, costs, and net benefits under the alternative reference case scenario.

Table F-4: Summary of Annual Values, Present Values, and Equivalent Annualized Values select years for the 2026–2050 Timeframe for Estimated Compliance Costs, Benefits, and Net Benefits for this Rule (millions of 2022$, discounted to 2024) – Alternative Reference Case Scenario [a,b,c,d,e]

Year	Climate Benefits (3%)	Costs (2%, 3%, 7%)			Net Benefits (2% Benefits; 2%, 3% or 7% Costs)		
2026	$246	$82			$164		
2030	$481	$103			$379		
2035	$448	$88			$360		
2040	$370	$70			$300		
2045	$278	$52			$226		
2050	$249	$53			$196		
Discount rate	**3%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**
PV	$6,205	$1,507	$1,342	$886	$4,697	$4,863	$5,319
EAV	$356	$77	$77	$76	$279	$279	$280

[a] Benefits include only those related to climate. Climate benefits are based on changes (reductions) in HFC emissions and are calculated using four different estimates of the social cost of HFCs (SC-HFCs): model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate. For the presentational purposes of this table, we show the benefits associated with the average SC-HFC at a 3 percent discount rate. See Chapter 5 for more discussion of the SC-HFC methodology.
[b] Rows may not appear to add correctly due to rounding.
[c] Present values are calculated using end of year discounting.
[d] The annualized present value of costs and benefits are calculated as if they occur over a 25-year period.
[e] The PV for the net benefits column is found by taking the difference between the PV of climate benefits at 3 percent and the PV of costs discounted at 7 percent, 3 percent or 2 percent. Because the SC-HFC estimates reflect net climate change damages in terms of reduced consumption (or monetary consumption equivalents), the use of the social rate of return on capital (7 percent under OMB Circular A-4 (2003)) to discount damages estimated in terms of reduced consumption would inappropriately underestimate the impacts of climate change for the purposes of estimating the SC-HFC. See Chapter 5 for more discussion.

Appendix G. SBREFA Assumptions and Methodology

This screening analysis finds that the rulemaking can be presumed not to have a ***significant economic impact on a substantial number of small entities (SISNOSE)***.

This section describes the approach and assumptions used to estimate the economic impact on small entities (businesses and governments) associated with the regulatory requirements for leak repair and use of automatic leak detection (ALD) systems for certain equipment using refrigerants containing HFCs with a GWP greater than 53 and certain substitutes; the servicing and/or repair of refrigerant-containing equipment in certain sectors or subsectors to be done with reclaimed HFCs; the servicing, repair, disposal, or installation of fire suppression equipment that contains HFCs, as well as requirements related to technician training in the fire suppression sector; recovery of HFCs from cylinders; and reporting and recordkeeping; the decision matrix used to make the SISNOSE determination; and the aggregated small entities impacts.[65] The rulemaking applies to equipment used across a wide variety of businesses and government entities,[66] including school districts and cities. This analysis first assesses the economic impact to small businesses and small governments separately and then aggregates the impact across both types of entities to make a SISNOSE determination for the rulemaking.

Approach for Estimating the Economic Impact on Small Businesses

The analysis uses a model entity approach to estimate impacts on small businesses for the requirements for leak repair and use ALD; the servicing and/or repair of refrigerant-containing equipment in certain sectors or subsectors to be done with reclaimed HFCs; the servicing, repair, disposal, or installation of fire suppression equipment that contains HFCs, requirements related to technician training in the fire suppression sector; and recovery of HFCs from cylinders. To estimate costs per small business, assumptions were developed for each industry category affected by the regulatory changes (i.e., the proportion of facilities that have appliances with refrigerant charges of 15 or more pounds) and the type and number of appliances per affected facility and business. Costs per model facility were developed to accurately reflect the range of compliance costs that a given small business owner or operator could experience from leak repair, leak inspection, ALD installation, and reporting and recordkeeping costs. Costs per model facility were then scaled to a model business on both an industry-specific and equipment-specific basis. Therefore, each model business reflects information about the average number of facilities a business has in a given industry category and equipment type (i.e., smaller businesses typically have fewer facilities per business than larger businesses).

The regulation also includes a requirement to recover refrigerant heels from disposable cylinders prior to disposal. Companies that sell and distribute HFCs, in particular refrigerant, will be impacted.

Model Facility and Small Business Cost Assumptions for Leak Repair and ALD Provisions

The model business approach is built up from the model equipment analysis described in Chapter 3 and model facility assumptions developed for the average number of refrigeration and air conditioning appliances and transit buses[67] per facility or business, for each industry category, as summarized in Table G-1. These assumptions were based on analysis of 2013 data reported under California's RMP, cross-

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[65] Costs associated with certain several mobile end-uses (i.e., Modern Rail Transport, Passenger Train AC, Vintage Rail Transport, and Marine Transport) were not considered in this analysis, as it was determined that these equipment types are wholly owned and operated by large entities.

[66] The Regulatory Flexibility Act (1980) defines small governments as the government of a city, county, town, township, village, school district, or special district with a population less than 50,000.

[67] Approximately 10% of transit buses are assumed to be operated by private industry (e.g., charter buses) (APTA 2023).

walked with assumptions made by similar analyses (CARB 2009; Stratus 2009) about equipment use by industry and reconciled with expert judgment.[68]

Table G-1: Average Number of Systems per Facility in Industries Containing Appliances with 15 or More Pounds of HFC Refrigerant

Industry Category	***Average Systems per Facility***		
	CC	***CR***	***IPR***
Agriculture and Crop Support Services	1	2	-
Arts, Entertainment, and Recreation	1	-	
Beverage and Ice Manufacturing	1	-	1
Charter Bus Industry	1		
Durable Goods Wholesalers and Dealers	2	-	-
Educational Services	4	1	-
Food Manufacturing	1	2	-
General Merchandise Stores	1	2	
Grocery and Specialty Food Stores	1	2	-
Hospitals	2	-	-
Ice Rinks	1	-	2
Non-durable Goods Wholesalers and Dealers	1	2	-
Non-food Manufacturing	2	-	3
Office Buildings	3	-	-
Other Warehousing, Storage, and Transportation	4	-	-
Refrigerated Warehousing and Storage	1	2	-

[68] Within each industry category, it was assumed that small businesses with annual revenue less than $200,000 do not utilize equipment with more than 15 pounds of refrigerant, given that these equipment typically cool larger spaces and equipment costs be cost prohibitive for these businesses (e.g., a typical commercial unitary air conditioning system can cost between $20,000 to $25,000, which would represent up to 25% of total annual revenue for a business with 2 CC units and an annual revenue of $200,000). Similarly, it was assumed that small businesses with revenue less than $500,000 would not utilize equipment with more than 1,500 pounds of refrigerant (i.e., would not have systems that require installation of ALD systems). Thus, these businesses would not have installed equipment affected by leak repair and inspection and ALD provisions of the rulemaking, respectively.

Industry Category	*Average Systems per Facility*		
	CC	***CR***	***IPR***
Research and Development	2	-	-
Utilities	2	-	-
Warehouse Clubs and Supercenters	1	3	

Potential compliance costs for each model facility were developed to accurately reflect the range of compliance costs that a given small business owner or operator could experience from leak repair, leak inspection, ALD installation, and reporting and recordkeeping requirements. For each business, there are many potential configurations of equipment types, equipment sizes, and repair outcomes that determine compliance costs for stock above the leak rate threshold. Considering these multiple possibilities, "worst case" model facility assumptions were adopted for standard leak repair and extension leak repair outcomes. The "worst case" reflects the possibility that appliances with leak rates above the threshold leak rate are clustered in individual facilities, such that all of the eligible appliances in a single model facility might trigger inspection and repair. Within each facility, it is assumed that multiple units of the same appliance type are maintained in the same way (e.g., if a facility has two CR systems, both appliances are assumed to have similar leak rates), and thus experience the same leak repair outcomes.

Model facility scenarios were developed for each industry category based on how many different sizes of appliances the industry is assumed to use within each sector and the expected number of leak repair outcomes. Retrofit outcomes were determined to only occur to a maximum of one piece of equipment per model facility. Each scenario features a different combination of appliance sizes and leak repair outcomes, with likelihood of each leak repair outcome based on estimates in Appendix A.

Economic impacts to small businesses associated with ALD installation and maintenance were also developed using the model facility approach. Although the number of potential configurations of equipment are lower because CC equipment are exempt from ALD requirements and only CR and IPR equipment with charge sizes greater than 1,500 pounds are impacted, a larger number of facilities are impacted because ALD requirements apply to new and existing CR and IPR equipment installed on or after January 1, 2017 with charge sizes greater than 1,500 pounds.[69]

[69] For the purposes of this screening analysis, facilities experiencing leak repair and inspection costs are separate from facilities experiencing ALD costs.

Expected compliance costs per model facility were estimated by multiplying the (a) unit cost assumptions described in Appendix A averaged across all equipment within a given size category for each sector plus the expected reporting and recordkeeping costs per facility, by the (b) model facility configurations for each industry sector. Costs to small businesses were then scaled based on the proportion of facilities-to-businesses for small businesses in each size category of each NAICS code in each industry category.

Some small businesses within each NAICS code and industry category, that operate appliances that are subject to the rule (i.e., CC, CR, and IPR equipment containing more than 15 pounds of refrigerant), are not expected to experience any compliance costs. This is because not all systems will leak above the threshold leak rates, and therefore do not require leak repair or inspection or the installation of ALD systems. However, these businesses may be subject to increased costs associated with the requirement to use reclaimed refrigerant for the servicing and/or repair of appliances, as discussed further below.

Small Business Cost Assumptions for Reclamation and Recycling Provisions

The final rulemaking institutes several requirements related to the reclamation and recycling of HFCs. A review of reporting under the AIM Act indicates that there are 37 EPA-certified reclaimers, of which 32 are small businesses. Under the final rule, HFC refrigerant sold as reclaimed can contain no more than 15 percent virgin HFC refrigerant, by weight. It is not known how much virgin refrigerant is currently used for blending with reclaimed refrigerant, and therefore it is assumed that reclaimers will experience negligible cost impacts associated with this requirement.

Reclaimers are subject to labeling and recordkeeping requirements. Costs for labeling and recordkeeping are based on the estimated burden time to prepare each reporting element and are discussed in further detail in the Information Collection Request associated with this rulemaking.

The rulemaking requires the servicing and/or repair of refrigerant-containing appliances in certain subsectors and applications in the RACHP sector to be done with reclaimed HFCs, including supermarket systems, refrigerated transport, and automatic commercial ice makers, and the servicing and/or repair of fire suppression equipment, including both total flooding systems and streaming applications, to be done with recycled HFCs. Many of the businesses subject to the leak repair and ALD requirements of the rulemaking would also be impacted by the requirement to use reclaimed or recycled HFCs for servicing/repair of certain refrigeration appliances and fire suppression equipment. Additional industries using equipment not covered by the leak repair and ALD provisions (e.g., road transport, intermodal containers, automatic commercial ice machines, and fire suppression equipment) were also identified.

Small businesses are anticipated to experience costs associated with the requirement to use reclaim refrigerant for servicing/repair of supermarket systems, refrigerated transport, and automatic commercial ice makers and recycled agent for servicing/repair of fire suppression equipment.[70] Servicing demand for these appliances and systems estimated by EPA's Vintaging Model was distributed across businesses in proportion to their annual sales (U.S. Census Bureau 2020) and it was assumed that businesses would incur a 10 percent price increase per pound of reclaimed or recycled HFCs (i.e., $0.40 per pound based on an assumed cost of $4 per pound for virgin material).

Small Business Cost Assumptions for Fire Suppression Provisions

The final rulemaking also institutes several additional requirements for fire suppression equipment containing HFCs. Specifically, fire suppression equipment containing a regulated substance may not release into the environment, such as by intentional venting during testing and EPA is requiring that all entities that employ fire suppression technicians who maintain, service, repair, install, or dispose of fire suppression equipment containing HFCs must provide training. EPA does not anticipate economic impacts associated with the restriction on intentional releases. Costs associated with technician training are discussed in further detail in the Information Collection Request associated with this rulemaking.

Furthermore, EPA is requiring that for the fire suppression sector where HFCs are used, the initial installation of fire suppression equipment, including both total flooding systems and streaming applications, must be with recycled HFCs, starting on January 1, 2030. A review of HFC fire suppression manufacturers indicates that 8 are small businesses. Manufacturers are anticipated to experience costs associated with the requirement to use recycled agent for the initial installation of fire suppression equipment. Demand for charging new fire suppression equipment estimated by EPA's Vintaging Model was distributed across businesses in proportion to their annual sales (U.S. Census Bureau 2020) and it was assumed that businesses would incur a 10 percent price increase per pound of recycled HFCs (i.e., $0.40 per pound).

Owners and operators of fire suppression equipment containing HFCs (including an HFC blend) dispose of this equipment by recovering the HFCs themselves or by arranging for HFC recovery by a fire suppression equipment manufacturer, distributor, or a fire suppressant recycler. EPA anticipates negligible to beneficial economic impacts associated with the requirement to recover HFCs from fire suppression equipment prior to disposal due to already established industry-wide practice to recover fire suppression agent and the resale value of recovered HFCs.

[70] EPA's Vintaging Model does not assume streaming systems are serviced.

Small Business Cost Assumptions for Requiring Heel Recovery from Disposable Cylinders

The regulation also institutes a requirement to recover refrigerant heels from disposable cylinders (i.e., non-refillable cylinders), which are primarily used to charge and service stationary refrigeration and air-conditioning systems and fire suppression equipment. Disposable cylinders are specifically manufactured to be single use. These cylinders are charged with refrigerant, sold for use to fill or service equipment, and disposed (EIA 2018). Disposable cylinders are typically discarded with amounts of refrigerants still in the cylinders that will be emitted over time including from amounts commonly referred to as heels.

EPA is requiring that disposable cylinders that have been used for the servicing, repair, or installation of refrigerant-containing equipment or fire suppression equipment must be sent to a reclaimer, fire suppressant recycler, or a final processor for recovery of the heel. EPA is requiring that the recovered heel must be sent to a reclaimer for further processing.

Small Entities Potentially Subject to Refrigerant Heel Recovery Requirements

The requirement to remove heels from cylinders before disposal would directly impact those companies that sell or distribute or repackage refrigerant in such cylinders, as these companies would be required to return their used cylinder to a reclaimer or a final processor for heel recovery prior to disposal. For this analysis, potentially affected entities are assumed to be producers, importers, exporters, reclaimers, and companies that sell and distribute HFCs (e.g., blenders, repackagers, and wholesalers or distributors of refrigerants) and disposal facilities (i.e., landfills or recycling facilities).[71] Table G-2 lists the potentially affected industries by NAICS code and the estimated number of small businesses affected.

Table G-2: List of Industries Potentially Affected by the Provisions on Disposable Cylinders by NAICS Code

NAICS Code	***NAICS Industry Description***	***Size Standard in Millions of Dollars***	***Size Standard in Number of Employees***	***Estimated Number of Small Businesses Affected***
325120	Industrial Gas Manufacturing		1,200	0[a]
562920	Materials Recovery Facilities	25		964[a]

[71] For the purposes of this analysis, it is conservatively assumed that producers transport refrigerant primarily in containers larger than 30-lbs. cylinders and therefore the total inventory of 4.45 million disposable refrigerant cylinders, adjusted to account for the proportion of cylinders containing HFC or HFC blends with a GWP > 53, was distributed across importers, exporters, reclaimers, and companies that sell and distribute HFCs (e.g., blenders, repackagers, and wholesalers or distributors of refrigerants) defined by the NAICS codes in Table G-2.

NAICS Code	NAICS Industry Description	Size Standard in Millions of Dollars	Size Standard in Number of Employees	Estimated Number of Small Businesses Affected
423740	Refrigeration Equipment and Supplies Merchant Wholesalers		125	288[b]
423730	Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers		175	1,017[b]
424690	Other Chemical and Allied Products Merchant Wholesalers		175	2,755[b]
562212	Solid Waste Landfill	47		609
238220	Plumbing, Heating, and Air-Conditioning Contractors	19		49,964

Source: Small Business Size Regulations, 3 CFR Part 121.201 (2023)
[a] Includes 32 known small business HFC reclaimers in addition to recycling facilities where disposable cylinders may be sent.
[b] It was assumed that 50 percent of businesses within these NAICS codes are refrigerant wholesalers and would be directly affected by the requirement to recover refrigerant heels from cylinders prior to disposal. It is also assumed that the remaining 50 percent of businesses could be affected by the provisions on disposable cylinders such that they are considered within the universe of potentially affected entities but are expected to experience minimal economic impacts.
[c] It was assumed that 50 percent of businesses within this NAICS code are refrigerant contractors and would be directly affected by the requirement to provide a certification statement if technicians evacuate a cylinder prior to disposal. It is assumed that the remaining 50 percent of businesses are other types of contractors (i.e., plumbing) that are not impacted by the rulemaking.

Estimated Economic Impacts of Requiring Refrigerant Heel Removal from Cylinders prior to Disposal

For the purposes of quantifying direct compliance costs for this analysis, it was assumed that producers, importers, exporters, reclaimers, and companies that sell and distribute refrigerant currently sell refrigerant using 4.455 million disposable cylinders,[72] adjusted to the proportion of cylinders containing HFC and blends containing HFCs versus other non-regulated substances such as hydrofluoroolefins (HFOs) estimated by EPA's Vintaging Model (EPA 2023f),[73] as shown in *Table G*-3.

[72] EPA estimates that there are 4.5 million refrigerant cylinders in circulation per year. Industry estimates that refillable cylinders account for between less than 1 percent and 10 percent of all 30-pound cylinders used, with a general assumption that the quantity of refillable cylinders as a percentage of all 30-pound cylinders used is closer to 1 percent (EPA 2024a). For the purposes of this analysis, it is assumed that 1 percent of all 30-pound cylinders sold in the United States are refillable (i.e., 45,000) and are therefore excluded from the heel recovery requirement.
[73] As explained in the RIA to the Allocation Framework Rule and associated addenda to that RIA, the Vintaging Model estimates the consumption and emissions from end-uses that traditionally relied on ODS and are transitioning to HFCs and other alternatives. The EPA (2023f) version of the model (VM IO file_v4.4_02.04.16_Final TT Rule 2023.xls) incorporates the transitions and practices anticipated to occur under the 2023 Technology Transitions RIA Base Case, which in turn incorporates provisions of that rule.

Table G-3: Assumed Cylinder Refrigerant Mix, 2028-2050

Year	***Percentage of Cylinders containing HFC and HFC blends***
2028	76%
2029	75%
2030	73%
2031	72%
2032	71%
2033	70%
2034	69%
2035	69%
2036	68%
2037	67%
2038	67%
2039	66%
2040	66%
2041	66%
2042	65%
2043	65%
2044	65%
2045	65%
2046	65%
2047	65%
2048	64%
2049	64%
2050	64%

All direct compliance costs are calculated as the difference between costs and savings currently incurred under the current business-as-usual (BAU) scenario and those estimated to be incurred under the provisions of the rulemaking.

Cost of transport. In the BAU scenario, disposable cylinders are assumed to travel from gas producer/filler to the wholesale distributor; wholesale distributor to end user/technician; and end user/technician to a disposal facility (e.g., landfill or steel recycler).

Transportation costs were updated to account for the distance traveled for each trip and the use of company fleets to transport cylinders based on a CARB (2011) analysis. It is assumed that companies already own or lease the proper vehicle fleet to transport cylinders.

*Table G-*4 summarizes distances per shipment for disposable cylinders. Based on the location of chemical production facilities around the United States, located primarily along the East Coast, Midwest, Southern United States, and California, it is assumed that a cylinder would travel an average of 1,000 miles from producer to the wholesale distributor. As assumed in CARB (2011), the distance between wholesale distributor and end-user/technician is assumed to be 25 miles. Other distances—75 miles from an end-user or wholesaler to a disposal facility and 50 miles from a distributor to a reclaimer— were also based on CARB (2011).

In the recovery scenario, it was assumed that approximately one-third of non-refillable cylinders would take one of three potential transportation scenarios: 1) cylinders would be returned directly to a reclaimer for heel recovery; 2) cylinders would be returned to the distributor and then to a disposal facility for heel recovery; or 3) cylinders would be sent directly to a disposal facility for heel recovery. Upon recovery of the heel, the disposal facility would store recovered refrigerant heels until the facility has accumulated enough refrigerant to send to a reclaimer. Based on an average heel of 0.96 pounds, it is assumed that a disposal facility would recover refrigerant from 25 cylinders in order to accumulate enough to fill one 30-pound cylinder (i.e., 24 pounds of refrigerant).

Table G-4: Travel Distances for Disposable Cylinders Before Disposal

Trip	***BAU***	***Recovery Scenario***				
		Disposable-1[a]	***Disposable-2***[a]		***Disposable-3***[a]	
		End-user to Reclaimer to Disposal Facility	***End-user to Distributor to Disposal***	***Disposal Facility to Reclaimer***	***End-user to Disposal Facility***	***Disposal Facility to Reclaimer***
Gas producer/filler to wholesale distributor	1,000	1,000	1,000	NA	1,000	NA
Wholesale distributor to end user/technician	25	25	25	NA	25	NA
End user/technician to disposal facility	75	NA	NA	NA	75	NA
End user/technician to reclaimer	NA	50	NA	NA	NA	NA
End user/technician to distributor	NA	NA	25	NA	NA	NA
Wholesale distributor or reclaimer to disposal facility	NA	75	75	NA	NA	NA
Disposal facility to Reclaimer	NA	NA	NA	75[b]	NA	75[b]
Total Miles	**1,100**	**1,150**	**1,125**	**75**	**1,110**	**75**

[a] Assumed for one-third of shipped HFC cylinders.
[b] Disposal facilities are assumed to recover refrigerant from 25 cylinders before sending one 30-lb cylinder (containing 24 pounds of refrigerant) to a reclaimer.

Table G-5 provides additional assumptions related to fuel use and labor associated with transporting cylinders.

Table G-5: Additional Transportation Assumptions

Parameter	***Assumption***
Average Fuel Efficiency	6.1 miles per gallon[a]
Diesel Fuel Cost	$4.034/gallon[b]
Average Truck Speed	50 miles per hour[c]
Labor Rate (Truck Transport)	$53.59[d]

[a] Geotab (2017)
[b] U.S. EIA (2024)
[c] CARB (2011)
[d] Labor rate for Heavy and Tractor-Trailer Truck Drivers from Bureau of Labor Statistic's Employer Costs for Employee Compensation – May 2022. Mean hourly wages rates were multiplied by a factor of 2.1 to reflect the estimated additional costs for overhead (BLS 2022).

Transportation costs were then calculated on a per cylinder basis. This analysis conservatively estimates transportation costs on a per cylinder basis assuming a truck could fit approximately 1,120 disposable cylinders (CARB 2011). Table G-6 summarizes the transport cost per cylinder based on the assumptions presented above.

To calculate annual transport costs per small business, it was assumed that a total of 4.445 million disposable cylinders are transported per year (adjusted for the proportion HFC and HFC blends in use per year, according to *Table G*-3) under both the BAU scenario and the provisions of the rulemaking. The number of cylinders transported before disposal per small business was distributed across businesses in proportion to their annual sales (U.S. Census Bureau 2020).

Table G-6: Transportation Assumptions before Disposal per Cylinder

Scenario		***Fuel Costs***	***Labor***	***Total***
BAU	Disposable	$0.65	$1.05	$1.70
Recovery Scenario	Disposable-1 [a]	$0.68	$1.10	$1.78
	Disposable-2[a]	$0.66	$1.08	$1.74
	Disposable-2 (Disposal Facility)[b]	$0.002	$0.003	$0.005
	Disposable-3[a] (End-user)	$0.65	$1.05	$1.70
	Disposable-3 (Disposal Facility)[b]	$0.002	$0.003	$0.005

[a] Assumed for one-third of HFC cylinders sold per year.
[b] Disposal facilities are assumed to recover refrigerant from 25 cylinders before sending one 30-lb cylinder (containing 24 pounds of refrigerant) to a reclaimer.

Recovered heel. Under the recovery scenario, disposable cylinders are returned to a reclaimer prior to disposal containing a refrigerant heel that is recovered and sold back into the market. It was assumed that cylinders contain a heel of approximately 0.96 pounds based on CARB (2011) and expert judgment. Recovered refrigerant is assumed to be resold at approximately $4 per pound based on average refrigerant costs applied in EPA (2021a). The total annual savings associated with recovered heel was distributed across businesses in proportion to their assumed number of cylinders (as estimated under previous steps).

Reporting and Recordkeeping. Under the recovery scenario, companies that sell or distribute or repackage refrigerant in disposable cylinders, final processors, and refrigerant reclaimers and fire suppressant recyclers are also subject to reporting and recordkeeping requirements. Specifically, if a certified technician evacuates a disposable cylinder prior to discarding the cylinder, they must provide a certification statement certifying that the cylinder was evacuated to a level of 15 in-Hg for each disposable cylinder handled and discarded to the final processor. The final processor must keep this record for a period of 3 years. In addition, reclaimers and refrigerant distributors who supply reclaimed HFCs are subject to a discrete reporting requirement in 2027 and 2028 on the volume of reclaimed HFCs intended for servicing and/or repair of appliances in use in certain subsectors.

These reporting and recordkeeping costs are based on the estimated burden time to prepare each reporting element and are discussed in further detail in the Information Collection Request associated with this rulemaking.

Table G-7 summarizes the cost assumptions associated with the requirement to recover the refrigerant heel from disposable cylinders prior to disposal. Because the proportion of disposable cylinders changes per year as equipment is assumed to transition towards lower-GWP substitutes that are not regulated by this rulemaking, the sales test was performed for 2028 for which the highest proportion of HFC cylinders are assumed in circulation, as shown in *Table G*-3 (i.e., 76 percent), and therefore the highest potential cost impacts.

Table G-7*: Cost Assumptions for BAU and Rulemaking from Cylinder Heel Recovery Requirement*

Assumption	***BAU***	***Rulemaking***			
		Reclaimer	***Wholesaler or Distributor***	***Disposal Facility***	***Refrigerant Technician***
Number of Disposable Cylinders Disposed (2028)	3,370,585	1,123,528	2,247,057		337,059[a]

Assumption		***BAU***	***Rulemaking***			
			Reclaimer	***Wholesaler or Distributor***	***Disposal Facility***	***Refrigerant Technician***
Average Transport Cost per Cylinder		$1.70	$1.78	$1.72[b]	$0.005[b]	NA
Cylinder Heel Amount (lbs.) and Percent of Cylinder		0.96 (4%)	0.96 (4%)	0.96 (4%)	0.96 (4%)	0.96 (4%)
Average Refrigerant Price ($/lbs.)		$4	$4	$4	NA	NA
Reporting and Recordkeeping	Certification of Evacuation to 15-in Hg (per cylinder)[a]	NA	NA	NA	NA	$28.93
	Recordkeeping of Certification Statement (per cylinder)[a]	NA	NA	NA	$1.79	NA
	Reclaim Use Volume Report[d]	NA	$646.46	$530.21	NA	NA
	Labeling and Recordkeeping[e]	NA	$4,391	NA	NA	NA

[a] Approximately 10 percent of cylinders are assumed to be emptied directly by the end-user (i.e., refrigerant technician) and require a certification statement.
[b] Represents an average of the per-cylinder cost for wholesalers or distributors under disposable scenario 2 ($1.74 per cylinder) and disposable scenario 3 ($1.70 per cylinder) as shown in Table G-6.
[c] Disposal facilities are assumed to recover refrigerant from 25 cylinders before sending one 30-lb cylinder (containing 24 pounds of refrigerant) to a reclaimer.
[d] Two-time report submitted by reclaimers and refrigerant distributors in 2027 and 2028 only.
[e] Represents one-time label redesign and recordkeeping costs for reclaimers noted in Section "Small Business Cost Assumptions for Reclamation and Recycling Provisions."

Summary of Economic Impacts. To inform the sales test, economic data about each affected industry—including number of firms by employment and receipts size—was obtained from the U.S. Census Bureau's Statistics of U.S. Businesses. Annualized compliance costs for 2028 for small businesses in each affected industry were compared to annual sales by firm size, as shown in *Table G*-8. As shown, small businesses are expected to experience a positive economic impact (i.e., cost savings) or impact less than 1 percent of annual sales associated with the requirement to recover heels prior to cylinder disposal.

Table G-8: Summary of Annual Economic Impacts from Cylinder Heel Recovery Requirement on Small Businesses by NAICS Code, 2028

Employee Size or Annual Revenue[a]	***Number of Small Businesses Affected***	***Average Annual Sales per Firm***	***Assumed Cylinder Fleet per Firm or Cylinders Returned[b]***	***Annual Cost per Small Business***			***Total Annual Cost per Small Business***	***Impact as Percent of Annual Sales***
				Average Incremental Annual Transport Costs	***Heel Savings***	***Reporting & Recordkeeping***		
Materials Recovery Facilities (Reclaimers)								
<5	13	$954,057	21	$1	-$81	$5,044	$4,964	0.52%
5-9	10	$2,727,975	60	$2	-$231	$5,044	$4,816	0.18%
10-19	6	$4,487,174	99	$4	-$380	$5,044	$4,668	0.10%
20-99	12	$11,410,450	251	$10	-$966	$5,044	$4,088	0.04%
100-499	1	$22,630,407	499	$19	-$1,915	$5,044	$3,148	0.01%
Refrigeration Equipment and Supplies Merchant Wholesalers								
<5	133	$835,730	18	$1	-$68	$621	$554	0.07%
5-9	63	$4,405,621	97	$4	-$359	$621	$266	0.006%
10-19	42	$7,287,619	161	$6	-$594	$621	$33	<-0.001%
20-99	42	$27,967,987	616	$24	-$2,280	$621	-$1,635	-0.006%
100-149	23	$52,375,136	1,154	$45	-$4,269	$621	-$3,603	-0.007%
Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers								
<5	391	$1,435,428	32	$1	-$120	$621	$502	0.03%
5-9	206	$4,027,378	89	$3	-$337	$621	$288	0.007%
10-19	170	$8,824,460	194	$8	-$738	$621	-$109	-0.001%
20-99	214	$28,135,080	620	$24	-$2,352	$621	-$1,707	-0.01%
100-199	36	$74,021,716	1,631	$63	-$6,187	$621	-$5,503	-0.01%
Other Chemical and Allied Products Merchant Wholesalers								
<5	1,526	$2,142,742	47	$2	-$180	$621	$442	0.02%
5-9	504	$6,251,162	138	$5	-$526	$621	$99.93	0.0016%
10-19	345	$15,508,336	342	$13	-$1,306	$621	-$672	-0.004%
20-99	341	$35,522,558	783	$30	-$2,991	$621	-$2,340	-0.01%
100-149	39	$143,599,156	3,165	$122	-$12,091	$621	-$11,347	-0.01%

Employee Size or Annual Revenue[a]	*Number of Small Businesses Affected*	*Average Annual Sales per Firm*	*Assumed Cylinder Fleet per Firm or Cylinders Returned*[b]	*Annual Cost per Small Business*			*Total Annual Cost per Small Business*	*Impact as Percent of Annual Sales*
				Average Incremental Annual Transport Costs	*Heel Savings*	*Reporting & Recordkeeping*		
Materials Recovery Facilities (Recyclers)								
<5	380	$954,057	4	$0.02	-	$177	$177	0.02%
5-9	178	$2,727,975	10	$0.05	-	$505	$505	0.02%
10-19	151	$4,487,174	17	$0.08	-	$831	$831	0.02%
20-99	174	$11,410,450	43	$0.20	-	$2,114	$2,114	0.02%
100-499	49	$22,630,407	86	$0.40	-	$4,192	$4,193	0.02%
Solid Waste Landfill								
<$100	31	$67,016	1	$0.00	-	$12	$12	0.02%
$100-499	167	$342,772	1	$0.00	-	$63	$64	0.02%
$500-999	114	$898,137	3	$0.01	-	$166	$166	0.02%
$1,000-2,499	132	$1,998,150	8	$0.04	-	$370	$370	0.02%
$2,500-4,999	74	$4,132,387	16	$0.07	-	$766	$766	0.02%
$5,000-7,499	32	$6,717,014	26	$0.12	-	$1,244	$1,244	0.02%
$7,500-9,999	11	$9,181,946	35	$0.16	-	$1,701	$1,701	0.02%
$10,000-14,999	16	$13,290,027	51	$0.24	-	$2,462	$2,462	0.02%
$15,000-19,999	8	$18,042,643	69	$0.32	-	$3,342	$3,343	0.02%
$20,000-24,999	9	$18,842,779	72	$0.33	-	$3,491	$3,491	0.02%
$25,000-29,999	8	$23,202,340	88	$0.41	-	$4,298	$4,299	0.02%
$35,000-39,999	3	$37,499,500[c]	143	$0.66	-	$6,947	$6,947	0.02%
$40,000-49,999	4	$28,208,524	107	$0.50	-	$5,226	$5,226	0.02%
Refrigerant Technicians[d]								
<$100	10,648	$59,313	7	-	-	$203	$203	0.34%
$100-499	16,969	$284,372	7	-	-	$203	$203	0.07%
$500-999	8,208	$846,409	7	-	-	$203	$203	0.02%
$1,000-2,499	8,098	$1,836,287	7	-	-	$203	$203	0.01%

Employee Size or Annual Revenue[a]	*Number of Small Businesses Affected*	*Average Annual Sales per Firm*	*Assumed Cylinder Fleet per Firm or Cylinders Returned*[b]	*Annual Cost per Small Business*			*Total Annual Cost per Small Business*	*Impact as Percent of Annual Sales*
				Average Incremental Annual Transport Costs	*Heel Savings*	*Reporting & Recordkeeping*		
$2,500-4,999	3,327	$4,083,819	7	-	-	$203	$203	0.005%
$5,000-7,499	1,209	$7,105,073	7	-	-	$203	$203	0.003%
$7,500-9,999	576	$10,040,971	7	-	-	$203	$203	0.002%
$10,000-14,999	605	$14,071,905	7	-	-	$203	$203	0.001%
$15,000-19,999	326	$19,865,787	7	-	-	$203	$203	0.001%

[a] In thousands of dollars.

[b] Disposal facilities are assumed to recover refrigerant from 25 cylinders before sending one 30-lb cylinder (containing 24 pounds of refrigerant) to a reclaimer.

[c] Revenue data was not available for businesses in the $35,000-39,999 revenue category. For purposes of the sales test, revenue was estimated as the midpoint of the $35,000-39,999 revenue range (i.e., $37,499).

[d] Approximately 10 percent of cylinders are assumed to be emptied directly by the end-user (i.e., refrigerant technician) and require a certification statement. Cylinders were equally distributed across refrigerant technician businesses under the assumption that the size of the business would not be relevant in the decision-making for a technician to choose to empty a cylinder directly. Distributing cylinders equally is a more conservative assumption as it assumes a larger number of cylinders are handled by small businesses than if cylinders were distributed proportional to sales.

Approach for Estimating the Economic Impact on Small Governments

This analysis also uses a model entity approach to estimate impacts on small school districts and small governments for the leak repair, leak inspection, and recordkeeping and reporting requirements for school buses and transit buses, respectively.[74]

In the United States, there are approximately 13,085[75] school districts with a total enrollment of 33.1 million students as of 2018 (Urban Institute 2022) and 482,714 yellow school buses[76] (EPA 2023f). There are approximately 57,006 public transit buses in the United States serving over 174 million people in 3,030 cities as of 2017 (GFOA N.d.). This analysis assumes that each school district utilizes school buses for student transportation, and each city utilizes transit buses for public transportation. Furthermore, although approximately 40% of school buses and 28% of transit buses are contracted, it is assumed that costs associated with the rulemaking would be passed down to the individual school districts and cities (APTA 2023). Therefore, this analysis assumes that every school district and city is potentially impacted by the rulemaking.

Model Facility and Small Government Cost Assumptions

To analyze and estimate the economic impact of the leak repair and inspection provisions on school and transit buses, school districts were grouped into ten groups based on enrollment and transit buses were grouped into thirteen groups based on population. For school districts, the average enrollment, population within the school district, and revenue for the associated local government of each school district were determined for each enrollment size. For cities, the average population and revenue for the associated local government of each city were determined for each population size. Of the ten school enrollment groups, four were defined as small government with an average population of 50,000 or less and represent 12,187 school districts. Of the thirteen city population groups, four were defined as a small government with populations less than 50,000 and represent 2,276 cities.

As noted above, there are approximately 482,714 yellow school buses in use in the United States across 13,085 school districts. Approximately 33% of students ride a school bus as their primary means of transportation (FHWA 2017), which equates to an average of 23students per school bus. With approximately 51,305 public-owned transit buses, about 5% of the total population utilizes bus transit

[74] Approximately 90% of transit buses are assumed to be operated by transit agencies (APTA 2023).
[75] 56 school districts have an enrollment of 0 students and were therefore not included in this analysis.
[76] While federal law does not require school buses to be yellow, the National Highway Traffic Safety Administration (NHTSA) provides recommendations to states on transportation safety and operational aspects of school buses. Along with other matters and uniform identifying characteristics, NHTSA recommends that school buses be painted "National School Bus Glossy Yellow."

(based on commuting patterns from Burrows et al. 2021), which equates to an average of 180 people per bus.

Table G-9 summarizes the average enrollment, population, revenue, and number of school buses per school district within the four small government enrollment groups and the average population, revenue, and number of transit buses per city within the four small government population groups.

Table G-9: School District and City Government Population and Revenue by Enrollment and Population Size

Enrollment Group	***Number of Districts***	***Average Enrollment per District***	***Average Population per District***	***Average Revenue per District***	***Average School Buses per District***
School Buses					
0-500	5,524	235	1,875	$4,138,069	3
501-999	2,538	712	5,458	$11,246,957	10
1,000-4,999	3,726	2,244	17,058	$37,866,965	33
5,000-9,999	399[a]	6,930	52,355	$112,226,575	101
	Population Group	***Number of Cities***	***Average Population per City***	***Average Revenue per City***	***Average Transit Buses per City***
Transit Buses					
	10,000-19,999	1,235	14,128	$29,805,843	4
	20,000-29,999	542	24,465	$51,459,646	7
	30,000-39,999	314	34,642	$72,953,140	10
	40,000-49,999	185	44,702	$99,530,151	13

Bolded rows represent a small government school district.
Source: Urban Institute (2022) and Government Finance Officers Association (n.d.).
a Approximately 59% of the school districts within the 5,000-9,999 enrollment group are below the small government threshold.

Based on the analysis outlined in Appendix A, 68,158 school buses with charge sizes greater than 15 pounds and 24,147 transit buses are anticipated to exceed the threshold leak rate in 2028, and both are assumed to experience the leak repair outcomes outlined in Table G-10. Total standard leak repairs are distributed to every school district and city in proportion to the number of buses each school district and city uses. Because there are significantly fewer extension and retrofit repairs than standard leak repairs, extension and retrofit repairs are distributed within each group based on total number of buses within each group such that some districts and cities within each enrollment and population size will experience extension and/or retrofit repairs. This analysis therefore assumes that every school district and city experiences at least one standard leak repair, but not every school district and city is assumed to experience an extension or retrofit repair.

Table G-10: Leak Repair Outcomes per School District or City

Enrollment Group	***School Districts***	***Average School Buses per District***	***Total School Buses per Enrollment Group***	***Standard Repairs per School District***	***Extension Repair per Enrollment Group***	***Retrofit Repair per Enrollment Group***
School Buses						
0-500	5,524	3	16,572	1	20	23
501-999	2,538	10	25,380	1	30	35
1,000-4,999	3,726	33	122,958	4	147	168
5,000-9,999	399	101	40,299	14	48	55
Population Group	***Cities***	***Average Transit Buses per City***	***Total Transit Buses per Population Group***	***Standard Repairs per City***	***Extension Repair per City***	***Retrofit Repair per City***
Transit Buses						
10,000-19,999	1,235	4	4,940	2	20	23
20,000-29,999	542	7	3,794	3	15	17
30,000-39,999	314	10	3,140	4	13	14
40,000-49,999	185	13	2,405	6	10	11

To estimate the economic impact of the leak repair and inspection provisions on school buses, four model government scenarios were established to represent various combinations of leak repair outcomes for each school district: standard repair only, standard repair + extension repair, standard repair + retrofit repair, and standard repair + extension repair + retrofit repair.

The four model governments are established based on the lowest number of repair type instances (in this case, extension repairs). It was therefore assumed that 50% of extension and retrofit repairs are experienced by a school district and city in addition to the assumed standard repair(s) for each group (i.e., standard repair + extension repair or standard repair + retrofit) and 50% of extension and retrofit repairs are experienced together by a school district and city in addition to the assumed standard repair(s) for each group (i.e., standard leak repair + extension repair + retrofit repair). The number of school districts and cities affected by each leak repair scenario is summarized in Table G-11.

Table G-11: Number of School Districts and Cities Affected by Leak Repair Scenarios

Enrollment Group	***School Districts***	***Average School Buses per District***	***Number of School Districts Impacted***			
			Standard Repair Only	***Standard + Extension Repair***	***Standard + Retrofit Repair***	***Standard + Extension + Retrofit Repair***
School Buses						
0-500	5,524	3	5,491	10	13	10
501-999	2,538	10	2,488	15	20	15
1,000-4,999	3,726	33	3,485	74	95	74

5,000-9,999	399	101	320	24	31	24

Population Group	***Cities***	***Average Transit Buses per City***	***Number of Cities Impacted***			
			Standard Repair Only	***Standard + Extension Repair***	***Standard + Retrofit Repair***	***Standard + Extension + Retrofit Repair***
Transit Buses						
10,000-19,999	1,235	4	1,204	10	13	10
20,000-29,999	542	7	518	8	10	8
30,000-39,999	314	10	294	7	8	7
40,000-49,999	185	13	169	5	6	5

Cost estimates for each leak repair scenario were applied to each school district and city to evaluate the burden compared to their average revenue (see Appendix A for discussion of leak repair, leak inspection, and reporting and recordkeeping cost estimates).

Decision Matrix for Determining Significant Economic Impact on a Substantial Number of Small Entities

This analysis uses the matrix shown in *Table G*-12 to determine whether this rulemaking would impose a SISNOSE. The economic threshold levels are set conservatively at 1% and 3% of sales, consistent with similar analyses of other Clean Air Act Title VI rules. These thresholds are set conservatively because the rulemaking affects small businesses in a range of different industries, which may have significantly different profit margins and abilities to pass compliance costs along to customers, and a range of small governments with significantly different revenue. Based on this decision matrix, this screening analysis finds that the rulemaking can be presumed to have **no SISNOSE**.

Table G-12: Decision Matrix for Certifying SISNOSE

Economic Impact	***Number of Small Entities Subject to the Rule and Experiencing Given Economic Impact***	***Percent of All Small Entities Subject to the Rule That Are Experiencing Given Economic Impact***	***Certification Category***
Less than 1% for all affected small entities	Any number	Any percent	Presumed No SISNOSE
1% or more for one or more affected small entities	Fewer than 100	Less than 20%	Presumed No SISNOSE
	Fewer than 100	20% or more	Uncertain – No Presumption
	Between 100 and 999	Less than 20%	Presumed No SISNOSE
	Between 100 and 999	20% or more	Uncertain – No Presumption
	1000 or more	Any percent	Uncertain – No Presumption

Economic Impact	*Number of Small Entities Subject to the Rule and Experiencing Given Economic Impact*	*Percent of All Small Entities Subject to the Rule That Are Experiencing Given Economic Impact*	*Certification Category*
Greater than 3% for one or more affected small entities	Fewer than 100	Less than 20%	Presumed No SISNOSE
	Fewer than 100	20% or more	Uncertain – No Presumption
	Between 100 and 999	Less than 20%	Uncertain – No Presumption
	Between 100 and 999	20% or more	Presumed Ineligible for Certification
	1000 or more	Any percent	Presumed Ineligible for Certification

Aggregate Small Entities Impacts of Regulatory Changes

As shown in *Table G*-13, an estimated 753,105 small businesses and 14,463 small governments may be subject to the regulatory actions.

Table G-13*: Summary of the Small Entities Impact*

Entity	*Estimated Number of Small Entities Affected by the Rule*
Small Business Industry Type	
Accommodations	8,522
Agriculture and Crop Support Services	3,015
Arts, Entertainment, and Recreation	183
Beverage and Ice Manufacturing	424
Charter Bus Industry	920
Disposal and Recycling Facilities	1,541
Durable Goods Wholesalers and Dealers	867
Educational Services	175
Electronics Manufacturing	1,563
Fire Suppression Manufacturers	8
Fitness and Recreational Sports	387
Food manufacturing	3,788
Grocery and Specialty Food Stores	48,556
Hospitals	354
Materials Recovery Facilities (Reclaimers)	32
Non-durable Goods Wholesalers and Dealers	2,364
Non-food Manufacturing	43,271

Entity	*Estimated Number of Small Entities Affected by the Rule*
Office Buildings	9,594
Other Chemical and Allied Products Merchant Wholesalers	2,755
Other Warehousing, Storage, and Transportation	50,882
Petrochemical Manufacturing	6
Refrigerant Technicians	49,964
Refrigerated Warehousing and Storage	399
Refrigeration Equipment and Supplies Merchant Wholesalers	280
Restaurants and Food Services	488,180
Support Activities for Transportation	218
Telecommunications and Information Services	29,695
Utilities	4,146
Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers	1,017
Small Government Type	
School Districts	12,187
City Government	2,276
Total	**767,568**

Totals may not sum due to independent rounding.

To analyze the economic impacts on small entities against the SISNOSE decision matrix, a "sales test" was applied, which calculates annualized compliance costs as a percentage of annual sales for businesses in each NAICS code by size category and annual revenue for governments. Total economic impact includes incremental compliance costs for leak repair and inspection and ALD installation, as well as compliance costs for reporting and recordkeeping. For industries for which annual sales data were not available through the Economic Census, annual receipts or annual value of shipments[77] was used as a proxy.

Table G-14 aggregates the estimated economic impacts on small entities, according to the categories set out in the SISNOSE decision matrix and using a 3% discount rate. Using the decision criteria established

[77] Total value of shipments includes the received or receivable net selling values of all products shipped (excluding freight and taxes).

in Table G-14, this screening analysis suggests that this rulemaking can be presumed to have no SISNOSE for the following reasons:

- About 75,167 small entities (9.8%) are not expected to incur compliance costs.
- About 691,866 small entities (90.1%) are estimated to incur compliance costs that will be less than 1% of annual sales/revenue.
- About 493 of the approximately 767,568 affected small entities (<0.06%) could incur costs in excess of 1% of annual sales/revenue. Approximately 12 small entities (<0.002%) could incur costs in excess of 3% of annual sales/revenue. These estimates are below the thresholds for a substantial number determination (i.e., between 100 and 999 entities and less than 20% of affected entities).

Table G-14: Aggregated Economic Impacts on Small Entities with 3% Discount Rate

Economic Impact	***Entity Type***	***Number of Small Entities Subject to the Rule and Experiencing Given Economic Impact***	***Percent of All Small Entities Subject to the Rule***
Less than 1% for all affected small entities [a]	Accommodations	8,522	
	Agriculture and Crop Support Services	3,008	
	Arts, Entertainment, and Recreation	181	
	Beverage & Ice Manufacturing	417	
	Charter Bus Industry	83	
	City Government	2,276	
	Disposal and Recycling Facilities	1,541	
	Durable Goods Wholesalers and Dealers	230	
	Educational Services	163	
	Electronics Manufacturing	1,563	
	Fire Suppression Manufacturers	8	
	Fitness and Recreational Sports	35	
	Food Manufacturing	2,130	
	Grocery & Specialty Food Stores	48,338	
	Hospitals	354	
	Materials Recovery Facilities (Reclaimers)	32	
	Non-durable Goods Wholesalers and Dealers	2,327	
	Non-Food Manufacturing	20,462	
	Office Buildings	1,778	
	Other Chemical and Allied Products Merchant Wholesalers	2,030	
	Other Warehousing, Storage, and Transportation	13,721	
	Petrochemical Manufacturing	6	

Economic Impact	*Entity Type*	*Number of Small Entities Subject to the Rule and Experiencing Given Economic Impact*	*Percent of All Small Entities Subject to the Rule*
	Refrigerant Technicians	49,964	
	Refrigerated Warehousing and Storage	397	
	Refrigeration Equipment and Supplies Merchant Wholesalers	238	
	Restaurants and Food Services	488,180	
	School Districts	12,187	
	Support Activities for Transportation	218	
	Telecommunications and Information Services	29,695	
	Utilities	1,226	
	Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers	597	
	Total	**691,908**	**90.1%**
1% or more for one or more affected small entities [b]	Agriculture and Crop Support Services	7	
	Arts, Entertainment, and Recreation	<5	
	Beverage & Ice Manufacturing	7	
	Charter Bus Industry	<5	
	Durable Goods	7	
	Educational Services	12	
	Food manufacturing	49	
	Grocery & Specialty Food Stores	217	
	Non-durable Goods	37	
	Non-food Manufacturing	72	
	Office Buildings	17	
	Other Warehousing, Storage, and Transportation	38	
	Refrigerated Warehousing and Storage	<5	
	Utilities	25	
	Total	**493**	**0.06%**
3% or more for one or more affected small entities [b]	Durable Goods	<5	
	Non-durable Goods	<5	
	Office Buildings	<5	
	Utilities	9	
	Total	**12**	**<0.01%**

Totals may not sum due to independent rounding.

Economic Impact	*Entity Type*	*Number of Small Entities Subject to the Rule and Experiencing Given Economic Impact*	*Percent of All Small Entities Subject to the Rule*

[a] Represents small entities affected with an economic impact equal to or less than 1% but greater than 0%. Approximately 75,167 affected small businesses—or 9.8 percent—would be expected to experience negligible to net positive (i.e., cost-saving) impacts.
[b] This category aggregates the number of small entities that would be expected to experience an impact of 1% to 3% with the number of small entities that would be expected to experience an impact of 3% or greater.

Appendix H. Industries Affected by This Rule

Table H-1: NAICS Classifications of Potentially Affected Entities

NAICS Code	NAICS Industry Description
236118	Residential Remodelers
236220	Commercial and Institutional Building Construction
238220	Plumbing, Heating, and Air-Conditioning Contractors
238990	All Other Specialty Trade Contractors

NAICS Code	NAICS Industry Description
311812	Commercial Bakeries
321999	All Other Miscellaneous Wood Product Manufacturing
322299	All Other Converted Paper Product Manufacturing
324191	Petroleum Lubricating Oil and Grease Manufacturing
324199	All Other Petroleum and Coal Products Manufacturing
325199	All Other Basic Organic Chemical Manufacturing
325211	Plastics Material and Resin Manufacturing
325412	Pharmaceutical Preparation Manufacturing
325414	Biological Product (except Diagnostic) Manufacturing
325998	All Other Miscellaneous Chemical Product and Preparation Manufacturing
326299	All Other Rubber Product Manufacturing
327999	All Other Miscellaneous Nonmetallic Mineral Product Manufacturing
332812	Metal Coating, Engraving (except Jewelry and Silverware), and Allied Services to Manufacturers
332999	All Other Miscellaneous Fabricated Metal Product Manufacturing
333415	Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing
333511	Industrial Mold Manufacturing
333912	Air and Gas Compressor Manufacturing
333999	All Other Miscellaneous General Purpose Machinery Manufacturing
334413	Semiconductor and Related Device Manufacturing
334419	Other Electronic Component Manufacturing
334516	Analytical Laboratory Instrument Manufacturing
335220	Major Household Appliance Manufacturing
336120	Heavy Duty Truck Manufacturing
336212	Truck Trailer Manufacturing
336214	Travel Trailer and Camper Manufacturing
3363	Motor Vehicle Parts Manufacturing
3364	Aerospace Product and Parts Manufacturing

NAICS Code	NAICS Industry Description
336411	Aircraft Manufacturing
336611	Ship Building and Repairing
336612	Boat Building
339112	Surgical and Medical Instrument Manufacturing
339113	Surgical Appliance and Supplies Manufacturing
339999	All Other Miscellaneous Manufacturing
423120	Motor Vehicle Supplies and New Parts Merchant Wholesalers
423450	Medical, Dental, and Hospital Equipment and Supplies Merchant Wholesalers
423610	Electrical Apparatus and Equipment, Wiring Supplies, and Related Equipment Merchant Wholesalers
423620	Household Appliances, Electric Housewares, and Consumer Electronics Merchant Wholesalers
423690	Other Electronic Parts and Equipment Merchant Wholesalers
423720	Plumbing and Heating Equipment and Supplies (Hydronics) Merchant Wholesalers
423730	Warm Air Heating and Air-Conditioning Equipment and Supplies Merchant Wholesalers
423740	Refrigeration Equipment and Supplies Merchant Wholesalers
423830	Industrial Machinery and Equipment Merchant Wholesalers
423840	Industrial Supplies Merchant Wholesalers
423850	Service Establishment Equipment and Supplies Merchant Wholesalers
423860	Transportation Equipment and Supplies (except Motor Vehicle) Merchant Wholesalers
423990	Other Miscellaneous Durable Goods Merchant Wholesalers
424690	Other Chemical and Allied Products Merchant Wholesalers
424820	Wine and Distilled Alcoholic Beverage Merchant Wholesalers
441310	Automotive Parts and Accessories Stores
443141	Household Appliance Stores
444190	Other Building Material Dealers
445110	Supermarkets and Other Grocery (except Convenience) Stores
445131	Convenience Retailers
445298	All Other Specialty Food Retailers

NAICS Code	NAICS Industry Description
446191	Food (Health) Supplement Stores
449210	Electronics and Appliance Retailers
452311	Warehouse Clubs and Supercenters
453998	All Other Miscellaneous Store Retailers (except Tobacco Stores)
45711	Gasoline Stations With Convenience Stores
481111	Scheduled Passenger Air Transportation
488510	Freight Transportation Arrangement
493110	General Warehousing and Storage
531120	Lessors of Nonresidential Buildings (except Mini warehouses)
541330	Engineering Services
541380	Testing Laboratories
541512	Computer Systems Design Services
541519	Other Computer Related Services
541620	Environmental Consulting Services
561210	Facilities Support Services
561910	Packaging and Labeling Services
561990	All Other Support Services
562111	Solid Waste Collection
562211	Hazardous Waste Treatment and Disposal
562920	Materials Recovery Facilities
621498	All Other Outpatient Care Centers
621999	All Other Miscellaneous Ambulatory Health Care Services
72111	Hotels (Except Casino Hotels) and Motels
72112	Casino Hotels
72241	Drinking Places (Alcoholic Beverages)
722511	Full-service Restaurants
722513	Limited-Service Restaurants
722514	Cafeterias, Grill Buffets, and Buffets
722515	Snack and Nonalcoholic Beverage Bars

NAICS Code	NAICS Industry Description
81119	Other Automotive Repair and Maintenance
811219	Other Electronic and Precision Equipment Repair and Maintenance
811412	Appliance Repair and Maintenance
922160	Fire Protection

Appendix I. Interim SC-HFC Estimates

Note that the tables in this appendix are replicated from Appendix E in the Allocation Framework Rule RIA updated to 2022$. The SC-HFC estimates are presented in 2022 dollars per metric ton of HFC emitted by year.

Table I-1: SC-HFC-32 (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	55,733.93	42,967.93	113,616.38	20,544.57
2021	57554.74	44512.12	117879.01	21468.90
2022	59375.56	46056.31	122141.64	22393.22
2023	61196.37	47600.50	126404.27	23317.55
2024	63017.18	49144.69	130666.89	24241.87
2025	64838.00	50688.88	134929.52	25166.20
2026	66796.16	52358.05	139406.71	26178.20
2027	68754.32	54027.22	143883.90	27190.20
2028	70712.48	55696.40	148361.09	28202.20
2029	72670.64	57365.57	152838.28	29214.19
2030	74628.80	59034.75	157315.47	30226.19
2031	76911.39	61011.37	163114.11	31479.78
2032	79193.98	62987.99	168912.75	32733.37
2033	81476.57	64964.61	174711.39	33986.96
2034	83759.15	66941.23	180510.03	35240.55
2035	86041.74	68917.85	186308.67	36494.13
2036	88481.38	71033.62	192381.37	37843.42
2037	90921.01	73149.39	198454.07	39192.72
2038	93360.65	75265.16	204526.77	40542.01
2039	95800.28	77380.93	210599.47	41891.30

2040	98239.92	79496.70	216672.18	43240.59
2041	100811.58	81776.70	223487.96	44792.58
2042	103383.24	84056.70	230303.75	46344.57
2043	105954.90	86336.70	237119.54	47896.57
2044	108526.56	88616.70	243935.33	49448.56
2045	111098.22	90896.70	250751.12	51000.55
2046	113832.31	93321.26	257460.90	52652.80
2047	116566.41	95745.83	264170.69	54305.04
2048	119300.51	98170.39	270880.48	55957.29
2049	122034.61	100594.96	277590.26	57609.53
2050	124768.70	103019.52	284300.05	59261.78

Table I-2: SC-HFC-125 (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	321682.24	236106.62	617916.46	92801.00
2021	330113.81	243017.79	637636.30	96408.17
2022	338545.38	249928.97	657356.14	100015.33
2023	346976.95	256840.15	677075.98	103622.49
2024	355408.52	263751.32	696795.82	107229.66
2025	363840.09	270662.50	716515.66	110836.82
2026	372882.44	278100.74	736313.10	114761.22
2027	381924.78	285538.98	756110.54	118685.62
2028	390967.13	292977.21	775907.98	122610.03
2029	400009.48	300415.45	795705.42	126534.43
2030	409051.83	307853.69	815502.85	130458.83
2031	418587.19	315870.10	837880.27	134988.53
2032	428122.56	323886.51	860257.68	139518.24
2033	437657.92	331902.92	882635.10	144047.94
2034	447193.29	339919.33	905012.51	148577.64
2035	456728.65	347935.74	927389.93	153107.34
2036	467095.25	356619.18	951131.37	157996.87
2037	477461.84	365302.62	974872.80	162886.40
2038	487828.43	373986.06	998614.24	167775.93
2039	498195.02	382669.49	1022355.68	172665.46
2040	508561.61	391352.93	1046097.11	177554.99
2041	518723.97	400057.80	1069610.97	182831.16
2042	528886.32	408762.68	1093124.83	188107.32

2043	539048.67	417467.55	1116638.70	193383.49
2044	549211.02	426172.42	1140152.56	198659.65
2045	559373.38	434877.30	1163666.42	203935.82
2046	570017.73	444056.32	1186714.87	209553.62
2047	580662.09	453235.35	1209763.32	215171.42
2048	591306.44	462414.37	1232811.77	220789.21
2049	601950.79	471593.40	1255860.21	226407.01
2050	612595.15	480772.42	1278908.66	232024.81

Table I-3: SC-HFC-134a (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	128956.54	97527.02	255715.50	42820.40
2021	132802.52	100735.17	264718.10	44616.78
2022	136648.50	103943.32	273720.70	46413.16
2023	140494.48	107151.47	282723.30	48209.55
2024	144340.47	110359.62	291725.90	50005.93
2025	148186.45	113567.77	300728.50	51802.32
2026	152352.92	117050.87	310239.57	53767.99
2027	156519.39	120533.97	319750.63	55733.67
2028	160685.86	124017.07	329261.69	57699.34
2029	164852.34	127500.17	338772.75	59665.02
2030	169018.81	130983.27	348283.82	61630.70
2031	173522.07	134824.42	359243.95	63935.01
2032	178025.34	138665.57	370204.08	66239.33
2033	182528.60	142506.72	381164.21	68543.65
2034	187031.87	146347.87	392124.34	70847.96
2035	191535.13	150189.02	403084.47	73152.28
2036	196341.40	154302.19	414341.34	75637.90
2037	201147.68	158415.37	425598.22	78123.51
2038	205953.95	162528.54	436855.09	80609.13
2039	210760.22	166641.71	448111.96	83094.75
2040	215566.49	170754.89	459368.83	85580.37
2041	220151.85	174773.25	469978.32	88194.69
2042	224737.21	178791.61	480587.82	90809.02
2043	229322.57	182809.97	491197.31	93423.34
2044	233907.93	186828.33	501806.80	96037.67
2045	238493.29	190846.69	512416.29	98651.99
2046	243358.39	195121.15	523311.11	101444.82

2047	248223.48	199395.61	534205.92	104237.65
2048	253088.58	203670.07	545100.73	107030.49
2049	257953.68	207944.54	555995.54	109823.32
2050	262818.78	212219.00	566890.36	112616.15

Table I-4: SC-HFC-143a (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	421132.12	299173.31	783238.95	106080.33
2021	431142.84	307198.96	806745.77	110005.01
2022	441153.56	315224.60	830252.59	113929.69
2023	451164.29	323250.25	853759.41	117854.37
2024	461175.01	331275.89	877266.23	121779.05
2025	471185.74	339301.54	900773.05	125703.73
2026	481799.68	347864.64	923395.31	129951.27
2027	492413.63	356427.74	946017.57	134198.81
2028	503027.57	364990.84	968639.82	138446.35
2029	513641.52	373553.94	991262.08	142693.89
2030	524255.46	382117.03	1013884.34	146941.43
2031	535361.32	391278.26	1038533.32	151839.09
2032	546467.18	400439.49	1063182.30	156736.75
2033	557573.04	409600.72	1087831.27	161634.40
2034	568678.90	418761.95	1112480.25	166532.06
2035	579784.75	427923.18	1137129.23	171429.72
2036	591602.07	437692.16	1162875.92	176677.98
2037	603419.40	447461.14	1188622.60	181926.23
2038	615236.72	457230.12	1214369.29	187174.49
2039	627054.04	466999.10	1240115.98	192422.75
2040	638871.36	476768.08	1265862.66	197671.01
2041	650640.86	486712.46	1293311.44	203452.05
2042	662410.35	496656.84	1320760.22	209233.09
2043	674179.85	506601.23	1348209.00	215014.13
2044	685949.35	516545.61	1375657.78	220795.17
2045	697718.84	526489.99	1403106.56	226576.21
2046	710175.88	537037.69	1431859.80	232726.23
2047	722632.92	547585.38	1460613.04	238876.25
2048	735089.95	558133.08	1489366.29	245026.27
2049	747546.99	568680.77	1518119.53	251176.30
2050	760004.02	579228.46	1546872.77	257326.32

Table I-5: SC-HFC-152a (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	7756.57	6000.16	15853.35	2938.14
2021	8011.03	6217.38	16457.20	3071.55
2022	8265.50	6434.60	17061.05	3204.96
2023	8519.96	6651.82	17664.91	3338.38
2024	8774.42	6869.04	18268.76	3471.79
2025	9028.88	7086.26	18872.61	3605.21
2026	9304.30	7322.12	19493.32	3751.50
2027	9579.73	7557.99	20114.03	3897.79
2028	9855.15	7793.86	20734.74	4044.08
2029	10130.57	8029.73	21355.45	4190.38
2030	10406.00	8265.59	21976.16	4336.67
2031	10731.00	8548.40	22805.88	4519.51
2032	11056.01	8831.21	23635.59	4702.35
2033	11381.01	9114.02	24465.31	4885.19
2034	11706.01	9396.83	25295.02	5068.03
2035	12031.02	9679.64	26124.74	5250.87
2036	12378.80	9982.48	26985.45	5447.56
2037	12726.58	10285.31	27846.17	5644.26
2038	13074.37	10588.15	28706.88	5840.95
2039	13422.15	10890.99	29567.60	6037.65
2040	13769.93	11193.83	30428.32	6234.34
2041	14184.53	11559.71	31588.17	6482.08
2042	14599.12	11925.58	32748.03	6729.82
2043	15013.71	12291.46	33907.88	6977.56
2044	15428.31	12657.33	35067.74	7225.30
2045	15842.90	13023.21	36227.59	7473.03
2046	16279.77	13409.45	37375.91	7735.42
2047	16716.64	13795.69	38524.22	7997.81
2048	17153.51	14181.93	39672.54	8260.20
2049	17590.38	14568.18	40820.85	8522.59
2050	18027.25	14954.42	41969.17	8784.98

Table I-6: SC-HFC-227ea (2022$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	297055.07	216155.46	566455.49	82545.11
2021	304615.60	222319.00	583582.24	85705.12
2022	312176.14	228482.54	600708.99	88865.14
2023	319736.68	234646.07	617835.74	92025.15
2024	327297.22	240809.61	634962.49	95185.17
2025	334857.75	246973.15	652089.25	98345.18
2026	342938.85	253590.74	669863.24	101778.56
2027	351019.95	260208.32	687637.24	105211.95
2028	359101.05	266825.91	705411.23	108645.33
2029	367182.15	273443.50	723185.23	112078.72
2030	375263.25	280061.09	740959.23	115512.10
2031	383757.34	287172.74	760683.78	119472.00
2032	392251.43	294284.39	780408.34	123431.90
2033	400745.53	301396.05	800132.90	127391.81
2034	409239.62	308507.70	819857.46	131351.71
2035	417733.71	315619.36	839582.01	135311.61
2036	426854.89	323251.93	860042.27	139569.23
2037	435976.06	330884.50	880502.52	143826.85
2038	445097.23	338517.07	900962.77	148084.47
2039	454218.40	346149.64	921423.03	152342.09
2040	463339.57	353782.21	941883.28	156599.71
2041	472317.41	361466.19	961555.81	161220.41
2042	481295.25	369150.17	981228.35	165841.11
2043	490273.09	376834.15	1000900.88	170461.81
2044	499250.93	384518.13	1020573.42	175082.51
2045	508228.77	392202.11	1040245.95	179703.20
2046	517791.18	400395.42	1061935.84	184636.50
2047	527353.59	408588.73	1083625.74	189569.80
2048	536916.00	416782.04	1105315.63	194503.10
2049	546478.41	424975.35	1127005.53	199436.40
2050	556040.82	433168.66	1148695.42	204369.70

Table I-7: SC-HFC-236fa (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	1088012.51	711629.23	1871276.22	204546.68
2021	1109343.77	727899.70	1917560.99	211581.34
2022	1130675.03	744170.17	1963845.75	218616.00
2023	1152006.30	760440.64	2010130.52	225650.66
2024	1173337.56	776711.11	2056415.29	232685.32
2025	1194668.83	792981.57	2102700.05	239719.98
2026	1217267.97	810303.11	2149615.48	247294.82
2027	1239867.12	827624.64	2196530.90	254869.67
2028	1262466.26	844946.17	2243446.33	262444.51
2029	1285065.40	862267.70	2290361.76	270019.35
2030	1307664.55	879589.24	2337277.18	277594.19
2031	1331403.16	898146.01	2391611.16	286386.37
2032	1355141.77	916702.79	2445945.13	295178.55
2033	1378880.39	935259.56	2500279.11	303970.72
2034	1402619.00	953816.34	2554613.08	312762.90
2035	1426357.61	972373.12	2608947.06	321555.08
2036	1451306.91	991960.75	2665502.72	330905.26
2037	1476256.21	1011548.39	2722058.39	340255.44
2038	1501205.50	1031136.02	2778614.05	349605.62
2039	1526154.80	1050723.66	2835169.72	358955.81
2040	1551104.10	1070311.29	2891725.38	368305.99
2041	1576689.31	1090753.23	2950311.80	378894.63
2042	1602274.52	1111195.18	3008898.23	389483.28
2043	1627859.73	1131637.12	3067484.65	400071.93
2044	1653444.95	1152079.06	3126071.07	410660.57
2045	1679030.16	1172521.00	3184657.49	421249.22
2046	1705768.95	1193986.92	3244613.16	432431.27
2047	1732507.75	1215452.83	3304568.83	443613.32
2048	1759246.54	1236918.74	3364524.50	454795.37
2049	1785985.34	1258384.65	3424480.18	465977.43
2050	1812724.13	1279850.56	3484435.85	477159.48

Table I-8: SC-HFC-245fa (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	89468.00	68623.70	180669.87	32002.52
2021	92309.89	71025.77	187355.76	33413.51
2022	95151.78	73427.84	194041.64	34824.49
2023	97993.67	75829.91	200727.53	36235.47
2024	100835.57	78231.98	207413.41	37646.46
2025	103677.46	80634.05	214099.30	39057.44
2026	106746.93	83237.14	221092.99	40601.70
2027	109816.41	85840.24	228086.68	42145.96
2028	112885.88	88443.34	235080.38	43690.22
2029	115955.36	91046.44	242074.07	45234.48
2030	119024.84	93649.54	249067.76	46778.74
2031	122498.30	96647.08	257844.49	48651.65
2032	125971.76	99644.61	266621.22	50524.56
2033	129445.22	102642.15	275397.95	52397.47
2034	132918.68	105639.69	284174.67	54270.39
2035	136392.14	108637.22	292951.40	56143.30
2036	140152.58	111877.65	302104.63	58168.31
2037	143913.02	115118.08	311257.87	60193.32
2038	147673.45	118358.51	320411.10	62218.32
2039	151433.89	121598.93	329564.33	64243.33
2040	155194.33	124839.36	338717.56	66268.34
2041	158869.74	128085.15	347843.81	68456.07
2042	162545.16	131330.93	356970.05	70643.79
2043	166220.58	134576.72	366096.30	72831.52
2044	169895.99	137822.50	375222.54	75019.24
2045	173571.41	141068.29	384348.79	77206.96
2046	177533.63	144563.42	393792.21	79557.03
2047	181495.86	148058.56	403235.62	81907.09
2048	185458.08	151553.70	412679.04	84257.16
2049	189420.31	155048.84	422122.46	86607.23
2050	193382.53	158543.98	431565.88	88957.29

Table I-9: SC-HFC-43-10mee (2022$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	148861.07	112098.04	293905.01	48396.89
2021	153189.60	115704.38	303937.05	50397.59
2022	157518.13	119310.71	313969.08	52398.29
2023	161846.66	122917.04	324001.11	54399.00
2024	166175.18	126523.38	334033.15	56399.70
2025	170503.71	130129.71	344065.18	58400.40
2026	175209.52	134052.62	354910.00	60589.73
2027	179915.33	137975.52	365754.83	62779.05
2028	184621.14	141898.43	376599.65	64968.38
2029	189326.94	145821.33	387444.47	67157.71
2030	194032.75	149744.24	398289.30	69347.03
2031	199086.33	154044.72	410454.48	71902.31
2032	204139.91	158345.21	422619.66	74457.59
2033	209193.49	162645.69	434784.85	77012.87
2034	214247.07	166946.18	446950.03	79568.15
2035	219300.64	171246.66	459115.21	82123.42
2036	224676.69	175840.53	471633.00	84877.15
2037	230052.73	180434.41	484150.78	87630.88
2038	235428.77	185028.28	496668.56	90384.61
2039	240804.81	189622.15	509186.34	93138.33
2040	246180.86	194216.03	521704.12	95892.06
2041	251333.77	198722.44	533472.51	98795.21
2042	256486.69	203228.85	545240.89	101698.35
2043	261639.61	207735.27	557009.28	104601.49
2044	266792.53	212241.68	568777.66	107504.64
2045	271945.45	216748.09	580546.05	110407.78
2046	277436.76	221555.48	592857.92	113511.21
2047	282928.07	226362.87	605169.80	116614.65
2048	288419.39	231170.26	617481.67	119718.08
2049	293910.70	235977.65	629793.55	122821.51
2050	299402.01	240785.04	642105.42	125924.94

Table I-10: SC-HFC-23 (2022$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	1660692.00	1081400.12	2873037.41	307668.79
2021	1693043.33	1106002.65	2942537.52	318230.46
2022	1725394.67	1130605.18	3012037.62	328792.13
2023	1757746.01	1155207.71	3081537.72	339353.80
2024	1790097.35	1179810.24	3151037.83	349915.47
2025	1822448.69	1204412.77	3220537.93	360477.14
2026	1856630.60	1230554.11	3292420.73	371844.71
2027	1890812.51	1256695.46	3364303.54	383212.29
2028	1924994.42	1282836.81	3436186.35	394579.86
2029	1959176.32	1308978.15	3508069.15	405947.44
2030	1993358.23	1335119.50	3579951.96	417315.01
2031	2029297.80	1363149.94	3662535.07	430524.12
2032	2065237.36	1391180.39	3745118.17	443733.22
2033	2101176.93	1419210.84	3827701.28	456942.33
2034	2137116.49	1447241.28	3910284.39	470151.43
2035	2173056.06	1475271.73	3992867.50	483360.54
2036	2210881.02	1504905.18	4077606.29	497436.61
2037	2248705.98	1534538.63	4162345.07	511512.68
2038	2286530.94	1564172.08	4247083.86	525588.75
2039	2324355.91	1593805.53	4331822.65	539664.81
2040	2362180.87	1623438.98	4416561.43	553740.88
2041	2400988.05	1654369.62	4507297.75	569678.01
2042	2439795.23	1685300.26	4598034.07	585615.13
2043	2478602.40	1716230.90	4688770.38	601552.25
2044	2517409.58	1747161.54	4779506.70	617489.38
2045	2556216.76	1778092.18	4870243.01	633426.50
2046	2596764.24	1810549.89	4963028.17	650233.41
2047	2637311.71	1843007.60	5055813.32	667040.33
2048	2677859.19	1875465.31	5148598.47	683847.25
2049	2718406.67	1907923.02	5241383.62	700654.16
2050	2758954.14	1940380.73	5334168.77	717461.08

Appendix J. Updated SC-GHG Estimates

EPA calculated updated estimates of the SC-HFCs consistent with the methodology set forth in the *EPA Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances* (EPA, 2023c). See EPA (2023c) for a full explanation of the updated methodology and how the updated SC-GHG estimates differ from those produced under the IWG-SCGHG (2021) methods. To recover updated estimates of the SC-HFCs for this rule consistent with EPA (2023c), several modifications were necessary. First, background emissions trajectories for HFC-236fa were added to the climate module (FaIR1.6.2) using the SSP2-4.5 storyline scenario; the other 7 HFCs affected by this rule were already contained within the climate module and are also drawn from SSP2-4.5. Second, the sea-level rise module underlying the DSCIM damage module (FACTS) has been updated to directly estimate changes in sea-level rise from probabilistic socioeconomics and emissions scenarios (i.e., RFF-SPs), as opposed to the use of an emulator as was done in EPA (2023c). Additional documentation and full replication of the models and their estimates are available at www.github.com/USEPA/schfc as well as in the docket.[78] Table J-1 presents the climate benefits from the final ER&R Rule using the updated SC-HFC estimates for each gas in 2022$.

Table J-1: Undiscounted Monetized Climate Benefits (2022$)[a,b,c]

	Base Case Incremental Climate Benefits (millions 2022$)		
	Near-Term Ramsey Discount Rate		
Year	**1.5%**	**2%**	**2.5%**
2024	$0.00	$0.00	$0.00
2025	$0.00	$0.00	$0.00
2026	$1,000.00	$710.00	$530.00
2027	$1,200.00	$830.00	$620.00
2028	$1,600.00	$1,100.00	$850.00
2029	$1,600.00	$1,100.00	$850.00
2030	$1,500.00	$1,100.00	$840.00
2031	$1,500.00	$1,100.00	$840.00
2032	$1,500.00	$1,100.00	$830.00
2033	$1,500.00	$1,100.00	$830.00
2034	$1,400.00	$1,100.00	$810.00
2035	$1,400.00	$1,000.00	$780.00
2036	$1,300.00	$970.00	$750.00
2037	$1,200.00	$920.00	$710.00
2038	$1,200.00	$870.00	$680.00
2039	$1,100.00	$820.00	$640.00

[78] GLOBAL_2023_AIM.xlsx

2040	$1,000.00	$770.00	$600.00
2041	$960.00	$720.00	$570.00
2042	$870.00	$660.00	$520.00
2043	$790.00	$600.00	$470.00
2044	$720.00	$550.00	$440.00
2045	$670.00	$510.00	$410.00
2046	$620.00	$480.00	$380.00
2047	$580.00	$450.00	$360.00
2048	$550.00	$430.00	$350.00
2049	$530.00	$410.00	$340.00
2050	$520.00	$410.00	$340.00
PV	**$22,000.00**	**$15,000.00**	**$11,000.00**
EAV	**$1,100.00**	**$790.00**	**$610.00**

[a] Rows may not appear to add correctly due to rounding.
[b] Present values are calculated using end of year discounting.
[c] The equivalent annual values of benefits are calculated over a 25-year period.

Appendix K. Cost of Reclaim/Recycled HFCs Sensitivity Results

In the base case scenario, EPA assumed reclaimed/recycled HFCs to be 10% more expensive than virgin HFCs. This was chosen as a conservative measure to prevent underestimating the total cost. However, as pointed out by comments received under the Notice of Proposed Rulemaking (NPRM), the cost of reclaim may be closer to parity with virgin manufacture. Thus, EPA ran an additional analysis where reclaimed/recycled HFCs cost were equivalent to virgin HFCs. The results for this analysis are shown in Table K-1.

Table K-1: Difference in annual incremental cost for all MAC options for different reclaim costs (millions of 2022$, discounted to 2024)[a,b,c]

Cost of Reclaim Sensitivity Analysis			
Year	***Reclaim > Virgin (Base Case)***	***Reclaim = Virgin***	***% Change***
2026	$79.71	$79.52	-0.2%
2027	$111.60	$111.40	-0.2%
2028	$93.49	$93.28	-0.2%
2029	$95.06	$91.42	-3.8%
2030	$93.05	$88.95	-4.4%
2031	$90.45	$86.49	-4.4%
2032	$87.51	$83.69	-4.4%
2033	$84.71	$81.01	-4.4%
2034	$83.03	$79.46	-4.3%

2035	$79.05			$75.58			-4.4%		
2036	$75.15			$71.79			-4.5%		
2037	$71.65			$68.41			-4.5%		
2038	$68.09			$64.95			-4.6%		
2039	$64.46			$61.44			-4.7%		
2040	$60.77			$57.87			-4.8%		
2041	$57.99			$55.22			-4.8%		
2042	$53.45			$50.79			-5.0%		
2043	$49.80			$47.22			-5.2%		
2044	$47.86			$45.26			-5.4%		
2045	$46.22			$43.60			-5.7%		
2046	$46.01			$43.37			-5.7%		
2047	$45.90			$43.24			-5.8%		
2048	$45.91			$43.22			-5.9%		
2049	$46.02			$43.31			-5.9%		
2050	$46.24			$43.51			-5.9%		
DR	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**
PV	$1,343	$1,196	$790	$1,292	$1,151	$764	-3.8%	-3.7%	-3.4%
EAV	$68.80	$68.69	$67.80	$66.17	$66.13	$65.52	-3.8%	-3.7%	-3.4%

[a] The first scenario represents the base case which assumes a 10% markup on the cost of reclaim. The second scenario assumes the reclaim and virgin HFCs are equivalent in cost.
[b] Present values are calculated using end of year discounting.
[c] The equivalent annual values of benefits are calculated over a 25-year period.

When assuming reclaim parity with virgin, annual incremental costs fall by $0.11 M to $2.44 M (0% to 5% decrease). However, when compared to the total cost of the rule this represents only a marginal decrease of ~2%.

Appendix L. Alternative Equipment Age Requirements for ALD

The EPA considered different equipment age cutoffs for the ALD requirement in this rule beyond new CR and IPR refrigerant-containing appliances, which are required to install the ALD system within 30 days of installation. Additional analyses were with equipment age thresholds of 5 years and all existing equipment in addition to the base case (10 years before the January 1, 2027 compliance date). Results are summarized in Table L-1.

Table L-1:Difference in annual incremental cost for all MAC options for different equipment age cutoffs for the ALD requirement (millions of 2022$, discounted to 2024)

Alternative Equipment Age Requirements for ALD Sensitivity Analysis					
	Cost (2022$)			***% Change from Base Case***	
Year	***2017+ (Base Case)***	***2021+***	***All Existing***	***2021+***	***All Existing***
2026	$80	$80	$80	0.0%	0.0%
2027	$112	$92	$148	-17.4%	32.9%
2028	$93	$84	$144	-9.6%	54.0%
2029	$95	$86	$142	-9.4%	49.8%
2030	$93	$84	$137	-9.6%	47.5%
2031	$90	$82	$131	-9.8%	45.4%
2032	$88	$79	$125	-10.1%	43.2%
2033	$85	$76	$119	-10.4%	40.7%
2034	$83	$73	$113	-11.8%	35.9%
2035	$79	$70	$106	-10.8%	34.5%
2036	$75	$68	$100	-9.9%	32.7%
2037	$72	$65	$94	-8.7%	30.5%
2038	$68	$63	$87	-7.4%	28.0%
2039	$64	$61	$81	-6.0%	25.2%
2040	$61	$57	$74	-6.3%	22.0%

2041	$58			$53			$67			-8.3%			16.2%		
2042	$53			$50			$61			-7.2%			13.9%		
2043	$50			$47			$56			-5.6%			11.7%		
2044	$48			$46			$53			-3.7%			10.5%		
2045	$46			$45			$51			-1.8%			9.5%		
2046	$46			$46			$50			0.0%			8.3%		
2047	$46			$46			$49			0.0%			7.4%		
2048	$46			$46			$49			0.0%			6.6%		
2049	$46			$46			$49			0.0%			6.0%		
2050	$46			$46			$49			0.0%			5.7%		
DR	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**	**2%**	**3%**	**7%**
PV	$1,343	$1,196	$790	$1,235	$1,098	$721	$1,746	$1,563	$1,048	-8%	-18%	-46%	30%	16%	-22%
EAV	$69	$69	$68	$63	$63	$62	$89	$90	$90	-8%	-8%	-10%	30%	30%	31%

Appendix M. Disposable Cylinder Management

Introduction

Most HFCs, including those used as refrigerants, are gases at room temperature and are typically transported and stored as compressed liquids in pressurized metal containers called cylinders. There are two primary types of cylinders. Disposable (also known as non-refillable or single-use or DOT-39) cylinders are used once before disposal, whereas refillable cylinders can be used multiple times throughout the cylinder lifetime. Disposable cylinders today are typically discarded with refrigerants still in the cylinders, including from amounts commonly referred to as heels (i.e., the small amount of refrigerant that remains in an “empty” cylinder). These residual refrigerants are emitted over time as they leak out or are expelled when the cylinder is crushed for disposal or metal recycling. So-called “30-pound” metal cylinders are most often disposable but may come in refillable designs as well and are used primarily in the stationary air-conditioning and refrigeration system servicing industry and, to a lesser extent, in motor vehicle air conditioning.

The provisions of this rule include requirements to remove the heel from used disposable cylinders before the cylinders are discarded; the requirement covers disposable cylinders used for servicing, repair, disposal, or installation of equipment. Both disposable and refillable cylinders will be available for transporting refrigerant; however, it is expected that refillable cylinders are returned and refilled several times in the baseline, and that no additional costs or benefits from refillable cylinders result based on this rule. For analytical purposes, the Agency focused on anticipated additional reductions in HFC consumption and emissions as well as industry costs and the potential savings from avoided refrigerant loss from disposable cylinders.

EPA has prepared a report, *Refrigerant Cylinders: Analysis of Use, Disposal, and Distribution of Refrigerants* (EPA 2024a), analyzing the costs and benefits of the requirement that disposable cylinders that have been used for the servicing, repair, or installation of refrigerant-containing equipment be transported to an EPA-certified reclaimer, and that reclaimers or another final processor within the supply and disposal chain remove all HFCs (i.e., heel) from disposable cylinders prior to discarding the cylinder. If the heel is removed by a final processor or otherwise in the supply chain, the removed heels may be consolidated, but must be sent to an EPA-certified reclaimer or fire suppressant recycler. This appendix presents a summary of some of the results from this report and provides further analysis.

Emission Estimates for Recovery of Disposable Cylinder Heels

The report assesses the typical distribution of refrigerants in cylinders, including refrigerant changes expected under the Base Case for this rule. Heels remaining in disposable cylinders were determined through both a theoretical and empirical study. Based on the wide range of disposal practices currently employed and expected to continue in absence of this final rule, three scenarios were developed to estimate the emissions avoided: a central scenario, a low scenario (i.e., a lower heel left in the cylinder), and a high scenario.

The emissions avoided by removing such heels are dependent on the number of disposable cylinders in circulation and the average heel that would otherwise be emitted in absence of this rule. Based on the report cited above, we assume in the central scenario that there are approximately 4.5 million cylinders in circulation, of which 99% are disposable. Further, we estimate that the average heel is approximately 4% by weight of the nominal capacity (e.g. 0.96 pounds for a 24-pound cylinder).[79] We use a heel of 0.288 pounds (1.2 percent) and 1.65 pounds (6.875 percent) for the low and high scenarios, respectively. Because of the other regulations in place, it is expected that the average GWP of the refrigerant in such cylinders will decrease. Other emissions associated with cylinders—for example, during transport and storage—are not expected to change based on this rule. Based on the expected transitions from these regulations, Table M-1, below, presents the avoided emissions for the years 2028 through 2050.

Table M-1: Estimated Annual Emission Changes Compared with BAU, 2028–2050

Year	***Average HFC GWP***	***Emission Reductions Relative to BAU (MMTCO₂e)***		
		Central	***Low***	***High***
2028	1,547	2.27	0.68	3.90
2029	1,498	2.17	0.65	3.73
2030	1,445	2.06	0.62	3.54
2031	1,390	1.95	0.59	3.35
2032	1,332	1.84	0.55	3.17
2033	1,274	1.74	0.52	2.99
2034	1,210	1.63	0.49	2.80
2035	1,142	1.52	0.46	2.61
2036	1,071	1.41	0.42	2.42
2037	1,002	1.31	0.39	2.25
2038	945	1.22	0.37	2.10
2039	900	1.16	0.35	1.99
2040	872	1.12	0.33	1.92
2041	843	1.07	0.32	1.84
2042	814	1.03	0.31	1.77
2043	788	0.99	0.30	1.71
2044	769	0.97	0.29	1.66

[79] R-404A is typically sold in a 24-pound cylinder. Cylinders for other HFC refrigerants are typically larger, from 25 to 50 pounds. We use 24 pounds as a conservative estimate here.

Year	Average HFC GWP	Emission Reductions Relative to BAU ($MMTCO_2e$)		
		Central	Low	High
2045	753	0.94	0.28	1.62
2046	742	0.93	0.28	1.60
2047	733	0.92	0.28	1.58
2048	726	0.91	0.27	1.56
2049	720	0.90	0.27	1.55
2050	717	0.90	0.27	1.54
Total		**30.96**	**9.29**	**53.21**

Cost Estimates for Recovery of Disposable Cylinder Heels

The report also assesses the cost implications for the requirement for heel removal, accounting for the costs associated with the change in procedure handling of cylinders (i.e., returning the cylinders for heels to be removed) and the potential savings from avoided refrigerant loss from heel emissions. There are multiple paths that the cylinder may take before the heel is removed and the truly-empty cylinder is landfilled or recycled. This analysis assumes that some cylinders will be: (a) sent directly to the reclaimer; (b) returned to a wholesaler or distributor,[80] who will ship disposable cylinders to a landfill or steel recycling facility, which would combine heels for shipment to a reclaimer; and (c) shipped directly from the end-user or technician to a landfill or steel recycling facility, which would combine heels for shipment to a reclaimer. For paths (b) and (c) above, we assume the landfill or steel recycling facility would reduce costs by combining 25 refrigerant heels (at 0.96 pounds as discussed above) of each HFC or HFC substitutes containing an HFC (e.g., HFC/HFO blends) they receive into individual 24-pound cylinders before sending those to a reclaimer. After recovering heels, reclaimers are assumed to send disposable cylinders to a landfill or steel recycler.

Neat HFOs, which are not regulated substances under this rulemaking but are used in some RACHP equipment, are not accounted for in the analysis. For HFCs and HFC/HFO blends, we divide cylinders equally amongst the transportation paths described above. Thus, we assume one-third follow path (a), one-third follow path (b), and one-third follow patch (c). Table M-2 displays the estimated mileage for each leg of the paths taken compared to the business-as-usual (BAU) route.

[80] Wholesalers and distributors could also perform the heel recovery, and likewise amass heels into a single cylinder to be shipped to a reclaimer. Based on comments to the NPRM that indicate an economic disincentive to doing that at a wholesaler/distributor facility, we assume cylinders with heels received by these entities are shipped directly to the landfill or steel recycler.

Table M-2: Estimated Distances for Disposable Cylinder Transportation Compared with BAU (Miles)[a]

Transportation Leg	***BAU***	***(a) End-user to Reclaimer to Landfill***	***(b) End-user to Distributor to Reclaimer***	***© End-user to Landfill***
Producer/Filler to Wholesale Distributor	1,000	1,000	1,000	1,000
Wholesale Distributor to End User/Technician	25	25	25	25
End User/Technical to Steel Recycler/Landfill	75	NA	NA	75
End User/Technical to Reclaimer	NA	50	NA	NA
End User/Technical to Wholesale Distributor	NA	NA	25	NA
Reclaimer to Steel Recycler/Landfill	NA	75	75	NA
Landfill sending Recovered Refrigerant to Reclaimer[b]	NA	NA	75	75
Total Miles per Cylinder	**1,100**	**1,150**	**1,128**	**1,103**

[a] CARB (2011)

[b] Each cylinder sent represents 25 cylinders received with heels (Central scenario).

The additional travel costs are influenced by how many cylinders fit on a truck, the fuel to drive the extra distances, and the incremental labor for such. By removing heels that would have otherwise been emitted, an additional supply is provided that would offset virgin production providing additional benefits based on the cost of refrigerant. These assumptions are shown in Table M-3 below.

Table M-3: Additional Disposable Cylinder Cost Assumptions

Factor (units)	***Value***	***Source***	***Notes***
Cylinders per Truck	1,120	CARB (2011)	
Average Truck Speed (miles per hour)	50	CARB (2011)	
Truck Transport Labor Rate ($/hour)	$53.59	U.S. Bureau of Labor Statistics (2023)	May 2022 mean, including 110% overhead
Average Fuel Consumption (miles per gallon)	6.1	Geotab (2017)	Average across all states
Fuel cost ($/gallon)	$4.034	U.S. EIA (2024)	Price of diesel as of March 25, 2024
Cost of HFC refrigerant ($/pound)	$4		Consistent with past AIM Act analyses

Accounting for the fuel and labor associated with the additional shipment of cylinders and the cost of refrigerants, we estimate costs and benefits, and hence the net benefits, as shown in Table M-4 for the Central scenario.

Table M-4: Costs, Benefits, and Net Benefits of Cylinder Management (Central Scenario) (Millions 2022$)[a,b]

Year	***Benefits***			***Costs***			***Net Benefits***		
2028	$12.94			$0.14			$12.80		
2029	$12.76			$0.14			$12.62		
2030	$12.57			$0.14			$12.43		
2031	$12.37			$0.13			$12.24		
2032	$12.19			$0.13			$12.06		
2033	$12.03			$0.13			$11.90		
2034	$11.88			$0.13			$11.75		
2035	$11.74			$0.13			$11.61		
2036	$11.62			$0.13			$11.49		
2037	$11.52			$0.13			$11.39		
2038	$11.43			$0.12			$11.30		
2039	$11.35			$0.12			$11.22		
2040	$11.28			$0.12			$11.16		
2041	$11.22			$0.12			$11.10		
2042	$11.16			$0.12			$11.04		
2043	$11.12			$0.12			$10.99		
2044	$11.09			$0.12			$10.97		
2045	$11.06			$0.12			$10.94		
2046	$11.05			$0.12			$10.93		
2047	$11.04			$0.12			$10.92		
2048	$11.03			$0.12			$10.91		
2049	$11.02			$0.12			$10.90		
2050	$11.02			$0.12			$10.90		
d.r.	2%	3%	7%	2%	3%	7%	2%	3%	7%
PV	$197.1	$170.9	$101.9	$2.1	$1.9	$11	$194.9	$169.1	$100.8
EAV	$10.09	$9.82	$8.74	$0.11	$0.11	$0.095	$9.98	$9.71	$8.65

[a] Present values are calculated using end of year discounting.
[b] The equivalent annual values of benefits are calculated over a 25-year period.

Climate Benefits from Recovery of Disposable Cylinder Heels

As discussed above, as the market transitions to lower-GWP refrigerants based on the 2023 Technology Transitions Rule, the mix of regulated refrigerants will change. In general, the transition would lead to higher use of refrigerants not covered by the disposable cylinder management provision (e.g., ammonia, carbon dioxide, hydrocarbons, HFOs) and less use of regulated substances (HFCs, HFC/HFO blends). The social cost implications are determined as discussed in Section 3.5 and added to the net benefits from the above table. *Table M-5* presents the emission reductions by gas, the social cost attributed to that mix of gases, and the net benefits inclusive of the social costs.

Table M-5: Emission Reductions, Social Cost Benefits, and Net Benefits of Cylinder Management (Central Scenario)

	Emission Reductions (Metric Tons)					***Benefits (millions 2022$)***	
	HFC-32	***HFC-125***	***HFC-134a***	***HFC-143a***	***HFC-245fa***	***SC Benefits***	***Net***
2028	680	332	203	81	0.44	$190	$202
2029	686	312	191	76	0.44	$186	$198
2030	693	292	176	71	0.45	$181	$193
2031	700	271	161	67	0.45	$176	$188
2032	706	249	148	63	0.45	$171	$183
2033	713	227	136	59	0.46	$166	$177
2034	720	204	126	55	0.46	$159	$171
2035	728	180	118	51	0.47	$152	$164
2036	736	156	112	46	0.47	$145	$157
2037	743	131	109	43	0.47	$139	$150
2038	749	112	105	39	0.48	$133	$145
2039	755	99	100	36	0.48	$130	$141
2040	759	93	95	32	0.48	$128	$139
2041	764	86	90	28	0.48	$126	$137
2042	769	80	85	24	0.48	$125	$136
2043	773	75	81	20	0.43	$123	$134
2044	776	73	79	17	0.34	$123	$134
2045	778	70	78	13	0.22	$123	$134
2046	780	69	76	11	0.12	$125	$135
2047	781	68	75	10	0.05	$126	$137
2048	783	67	74	8.2	0.01	$128	$139
2049	783	67	73	6.9	0	$129	$140
2050	784	67	73	6.5	0	$132	$143
Present Value (2% discount rate)						N/A	$2,360
Present Value (3% discount rate)						$2,165	$2,335
Present Value (7% discount rate)						N/A	$2,266
Equivalent Annual Value (2% discount rate)						N/A	$134
Equivalent Annual Value (3% discount rate)						$124	$134
Equivalent Annual Value (7% discount rate)						N/A	$133

Sensitivity Analyses for Recovery of Disposable Cylinder Heels

Several entities provided comments on the assumptions found in the report relied upon above (*e.g.*, Worthington, 2023). One commenter indicates the assumed number of cylinders of 4,500,000 is too low, that the heel remaining in a cylinder upon disposal of 4 percent is too high, and that the assumption that all or nearly all of such cylinders will emit the totality of the heel rather than be removed is not the case. Below we summarize the potential effects on the costs and emission reductions under alternate assumptions based on these comments.

The commenter says that their own sale of disposable cylinders is nearly 50% greater than EPA's estimate, that records indicate 3,941,577 cylinders were imported from China, and that other countries also supply an unspecified number of cylinders. Although it is not clear what percentage of these cylinders would be used for refrigerants covered by this rule, for this sensitivity analysis, we add to our central estimate a full 50% increase, plus the full number of reported cylinders from China, and we assume that the other countries contribute 1 million cylinders, for a total of 11,691,577 cylinders.

Comments also discussed the expected heel within a cylinder. One commenter indicated an estimated heel of 1.2 percent of the charged weight, while also citing various other estimates including 1.85 percent from CARB, noting this was also corroborated by the Heating, Air-conditioning and Refrigeration Distributers, International (HARDI), and 0.2 percent to 4.4 percent from Chemours, an HFC producer. Below we examine the lowest of these estimates, a 0.2 percent heel in lieu of our central estimate of 4 percent.

In addition, commenters took issue with the assumption that all cylinders will fully emit those heels. Instead, they argued that service technicians fully evacuate cylinders so that very little if any heel remains. The commenter above cited National Refrigerants, a reclaimer, stating that 90 percent of cylinders have a remaining heel of 0.5 pounds (about 2 percent) or less and that 60 percent have no discernible heel, an indication that cylinder heel removal is occurring in the field already. The commenter also pointed to CARB, which estimated that 70 percent of disposable cylinders are recycled or disposed without heel evacuation. The commenter held that it would be reasonable to assume between 10 percent and 70 percent are not properly evacuated before disposition. For this sensitivity analysis, we use the extreme conservative end of this range, i.e., 10 percent.

Table M-6 below presents the present value of the costs and the emissions avoided using the above discussed variables. Note these costs are based on handling and transportation alone, and do not include climate benefits.

Table M-6: Costs and Emission Reductions of Cylinder Management under Different Assumptions (Millions 2022$)

	Number of Cylinders	***Heel***	***Not Vented***	***Benefits; NPV in 2022$ (3% discount rate, discounted to 2024)***	***Emission Reductions (MMTCO$_2$e)***
Central Scenario	4,500,000	4%	0%	$169.1 million	30.96
Higher Cylinders	11,691,577	4%	0%	$439.3 million	80.43
Lower Heel	4,500,000	0.2%	0%	$6.69 million	1.548
Low Vented	4,500,000	4%	90%	$16.91 million	3.096
Combined	11,691,577	0.2%	90%	$1.74 million	0.402

Regulatory Option

EPA proposed that requirements for disposable cylinder management begin in 2025. For reasons stated in the final rule, EPA has removed some of those requirements and delayed the date upon which they begin to January 1, 2028. The draft RIA Addendum included with the proposed rule examined the costs and benefits of the proposed action. Table M-7 below provides the costs and emission reductions that would have been achieved under the finalized requirements with the proposed start date of 2025. The delay results in lower emission reductions and lower costs for the final rule compared to an earlier effective date as proposed.

Table M-7: Net Benefits and Emission Reductions of Cylinder Management under Different Start Years ($MMTCO_2e$, Millions 2022$)

	Effective in 2028 (final rule)	***Effective in 2025 (proposed rule)***	***Difference***	***Percentage change from proposed rule start date***
Emission Reductions ($MMTCO_2e$)	30.96	38.49	-7.53	-19.6%
Net Benefits[a] (millions 2022$)	$169.1	$205.3	-$36.2	-17.6%

[a]Net benefits represent the present value at a 3% discount rate discounted to 2024.