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

June 2023

Executive Summary

The final rule *Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years* furthers the implementation of the phasedown of hydrofluorocarbons (HFCs) that was outlined in the final rule *Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act* (Allocation Framework Rule or Framework Rule, 86 FR 55116). The benefits and costs of the entire HFC phasedown from 2022 through 2050 were estimated at the time of the Framework Rule. However, this rule lowers the consumption baseline that in part determines the maximum allowed consumption of HFC in future years, starting in 2024. Establishing a lower consumption baseline for the rest of the HFC phasedown changes the climate benefits and compliance costs relative to the estimates presented in the regulatory impact analysis (RIA) for the Framework Rule. This analysis—an addendum to the Framework Rule RIA—estimates the incremental changes in benefits and costs that result from the decrease of the consumption baseline. This document also updates one element of the cost modeling of the Framework Rule RIA and costs associated with recordkeeping and reporting. These adjustments, in combination with the incremental benefits and costs due to the baseline change, serve to update the previously calculated totals of the benefits, costs, and net benefits of the HFC phasedown. With the lower consumption baseline and updated assumptions described in this addendum, the revised estimate of the net benefit of the HFC phasedown between 2022 and 2050 is $269.9 billion with a 3 percent discount rate and $265.8 billion with a 7 percent discount rate, in 2020 dollars and discounted to 2022.

EPA has also updated the environmental justice analysis to reflect new data on the public health risks experienced by communities surrounding HFC production facilities and has conducted additional analysis to further characterize these communities.

Climate Benefits

The incremental 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 would stem from the reduction of permitted levels of HFC consumption that would be necessary to comply with the HFC phasedown with the lower baseline. The benefits of avoided climate damages are monetized using previously established social cost of HFCs (SC-HFCs) estimates and are presented in Table ES-1. The regulatory change of lowering the HFC consumption baseline is estimated to produce benefits of $2.9 million from 2024–2050, in 2020 dollars and discounted to 2022 at 3 percent.

Compliance Costs

Incremental compliance costs of this rule stem from the additional transitions away from the use of HFCs that would be necessary in some years to allow total U.S. consumption to comply with new consumption caps that would be about 0.44 percent lower than previously established in the Framework Rule. The costs of those transitions are derived from abatement options in a marginal abatement cost model, just as was done in the RIA for the Framework Rule. In any year where additional abatement options need to be utilized to generate incremental consumption reductions relative to the previous modeling, the costs of those additional abatement options are taken as the incremental cost of lowering the baseline. Those incremental costs are shown in Table ES-1 in 2020 dollars, discounted back to 2022 at both 3 percent and 7 percent.

Incremental compliance costs of this rule also stem from additional recordkeeping and reporting requirements. The additional cost burden from these requirements is estimated to be approximately $370.5 thousand annually, starting in 2024. These incremental costs are also shown in Table ES-1 below.

Net Benefits

The net benefits of this rule are simply the climate benefits minus the compliance costs in each year. The annual net benefits 2024–2050 are presented in Table ES-1, along with the net present value of the incremental benefits and costs. Regulatory changes from this rule, including the lower consumption baseline, are estimated to have incremental net costs of $344 million in 2020 dollars from 2024 through 2050, discounted at 3 percent to 2022, equivalent to $20 million in incremental annual costs 2024–2050. When a discount rate of 7 percent is used for the costs, the net present value of the incremental net costs is estimated at $279 million, equivalent to $27 million in incremental annual costs 2024–2050.

Table ES-1: Summary of Annual Values, Present Values, and Equivalent Annualized Values for the 2024–2050 Timeframe for Estimated Abatement Costs, Benefits, and Net Benefits for this Rule (millions of 2020$, discounted to 2022)[a,b,c,d,e,f]

Year	Climate Benefits (3%)[c]	Costs (annual)[d]	Net Benefits (3% Benefits, 3% or 7% Costs)
2024	$0.3	$29.8	-$29.7
2025	$0.5	$85.9	-$85.4
2026	$0.7	$89.8	-$89.1
2027	$0.9	$94.9	-$94.0
2028	$1.1	$100.8	-$99.7
2029	$0	$0.4	-$0.4
2030	$0	$0.4	-$0.4
2031	$0	$0.4	-$0.4
2032	$0	$0.4	-$0.4
2033	$0	$0.4	-$0.4
2034	$0	$0.4	-$0.4
2035	$0	$0.4	-$0.4
2036	$0	$0.4	-$0.4
2037	$0	$0.4	-$0.4
2038	$0	$0.4	-$0.4
2039	$0	$0.4	-$0.4
2040	$0	$0.4	-$0.4
2041	$0	$0.4	-$0.4
2042	$0	$0.4	-$0.4
2043	$0	$0.4	-$0.4
2044	$0	$0.4	-$0.4
2045	$0	$0.4	-$0.4
2046	$0	$0.4	-$0.4

2047	$0	$0.4		-$0.4	
2048	$0	$0.4		-$0.4	
2049	$0	$0.4		-$0.4	
2050	$0	$0.4		-$0.4	
Discount rate	**3%**	**3%**	**7%**	**3%**	**7%**
PV	**$2.9**	**$347**	**$282**	**-$344**	**-$279**
EAV	**$0.2**	**$20**	**$27**	**-$20**	**-$27**

[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, but the Agency does not have a single central SC-HFC point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-HFC estimates. As discussed in Chapter 4, a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts. The costs presented in this table are annual estimates.
[b] Rows may not appear to add correctly due to rounding.
[c] The annualized present value of costs and benefits are calculated as if they occur over a 27-year period from 2024 to 2050.
[d] Compliance costs include those due to transitions necessary to meet the new consumption caps and additional recordkeeping and reporting requirements.
[e] These estimates are year-specific estimates.
[f] For the years 2029 through 2050 the abatement options modeled previously using the higher baseline had already lowered consumption below the maximum consumption allowed. This overshoot reached a level of consumption that is already below the maximum consumption that would be allowed with the lowered baseline, so no additional abatement options are needed in these years and no incremental costs are accrued.

Update to the Cost Estimate from the Framework Rule RIA

In addition to updating the previously modeled benefits and costs of the HFC phasedown to include the incremental benefits and costs from lowering the HFC baseline, this addendum also documents an adjustment to the estimated cost of the HFC phasedown 2022–2050 due to a changed abatement option in the Marginal Abatement Cost (MAC) model. Based on information from industry stakeholders, EPA is revising the cost assumptions associated with the transition away from using HFC-134a as a blowing agent to manufacture extruded polystyrene (XPS) foam boardstock. This revision is not a change in the policy decisions of the Framework Rule, nor is it a result of the statutory requirements set forth in that rule. Rather, it provides additional information on the potential costs and benefits of the rule as described in the RIA. Comments on the Framework Rule indicated the assumed transition in this application is unlikely to proceed as it was previously modeled. The new abatement option modeled for this application assumes a more expensive transition cost than the abatement option used in the Framework Rule analysis, so any year in which the XPS foam abatement option in the MAC model is utilized to lower consumption below the consumption cap would now have greater compliance costs than previously estimated for that year. While not an incremental cost of this action, rather attributable to the Framework Rule, this change in the assumption for the costs of the XPS foam transition results in an increase in the estimated total costs of the HFC phasedown of $2.7 billion through 2050, in 2020 dollars discounted to 2022 at 3 percent, and $1.6 billion discounted at 7 percent. This is equivalent to an increase in the estimate of the annual cost of $141 million and $128 million, respectively.

Environmental Justice

EPA updated the environmental justice analysis that was conducted as part of the Framework Rule. Following the analytical approach used in the Framework Rule RIA, EPA has updated data on the total number of Toxics Release Inventory (TRI) facilities near HFC production facilities and the cancer and respiratory risks to surrounding communities. This update includes the most recent data available for the AirToxScreen dataset from 2019, replacing the 2014 National Air Toxics Assessment (NATA) data used in the Framework Rule's analysis. Additionally, EPA updated the list of HFC production facilities as part of this analysis to include an additional ninth facility that reported production of HFCs in 2022.

Updated TRI data is available for these facilities, so EPA has provided relevant 2020 and 2021 TRI release data by facility in addition to the 2019 data originally provided in the Framework Rule RIA. The Agency also updated the list of chemicals that may be relevant to HFC production to include coproducts, byproducts, or emissions from an HFC production line that were reported consistent with the one-time reporting requirement in the Framework Rule (40 CFR 84.31(b)(1)(v). There is not a consistent trend in releases across the nine facilities, with different facilities showing declining, increasing, or generally constant releases over the of 2019-2021 timeframe across the list of chemicals identified by EPA that are potentially associated with HFC production. For facilities with increases, at this time EPA is not able to confirm whether they are related specifically to HFC production, the production of HFC substitutes, or other chemicals or compounds also produced at these facilities.

Using the updated 2019 AirToxScreen data, the total cancer risk and total respiratory risk generally decreased compared to the previous analysis for the communities surrounding several production facilities. Additionally, the risks from air emissions (not all of which necessarily stem from HFC production), while varied, were still generally higher, and in some cases much higher, within one to three miles of an HFC production facility compared to the overall national and state averages.

For the additional ninth facility, IsleChem, the total cancer risk and total respiratory risk within one to 10 miles of the facility were similar to or lower than the risks based on the national and state average. The proportion of low-income and Black or African-American and other communities of color were lower than the national and state averages and increased with increasing distance from this facility.

Chapter 1: Introduction and Background

This document describes changes in the estimated costs and benefits of the phasedown of hydrofluorocarbons (HFCs) that was established in the final rule *Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing Act* (hereafter referred to as the Framework Rule or Allocation Framework Rule, 86 FR 55116).

The Framework Rule was promulgated under the authority of the American Innovation and Manufacturing Act of 2020 (AIM Act), and while it established the cap for how many allowances for production and consumption of HFCs would be allocated for all years, the rule only finalized a methodology for allocating general pool allowances for 2022 and 2023. Establishment of an allocation methodology for later years was left to subsequent actions, including this rule. The costs and benefits of the phasedown of HFCs are described in *Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs)*, with the costs and benefits of the entire phasedown, including allocation of allowances for production and consumption of HFCs, for the period 2022 through 2050. This analysis accompanies the rule *Phasedown of Hydrofluorocarbons: Allowance Allocation Methodology for 2024 and Later Years*, which focuses on establishing an allocation methodology for part of the full time period, and as such the costs and benefits of the allocation of allowances for 2024 through 2028 were already estimated and accounted for in the RIA for the full HFC phasedown as described in the Framework Rule.

While the majority of the costs and benefits of the HFC phasedown remain the same as estimated in the RIA for the Framework Rule, this analysis modifies the previous estimates in two ways. First, EPA has updated the assumptions for one abatement option in the model used to estimate the costs of the phasedown based on new information the Agency has received. This analysis recalculates the costs of the full HFC phasedown from 2022–2050 using the updated abatement option, assuming no regulatory changes to the requirements of the HFC phasedown as codified in the Framework Rule.

Second, this document presents changes to the costs and benefits of the HFC phasedown resulting from regulatory changes from the current action. Due to updated information on the consumption of HFCs during the years 2011–2013, the rule lowers the baseline used to calculate the total number of consumption allowances issued starting in 2024. The formula for calculating the baseline is statutorily determined in the AIM Act, and lowering the baseline amends the baseline used for the HFC phasedown to follow that formula using the revised data. Lowering the baseline will result in fewer allowances allocated each year, leading to an increase in both costs and benefits in some years. This rule also includes additional recordkeeping and reporting requirements, resulting in additional estimated costs starting in 2024.

1.1 Hydrofluorocarbons

HFCs are anthropogenic fluorinated chemicals that have no known natural sources. HFCs are used in a variety of applications such as refrigeration and air conditioning, foam blowing agents, solvents, aerosols, and fire suppression. HFCs are potent GHGs with 100-year global warming potentials (GWPs) (a measure of the relative climatic impact of a GHG) that can be hundreds to thousands of times that of carbon dioxide (CO_2). See Appendix A and Chapter 4 of the RIA of the Framework Rule for a more complete discussion of HFCs and their properties.

1.2 The AIM Act

The AIM Act authorizes EPA to address HFCs in three main ways: phasing down HFC production and consumption through an allowance allocation program; facilitating sector-based transitions to next-generation technologies; and promulgating certain regulations for purposes of maximizing reclamation and minimizing releases of HFCs and their substitutes from equipment.

This analysis is associated with a rulemaking that focuses on the first area - the phasedown of the production and consumption of HFCs.

The AIM Act gives EPA authority to phase down the production and consumption of listed HFCs through an allowance allocation and trading program. The Act lists 18 saturated HFCs, and by reference any of their isomers not so listed, that are covered by the statute's provisions, referred to as "regulated substances" under the Act.[1] Congress also assigned an "exchange value"[2] for each of the listed 18 HFCs (along with other chemicals that are used to calculate the baseline). See Appendix A to this document or 40 CFR part 84, Appendix A available at https://www.ecfr.gov/current/title-40/chapter-I/subchapter-C/part-84#Appendix-A-to-Part-84 for the list of regulated substances and their exchange values.

The AIM Act requires EPA to phase down the production and consumption of statutorily listed HFCs in the United States. The allowed production and consumption in each year of the phasedown is based on the total of the regulated substances, with each weighted by an exchange value (EV) equal to the GWP of that HFC. Starting with a baseline level of production and consumption, the phasedown begins with a 10 percent reduction from the baseline in 2022 and proceeds through a series of steps until the final step down to an 85 percent reduction in 2036. In October 2021, EPA promulgated the Framework Rule to establish the phasedown required under the AIM Act, along with other supporting provisions. For a more thorough discussion of the AIM Act, see the preamble and RIA of the Framework Rule.

1.3 HFC Consumption Baseline

The AIM Act instructs EPA to calculate the consumption baseline using the average annual quantity of all regulated substances consumed in the United States from January 1, 2011, through December 31, 2013. In the Framework Rule, based on the data available at the time, EPA codified the final consumption baseline as 303,887,017 Metric Tons of Exchange Value Equivalent (MTEVe) (40 CFR 84.7(b)(2)).

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[1] Unless stated otherwise, this report uses "HFCs" and "18 HFCs" to refer to all the HFCs that are regulated substances in the AIM Act (e.g., including isomers not listed and for which an exchange value is not provided in the legislation).

[2] EPA has determined that the exchange values included in subsection (c) of the AIM Act are identical to the GWPs included in IPCC (2007). EPA uses the terms "global warming potential" and "exchange value" interchangeably. One MMTEVe is therefore equivalent to one $MMTCO_2e$.

In subsection (e)(2)(C) of the AIM Act, Congress provided the HFC phasedown schedule measured as a percentage of the baseline.[3] In the Framework Rule, EPA codified this phasedown schedule at 40 CFR 84.7(a). EPA also codified the total production and consumption in MTEVe for regulated substances in the United States in each year by multiplying the finalized production and consumption baselines by the percentages of the phasedown schedule. EPA codified total production and consumption allowance quantities that could be allocated in each year at 40 CFR 84.7(b)(3).

After EPA finalized the Framework Rule, one company informed EPA that their 2011 and 2012 HFC import data that they had reported to the Greenhouse Gas Reporting Program was significantly more than their actual import quantities. EPA subsequently provided a final opportunity for entities to confirm and, if necessary, correct their historic data. Through the process, several additional entities submitted updates to historic data that EPA then verified, which result in a further adjustment of the baseline. As a result, EPA is updating the codified consumption baseline with the corrected data. Specifically, EPA is revising the consumption baseline from 303,887,017 MTEVe to 302,538,316 MTEVe, which is a decrease of 1,348,701 MTEVe.

As the maximum consumption of HFCs permitted in the United States in any year of the HFC phasedown is a percentage of the consumption baseline, updating the baseline to a new, lower value also decreases the permitted consumption in all years after the change goes into force in 2024.

Table 1-1: Previous and Revised Consumption Caps of the HFC Phasedown

Year	Previously Codified Total Consumption (MTEVe)	Revised Total Consumption (MTEVe)
2024–2028	182,332,210	181,522,990
2029–2033	91,166,105	90,761,495
2034–2035	60,777,403	60,507,663
2036 and thereafter	45,583,053	45,380,747

[3] Unless otherwise noted, "baseline" in this document refers to the HFC consumption baseline. EPA is not revising the HFC production baseline in this action.

1.4 Overview of this Analysis

This analysis presents changes to the estimates of compliance costs, climate benefits, and net benefits of the HFC phasedown under the AIM Act in the United States, as implemented in the Framework Rule. The analysis of the effects of updating the marginal abatement cost (MAC) model covers the entire HFC phasedown, starting in 2022 and running through 2050. The analysis of the effects of lowering the HFC baseline as finalized in this rule begins when the regulatory change takes effect, and so covers 2024 through 2050. The schedule of the HFC phasedown for both production and consumption is a 10 percent reduction from baseline in 2022 and 2023, a 40 percent reduction in 2024–2028, a 70 percent reduction in 2029–2033, an 80 percent reduction in 2034–2035, and an 85 percent reduction in 2036 and all later years.

Chapter 2 presents updates to the previous estimates of the costs and benefits of the HFC phasedown based on a change in model assumptions.

Chapter 3 discusses the methods and results of estimating the costs of complying with the reductions of production and consumption of HFCs throughout the HFC phasedown. The potentially affected industries under this analysis are the same as in the cost analysis in the Framework Rule RIA, and a list of the NAICS codes of potentially affected entities can be found in Appendix F of the Framework Rule RIA. This chapter also provides updated estimates of recordkeeping and reporting costs for affected entities. The estimates reflect new requirements promulgated in this rule as well as updates to EPA's previous cost burden calculation assumptions.

Chapter 4 discusses the change in the climate benefits of the HFC phasedown due to lowering the HFC baseline. The reduction of the baseline starting in 2024 will result in less consumption of the 18 regulated HFCs on an EV-weighted basis. This reduction in consumption will lead to reduced HFC emissions, and reduced emissions of these greenhouse gases (GHGs) would yield social benefits by reducing climate impacts. The climate benefits of the regulatory change are monetized by multiplying the change in emissions of each regulated HFC by the social cost of HFCs (SC-HFC) for that chemical. The methodology for calculating the SC-HFCs is described in detail in Section 4.1 of the Framework Rule RIA, and the SC-HFC values are given Appendix E of this document.

Chapter 5 compares the changes in the benefits and costs of the HFC phasedown as detailed in Chapters 3 and 4. In addition, all of the changes in costs and benefits, including the cost estimate updates from Chapter 2, are combined with the previous estimates of the net value of the HFC phasedown to provide an updated accounting of the net benefit of all provisions of the phasedown through 2050.

Chapter 2: Benefits and Costs of the HFC Phasedown

2.1 Introduction

This chapter provides the estimated benefits, costs, and net benefits of the HFC phasedown as it stands before any regulatory changes from this rule. These values are the status quo from which any incremental costs and benefits of this rule will be calculated. While estimates of the benefits and costs of the HFC phasedown from 2022 through 2050 are given in the RIA of the Framework Rule, this chapter describes updates to the estimated costs based on new information EPA has incorporated into its cost model. Note that this revision is not a change in the policy decisions of the Framework Rule, nor is it a result of the statutory requirements set forth in that rule.

The methods used to calculate costs and benefits for the Framework Rule are the same as those used for this rule. Details on the methods used to calculate costs are in Chapter 3 of this document. Details on the methods used to calculate benefits are in Chapter 4.

2.2 Previous Estimates

In the Framework Rule RIA, EPA estimated that the present value (PV) of cumulative net benefits evaluated from 2022 through 2050 is $272.7 billion at a 3 percent discount rate.[4] The PV of net benefits is calculated over the 29-year period from 2022–2050 to account for additional years that emissions will be reduced following the consumption reductions from 2022–2036. The equivalent annual value (EAV) over the period 2022–2050 is $14.2 billion when using a 3 percent discount rate and $14.1 billion when using a 7 percent discount rate. Over the 15-year

[4] Unless specified otherwise, costs and benefits are presented in 2020 U.S. dollars.

period of the phasedown of HFCs, the PV of cumulative abatement costs is negative $5.4 billion, or $5.4 billion in savings,[5] and the PV of cumulative benefits is $94.8 billion, both at a 3 percent discount rate. Over the same 15-year period of the phasedown, the PV of cumulative net benefits is $100.2 billion. The comparison of benefits and costs in PV and EAV terms for the rule can be found in Table 2-1. Estimates in the table are presented as rounded values.

[5] Modeled transitions away from HFCs to comply with the phasedown schedule are expected to result in net savings due to the cost savings associated with specific abatement options. The Allocation Framework Rule analysis found that some transitions will result in net positive costs due to required investments in new lower-GWP technologies and refrigerants. For other cases, the analysis found these costs are outweighed by assumed energy savings from the deployment of new technologies, lower-cost refrigerants, and other factors, resulting in net-negative compliance costs (i.e., cost savings). On the whole, it was found that the rule would result in net negative abatement costs. More details are provided in the RIA for the Allocation Framework Rule, available at www.regulations.gov in docket EPA-HQ-OAR-2021-0044.

Table 2-1: Summary of Annual Values, Present Values, and Equivalent Annualized Values for the 2022–2050 Timeframe for Estimated Abatement Costs, Benefits, and Net Benefits for the Framework Rule (billions of 2020$, discounted to 2022)[a,b,c,d]

Year	Climate Benefits (3% discount rate)[c]	Costs (annual)[d]		Net Benefits	
2022	$1.4	-$0.3		$1.7	
2023	$1.8	-$0.5		$2.3	
2024	$5.2	$0.1		$5.2	
2025	$6.4	$0.1		$6.2	
2026	$6.8	$0.1		$6.7	
2027	$7.7	-$0.1		$7.8	
2028	$8.5	-$0.1		$8.5	
2029	$7.5	-$0.6		$8.2	
2030	$8.5	-$0.7		$9.3	
2031	$9.4	-$0.8		$10.2	
2032	$10.3	-$0.9		$11.2	
2033	$11.3	-$1.0		$12.3	
2034	$12.4	-$0.9		$13.3	
2035	$13.4	-$1.0		$14.4	
2036	$15.7	-$0.7		$16.4	
2037	$16.5	-$0.8		$17.3	
2038	$17.6	-$0.8		$18.4	
2039	$18.7	-$0.8		$19.5	
2040	$19.8	-$0.8		$20.6	
2041	$21.0	-$0.9		$21.9	
2042	$22.1	-$0.9		$23.0	
2043	$23.1	-$0.9		$24.0	
2044	$24.1	-$0.9		$25.0	
2045	$25.1	-$0.9		$26.0	
2046	$26.0	-$0.9		$26.9	
2047	$27.0	-$0.9		$27.9	
2048	$27.9	-$1.0		$28.9	
2049	$28.8	-$1.0		$29.8	
2050	$29.7	-$1.1		$30.8	
Discount Rate	**3%**	**3%**	**7%**	**3%**	**7%**
Present Value	**$260.9**	**-$11.8**	**-$6.4**	**$272.7**	**$267.4**
Equivalent Annualized Value	**$13.6**	**-$0.6**	**-$0.5**	**$14.2**	**$14.1**

[a] Rows may not appear to add correctly due to rounding.
[b] This table presents year-specific estimates, present-value estimates, and annualized estimates. The annualized present value of costs and benefits are calculated over a 29-year period from 2022 to 2050, discounted using both 3% and 7%.
[c] Climate benefits are based on changes (reductions) in HFC emissions and are calculated using four different estimates of the SC-HFC (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). For purposes of this table, we show the benefits (climate benefits and net benefits) associated with the model average at a 3 percent discount rate, but the Agency does not have a single central SC-HFC point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-HFC estimates. As discussed in Chapter 4, a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.

[d] The costs presented in this table are consistent with the costs presented in Chapter 5, Table 5-1, of the Framework Rule RIA.

As seen in Table 2-1, the net benefits of the HFC phasedown in 2022–2050, as assessed in the Framework Rule RIA, are substantial: $272.7 billion when discounted back to 2022 at a 3 percent discount rate. While the update to the cost modeling and the estimated costs of lowering the HFC baseline both show increases to the previous estimate of costs, it is worth noting that the costs in this analysis are small compared with the climate benefits that will be achieved by the HFC phasedown.

2.3 Modeling Method for Abatement Costs

2.3.1 The Vintaging Model

The costs of complying with the reduced consumption of HFCs were generated using EPA's Vintaging Model to estimate baseline HFC demand and abatement potential. The model tracks the use and emissions of each of the substances separately for each of the ages or "vintages" of equipment. The Vintaging Model is a peer-reviewed[6] tool used to produce the estimates of GHG emissions in the official U.S. GHG Inventory, and it 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*[7] and is described in detail in Section 3.2.1 of the Framework Rule RIA.

2.3.2 Abatement Options

A set of abatement options was developed that can be applied to Vintaging Model runs that assume transitions away from use of HFCs. The abatement options were used to estimate marginal abatement cost curves (MACCs) in a reduced-form MAC model in a manner similar to that presented in EPA's Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation, 2015–2050 report. The MACCs describe the supply of abatement available at a given cost in a particular year. When evaluated against the HFC phasedown schedule the cost of abatement can be determined.

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[6] David S. Godwin & Rebecca Ferenchiak (2020) *The implications of residential air conditioning refrigerant choice on future hydrofluorocarbon consumption in the United States*, Journal of Integrative Environmental Sciences, 17:3, 29-44, DOI: 10.1080/1943815X.2020.1768551

[7] U.S. EPA. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2014.* April 2016. EPA Report EPA-430-R-16-002. Available at https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2014.

In each year modeled, a set of abatement options is assumed to be available, each with a potential to reduce consumption of one or more regulated HFCs and a cost per EV-weighted ton abated. Abatement options are selected from lowest-cost to highest-cost per EV-weighted ton until the number of EV-weighted tons abated lowers the business-as-usual (BAU) consumption to a level below the consumption cap for that year. With one exception described below, all the abatement options used in the cost model are the same as in the Framework Rule analysis. A list of the abatement options necessary to meet the cap for each reduction step is in Appendix C. A description of the various abatement options including their reduction efficiency and the timing of market penetration is given in Appendix D.

2.4 Updated XPS Foam Abatement Option

In the previous analysis of costs of the HFC phasedown, it was assumed that some consumption of HFC-134a could be abated by transitioning the foam-blowing agent used to produce extruded polystyrene (XPS) boardstock foam. If XPS foam producers shifted from using a combination of HFC-134a and carbon dioxide to a mixture of liquid carbon dioxide (LCD) and alcohol, all of the HFC consumption associated with producing XPS foam could be avoided. However, EPA received comment from one manufacturer of XPS foam that the abatement option of using LCD/alcohol has not been proven to meet the safety and performance standards required in the United States (attachment 3 to EPA-OAR-HQ-2021-0044-0227, Response to Comments document, page 697). A second manufacturer concurred indicating that the abatement option would not be a viable option and would not meet building codes in the United States (Ibid, page 720 - 721). While the LCD/alcohol technology is successfully used in other countries, we understand that U.S. companies expect XPS foam production to transition from using HFC-134a/CO_2 to blends containing a hydrochlorofluoroolefin (HCFO) and/or a hydrofluoroolefin (HFO). On January 22, 2022, a blend of HFO-1234ze(E) and HCFO-1233zd(E) was listed as acceptable under EPA's Significant New Alternatives Policy (SNAP) Program. Although a wide range of compositions was listed (from 10 percent to 90 percent of each component), the GWPs of the two components are close enough that assuming a 50/50 blend would accurately represent such a transition. Updating the assumptions for this abatement option to reflect this transition lowers HFC-134a consumption by the same amount, without an increase in other regulated HFCs such as HFC-152a, but the HCFO/HFO blend was estimated to be more expensive than an LCD/alcohol blend at current HCFO and HFO prices. The previous mitigation option was estimated to have a negative cost (i.e., savings) of -\$3.47 per $MTCO_2e$ abated because the LCD/alcohol foam-blowing agent is less expensive than the HFC-134a it substitutes for. In the updated abatement option assuming transition from HFC-134a to an HCFO/HFO blend, the modeled cost is \$8.25 per $MTCO_2e$ abated. This increase is in part due to the increased cost of the HCFO/HFO blend, which is assumed to cost more than HFC-134a, as compared to the LCD/alcohol, which was assumed to cost less than HFC-134a, resulting in a higher annual cost. Also, capital costs were assumed in adopting this option, primarily due to safety upgrades to handle the flammable component of the blend (HFO-1234ze(E)), and those capital costs were more than those for the LCD/alcohol option, which were for dealing with the increased pressure, safety and incineration. Therefore, in any year where the XPS foam abatement option is used in the model to bring consumption below the cap, benefits would stay the same (as the complete reduction of HFC-134a use is still achieved), but the cost would be higher than previously modeled. EPA notes that this estimate of higher costs likely overestimates the costs of transition given EPA has assumed the cost of the HCFO/HFO blend would not change in real terms over the timeframe analyzed. As the technology matures and is further commercialized, it is likely that costs will decrease.

2.5 Changes to Costs from the Updated XPS Foam Abatement Option

Using both the previous cost of the XPS abatement option and the updated cost under the revised transition assumption, the XPS abatement option is utilized in the cost model for all years 2024–2050. Table 2-2 shows the modeled cost of transition from HFC-134a to a substitute in XPS boardstock manufacturing. Using a discount rate of 3 percent, the present value of the abatement option costs discounted to 2022 goes from a savings of \$808 million to a cost of \$1,920 million, an incremental change from this model update of \$2,728 million in 2020 dollars. With a discount rate of 7 percent, the present value goes from a savings of \$468 million to a cost of \$1,113 million, an incremental change from this model update of \$1,581 million.

Table 2-2: Cost Adjustment of Updating XPS Foam Transition[a]

Year	Modeled Cost of XPS Option (Millions 2020 dollars)		
	Previous Transition –\$3.47/MTEVe	New Transition \$8.25/MTEVe	Change in Cost Estimate

2022	$0		$0		$0	
2023	-$8		$19		$27	
2024	-$16		$39		$56	
2025	-$25		$60		$85	
2026	-$35		$82		$117	
2027	-$44		$105		$149	
2028	-$45		$108		$153	
2029	-$47		$110		$157	
2030	-$48		$113		$161	
2031	-$48		$114		$162	
2032	-$48		$115		$164	
2033	-$49		$116		$165	
2034	-$49		$117		$166	
2035	-$50		$118		$167	
2036	-$50		$119		$169	
2037	-$51		$120		$170	
2038	-$51		$121		$172	
2039	-$51		$122		$173	
2040	-$52		$123		$174	
2041	-$52		$124		$176	
2042	-$53		$124		$177	
2043	-$53		$125		$178	
2044	-$53		$126		$180	
2045	-$54		$128		$181	
2046	-$54		$129		$183	
2047	-$55		$130		$184	
2048	-$55		$131		$186	
2049	-$56		$132		$187	
2050	-$56		$133		$189	
Discount Rate	3%	7%	3%	7%	3%	7%
Present Value	-$808	-$468	$1,920	$1,113	$2,728	$1,581
EAV	-$42	-$38	$100	$91	$142	$129

[a] Rows may not appear to add correctly due to rounding.

2.6 Updated Benefits and Costs

As explained in Section 2.4, the change in the assumption for the XPS boardstock manufacturing abatement option does not change the modeled benefits of the HFC phasedown. The climate benefits of all provisions of the HFC phasedown remain at $260.9 billion over the period 2022–2050. Based on the new assumption on the likely transition away from use of HFC-134a in the XPS boardstock foam application, the present value of the costs of the HFC phasedown are adjusted from the previous estimate of -$11.8 billion to an updated estimate of -$9.0 billion, when discounted to 2022 at 3 percent, and updated from -$6.4 to -$4.8 billion discounted at 7 percent. The negative values in the previous estimates and the updated estimates indicate savings. With this update to the assumptions, the estimate of the net benefit of the HFC phasedown 2022–2050 changes by about 1 percent from $272.7 billion to $270.0 billion with a discount rate of 3 percent and from $267.4 billion to $265.8 billion discounted at 7 percent. The previously estimated net benefits, as presented in the Framework rule, are reported in Table 2-1. These updated estimates of revised net benefits reflect an adjustment to previous estimates but do not affect the benefits, cost, or net benefits of this action.

Chapter 3: Compliance Costs

3.1 Introduction

This chapter explains how EPA estimated the compliance costs of reducing HFC consumption to comply with the HFC phasedown schedule described in the AIM Act and the Framework Rule. The HFC phasedown schedule requires the EV-weighted total of both production and consumption of the 18 regulated HFCs to be below certain limits starting in 2022. However EPA believes that the cap on consumption will be the limiting factor in achieving the HFC phasedown, and no additional costs or benefits of meeting the production cap are anticipated above those costs and benefits of complying with the consumption cap. The total costs of the HFC phasedown as previously presented in the Framework Rule RIA included the costs of complying with the consumption cap starting in 2022, but also evaluated costs from other provisions of the HFC phasedown.

This chapter summarizes the estimated costs directly stemming from abating HFC consumption to meet the phasedown schedule, and specifically the reduction of the HFC consumption baseline. In addition, this chapter provides updated recordkeeping and reporting cost burden estimates, including changes stemming from updated requirements promulgated in this rule.

3.2 Modeling Method for Abatement Costs

The costs of complying with reduced consumption of HFCs was generated using EPA's Vintaging Model to estimate baseline HFC demand and abatement potential. The Vintaging Model is described in detail in Section 3.2.1 of the Framework Rule RIA. The abatement options, including the revised abatement option described in Chapter 2, were used to estimate MACCs in a reduced-form MAC model in a manner similar to that presented in EPA's *Global Non-CO2 Greenhouse Gas Emission Projections & Mitigation, 2015–2050* report. The MACCs describe the supply of abatement available at a given cost in a particular year. When evaluated against the HFC phasedown schedule the cost of abatement can be determined.

In each year modeled, a set of abatement options is assumed to be available, each with a potential to reduce consumption of one or more regulated HFCs and a cost per EV-weighted ton abated. Abatement options are selected from lowest-cost to highest-cost per EV-weighted ton until the number of EV-weighted tons abated lowers the BAU consumption to a level below the consumption cap for that year. The list of abatement options is detailed in Appendix C.

3.3 Changes to Costs from Lowering the Consumption Baseline

With a lower consumption baseline, more abatement will be necessary in each year starting in 2024 to reduce HFC consumption from its BAU level to a level below the maximum allowed consumption. However, in some years the abatement options modeled previously using the higher baseline had already lowered consumption below the maximum consumption allowed. If this overshoot reached a level of consumption that is already below the maximum consumption that would be allowed with the lowered baseline, then no additional abatement options would be needed in that year and no incremental costs accrued. As shown in Appendix B, an additional abatement option was required to meet the 2024–2028 maximum consumption level based on the lowered baseline. For the years 2029 through 2050, no additional abatement options were required and therefore incremental costs are zero during that timeframe. The incremental costs for each year with a phasedown step (plus 2045 and 2050) are shown in Table 3-1. Note that later years of the phasedown show negative costs (savings) because the modeled transitions away from HFCs to comply with the phasedown schedule are expected to use less expensive substitutes in many applications. The present value of the incremental costs from 2024–2050 associated with the change in the baseline is estimated at $175 million when discounted to 2022 using a 3 percent discount rate, and $144 million using a 7 percent discount rate.

Table 3-1: Incremental Costs of Lowering the HFC Consumption Baseline (millions 2020$)

Year	Compliance Costs with Previous Baseline	Compliance Costs with Revised Baseline	Incremental Costs

2024	-$5		$25		$29	
2029	-$471		-$471		$0	
2034	-$767		-$767		$0	
2036	-$529		-$529		$0	
2045	-$737		-$737		$0	
2050	-$909		-$909		$0	
Discount Rate	3%	7%	3%	7%	3%	7%
PV	-$8,703	-$4,560	-$8,527	-$4,315	$175	$144
EAV[a]	-$504	-$426	-$494	-$412	$10	$14

a The equivalent annual value is calculated as 27 equal payments 2024–2050.

3.4 Changes to Costs from Recordkeeping and Reporting Updates

As part of the process to implement the recordkeeping and reporting requirements of the AIM Act and to assess the costs associated with this rule, EPA prepared and updated an information collection request (ICR), ICR Number 2685.04. Among other figures, EPA calculated the estimated expected total burden costs to respondents as a result of the recordkeeping and reporting requirements. These estimates were initially included in section 3.8 of the Framework Rule RIA.

As detailed in Section VI and portions of other sections of the rule preamble, EPA is finalizing in this rulemaking a number of updates to the recordkeeping and reporting requirements originally established in the Framework Rule. While some of these updates represent clarifications of the existing requirements, others represent additional requirements for specific entities that were not previously in effect. Specific amendments resulting in additional anticipated cost burden include: annual importer of record reporting requirements and the maintenance of sampling/testing records. As a result of these updates, EPA has revised its estimates of anticipated recordkeeping and reporting costs.

In addition to these, EPA has made changes to some of its underlying assumptions that impact these cost calculations. These changes include updated assumptions regarding the number of respondents for specific reporting forms, the number of responses per year for specific reports, and assumed costs for specific activities. These changes were made to reflect more up-to-date data and information and are unrelated to the changes stemming from this regulatory action.

Table 3-2 below shows an adjusted version of EPA's cost recordkeeping and reporting cost burden calculations from the Framework Rule reflecting these changes to underlying assumptions. Table 3-3 then shows the total cost burden calculations for this rule, reflecting the additional reporting requirements. The Agency notes that the increased numbers of responses, hours, and associated costs from year 1 to years 2 and 3 reflect provisions established in the Framework Rule that become effective in 2025 and 2026. Finally, table 3-4 shows the incremental costs stemming from the additional reporting requirements in isolation (i.e., the delta between the two tables). All estimates are shown for the three-year period of 2024-2026.

Table 3-2: Adjusted Recordkeeping and Reporting Costs (Framework Rule Reporting Requirements Only)

Year	Total Responses	Total Hours	Total Labor Costs	Total O&M Costs	Total Costs
Year 1 (2024)	10,337	33,986	$3,936,983	$1,025,400	$4,962,383
Year 2 (2025)	1,497,563	46,699	$5,553,245	$1,025,400	$6,578,645
Year 3 (2026)	8,189,958	82,595	$10,116,751	$1,025,400	$11,142,151

Table 3-3: Updated Total Recordkeeping and Reporting Costs (Including 2024 Rule Additional Requirements)

Year	Total Responses	Total Hours	Total Labor Costs	Total O&M Costs	Total Costs
Year 1 (2024)	10,466	37,616	$4,304,853	$1,028,100	$5,332,953
Year 2 (2025)	1,497,692	50,329	$5,921,114	$1,028,100	$6,949,215
Year 3 (2026)	8,190,087	86,225	$10,484,621	$1,028,100	$11,512,721

Table 3-4: Incremental Cost Burden Stemming from 2024 Rule

Year	Total Responses	Total Hours	Total Labor Costs	Total O&M Costs	Total Costs

Year 1 (2024)	129	3,630	$367,870	$2,700	$370,570
Year 2 (2025)	129	3,630	$367,870	$2,700	$370,570
Year 3 (2026)	129	3,630	$367,870	$2,700	$370,570

Chapter 4: Climate Benefits

4.1 Introduction

The primary benefits of the HFC phasedown derive mostly from preventing the emissions of HFCs with high GWPs, thus reducing the damage from climate change that would have been induced by those emissions. The reduction in emissions follows from a reduction in the production and consumption of HFCs, measured in MTEVe. The 18 regulated HFCs and their isomers are GHGs that can trap much more heat per ton emitted than CO_2, a ratio shown in each chemical's GWP (and MTEVe). 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[8], with the vast majority of HFCs emitted having GWPs over 1,000. In a BAU scenario without the HFC phasedown, 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 change and the social costs that are caused by climate change. 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 Framework Rule RIA.

While there may be other benefits to phasing down HFCs, the benefits monetized in the Framework Rule RIA and this analysis are limited to the climate benefits of reduced HFC emissions.

[8] 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). EPA uses the terms "global warming potential" and "exchange value" interchangeably. One MMTEVe is therefore equivalent to one $MMTCO_2e$.

4.2 Social Cost of HFCs

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) recognized a basket of six gases as GHGs, 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.[9] We estimate the climate benefits for this rulemaking using a measure 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, 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.[10] 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 the estimation of the benefits of the full HFC phasedown in the Framework Rule RIA. For ease of reference, these values can be found in Appendix E of this document. The SC-HFC values are listed in 2020 dollars per metric ton of HFC emitted by year. The SC-HFC 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

[9] In the case of CH_4, the climate effect can encompass the atmospheric reactions of the gas that change the abundance of other substances with climatic effects, such as ozone (O_3) and stratospheric water vapor (H_2O).

[10] Since the SC-HFC estimates are based on the same methodology underlying the SC-GHG estimates presented in the IWG February 2021 TSD, they share a number of limitations that are common to those SC-GHG estimates. The IAMs used to produce those interim estimates do not include all of the important physical, ecological, and economic impacts of climate change recognized in the climate change literature and the science underlying their "damage functions" — i.e., the core parts of the IAMs that map global mean temperature changes and other physical impacts of climate change into economic (both market and nonmarket) damages — lags behind the most recent research. For example, limitations include the incomplete treatment of catastrophic and non-catastrophic impacts in the integrated assessment models, their incomplete treatment of adaptation and technological change, the incomplete way in which inter-regional and intersectoral linkages are modeled, uncertainty in the extrapolation of damages to high temperatures, and inadequate representation of the relationship between the discount rate and uncertainty in economic growth over long time horizons. Please see section 4 of the Framework Rule RIA for a complete discussion of the limitations associated with the SC-HFC estimates used in this analysis.

emissions produce larger incremental damages as physical and economic systems become more stressed in response to greater climatic change, and because 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 Framework Rule RIA.

4.2.1 SC-HFC and Discount Rates

Climate damages due to emissions of a greenhouse gas accumulate for many years after emission as the gas remains in the atmosphere trapping heat, and then as the trapped heat continues to cause damages. Therefore, the SC-HFC value for a particular HFC in a given emission year is highly dependent on the way the future damages are discounted back to the year of emissions. As explained in *Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under E.O. 13990*,[11] it is appropriate for agencies to revert to the same set of four values drawn from the social cost of greenhouse gases (SC-GHG)[12] 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.

4.3 Methodology

As described in Section 2.3, the transitions needed to lower consumption from a BAU level to a level that complies with the consumption cap are modeled using a MAC analysis. In each year

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[11] Interagency Working Group on Social Cost of Greenhouse Gases, United States Government (2021), 86 FR 24669, available at *https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf.*

[12] SC-GHG refers collectively to social costs of different greenhouse gases, e.g., SC-CO2, SC-CH4, and SC-HFC. In each case it is the monetized net social cost of a marginal increase in emissions of the GHG, or the benefit of avoiding that increase.

abatement options are chosen from lowest to highest cost, each with an attendant number of tons of abatement of HFCs, until enough EV-weighted tons have been abated to lower consumption from the BAU level to below the consumption cap. Note that the last abatement option utilized may mitigate more than the number of EV-weighted tons necessary to just reach the consumption cap, in which case there is some "overshoot" where the modeled consumption is lower than the maximum permitted consumption in that year. Summing the total EV-weighted tons abated over all years gives one measure of the consumption benefits, but the abated tons of each HFC is needed to monetize the benefits.

This analysis estimates the incremental benefits of lowering the HFC consumption baseline. This is done by evaluating the change in abatement options—relative to the prior Framework Rule Analysis—that are required to meet the corrected consumption reduction schedule. Lowering the HFC consumption baseline will lower the permitted EV-weighted consumption in each year starting in 2024, so the amount of abatement needed to reduce consumption from the BAU level to under the cap is greater. In some years, the overshoot of abatement from the previously modeled set of abatement options may have lowered consumption enough below the cap that lowering the cap does not require any additional abatement options to be utilized. In those years there will be no incremental costs or benefits from lowering the baseline. In other years, one or more additional abatement options will need to be utilized to lower consumption under the cap, and the sum of those additional abated tons would be the incremental benefits from lowering the baseline.

In the Framework Rule, the consumption baseline was set at 303.9 MMTEVe based on the consumption data 2011–2013 of various companies reported to EPA and the formula for calculating the baseline in The AIM Act. Since then, corrections in reported consumption from several companies have been identified and verified by EPA, which have the net effect of reducing U.S. HFC consumption for 2011–2013 relative to the previous estimate. In order to comply with the statutorily determined method for calculating the consumption baseline, EPA is revising the consumption baseline based on the corrected data to 302.5 MMTEVe, a decrease of less than 0.5 percent, starting in 2024.

4.4 Consumption Abatement

As shown in Table 4-1, no additional abatement options were needed in the years 2029 through 2050, as the previous modeling already had enough overshoot to accommodate a lower consumption cap in those years. All other years (i.e., 2024-2028) showed incremental benefits, totaling 6.3 MMTEVe consumption avoided with the lower HFC baseline. Total consumption benefits of the HFC phasedown would increase from 7,156 MMTEVe to 7,163 MMTEVe. Thus, because the consumption benefits as modeled for the Framework Rule included some consumption abatement that was not necessary to meet the consumption cap, the reduction of the HFC baseline of about 0.44 percent is estimated to lead to a further reduction in consumption of about 0.1 percent. This small increase is partly because some of the benefits that would follow from the lower baseline in this rule were already counted as benefits in the Framework Rule RIA, and so to avoid double-counting those benefits, they are not counted in this analysis as additional reductions resulting from the change to the consumption baseline.

Table 4-1: Abated HFC Consumption 2024–2050 (millions EV-weighted Tons)[a]

Consumption Reductions (MMTEVe)			
Year	Previous Baseline	Revised Baseline	Incremental Benefits
2024	144	145	0.9
2025	192	193	1.3
2026	214	216	1.3
2027	230	231	1.4
2028	243	245	1.5
2029	230	230	0
2034	267	267	0
2036	282	282	0
2045	285	285	0
2050	293	293	0

[a] For the years 2029 through 2050 the abatement options modeled previously using the higher baseline had already lowered consumption below the maximum consumption allowed. This overshoot reached a level of consumption that is already below the maximum consumption that would be allowed with the lowered baseline, so no additional abatement options are needed in these years and no incremental costs are accrued.

4.5 Emissions Abatement

Once the change in consumption of each HFC for each year was modeled, EPA used the Vintaging Model to estimate the change in emissions of each HFC. HFCs used in some applications, e.g., aerosols, are emitted very soon after their use. In others, HFCs used in one year are emitted slowly over time, such as refrigerant that is emitted from a domestic refrigerator when the refrigerator is disposed of at the end of its useful life. For this reason the particular uses in which mitigation occurs when individual abatement options are utilized impacts future emissions, and the consumption reductions shown in Table 4-1 would be insufficient to model the stream of emissions reductions, even if it were disaggregated by HFC.

The incremental changes in emissions of all regulated HFCs 2024–2050, summed and weighted by Exchange Value, is shown in Table 4-2. Note that the emissions reductions tend to increase over the time period shown because (1) the difference between the BAU and regulatory baseline increases over time, and (2) early years contain emissions only in applications that cause emissions quickly, while later years comprise both these quick emissions as well as the delayed emissions from consumption reductions years earlier. The lowering of the HFC baseline would be expected to reduce total HFC emissions 2024–2050 by 0.05 MMTEVe. Note that the incremental reduction in emissions is lower than the incremental reduction in consumption because much of the additional avoided consumption modeled is in end uses with significant delays between when an HFC is used (e.g., in filling a new chiller with refrigerant) and when the HFC would be emitted (e.g., refrigerant leaking from a chiller during disposal at the end of its useful life).

Table 4-2: Abated HFC Emissions 2024–2050 (millions EV-weighted Tons)

Emission Reductions (MMTEVe)			
Year	Previous Baseline	Revised Baseline	Incremental Benefits
2024	77.5	77.51	0.004
2029	97.9	98.0	0
2034	141.8	141.8	0
2036	170.8	170.8	0
2045	223.9	223.9	0
2050	239.1	239.1	0

4.6 Monetized Climate Benefits

To monetize the incremental climate benefits of lowering the HFC consumption baseline, the change in emissions for each HFC in each year is multiplied by the corresponding SC-HFC for that HFC in that year. The sum of the monetized benefits from all the regulated HFCs are shown for each year in Table 4-3. When the benefits are discounted to 2022 using a discount rate of 3 percent, the present value of the benefits of this rule from 2024–2050 are estimated to be 2.9 million in 2020 dollars. This is equivalent to an annual benefit of $168 thousand per year over that time frame.

Table 4-3: Benefits of the HFC Phasedown 2024–2050 (millions of 2020$, discounted to 2022)[a,b,c,d]

Year	Previous Estimate (millions 2020$)	Climate Benefits with Lower Baseline (millions 2020$)	Incremental Climate Benefits (millions 2020$)
2024	$5,220	$5,220	$0.2
2029	$7,530	$7,530	$0
2034	$12,360	$12,360	$0
2036	$15,690	$15,690	$0
2045	$25,090	$25,090	$0
2050	$29,720	$29,720	$0
PV (3% d.r.)	**$257,877**	**$257,880**	**$2.9**
EAV (3% d.r.)	**$14,927**	**$14,927**	**$0.17**

[a] Rows may not appear to add correctly due to rounding.
[b] The equivalent annual values of benefits are calculated over a 27-year period from 2024 to 2050.
[c] Climate benefits are based on changes (reductions) 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). For purposes of this table, we show the benefits (climate benefits and net benefits) associated with the model average at a 3 percent discount rate, but the Agency does not have a single central SC-HFC point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-HFC estimates. A consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.
[d] For the years 2029 through 2050 the abatement options modeled previously using the higher baseline had already lowered consumption below the maximum consumption allowed. This overshoot reached a level of consumption that is already below the maximum consumption that would be allowed with the lowered baseline, so no additional abatement options are needed in these years and no incremental costs are accrued.

Chapter 5: Comparison of Benefits and Costs

5.1 Incremental Net Benefits

This chapter presents the estimated incremental net benefits of this rule, reflecting the change to the HFC baseline[13] as well as recordkeeping and reporting requirements described in more detail in the previous sections of this RIA Addendum.

In Table 5-1, the incremental net benefits for each year from 2024 through 2050 are shown. The table also gives the net present value of the stream of incremental costs and benefits and the equivalent annual value, discounted to 2022. Note that while the NPV of the costs and net benefits are calculated with discount rates of 3 percent and 7 percent, the monetized climate benefits are only discounted at 3 percent. In 2020 dollars, using a discount rate of 3 percent, the incremental net benefits of this rule are estimated to be -$344 million from 2024 through 2050. This is equivalent to annual net benefits of -$20 million over the same years. Using a 7 percent discount rate, the estimated net benefit of this rule is -$279 million from 2024 through 2050, equivalent to annual net benefits of -$27 million. It is important to note that these are incremental benefits compared to the estimate of costs performed in the Framework Rule RIA (see for instance Tables 5-1 and 5-3 in EPA-HQ-OAR-2021-0044-0227). In most years (2029-2050), the climate benefits are equal to the previous estimate of climate benefits. The annual compliance costs are also the same as the previous estimate of costs for those years, however due to a change in the recordkeeping and reporting cost estimates, the annual total costs is $370.5 thousand higher compared to the previous estimates of annual total costs. Additionally, for the years 2024–2029 the annual climate benefits and associated compliance costs are higher than those in the Framework Rule RIA. For instance, in 2024, the costs in the Framework Rule RIA were $118 million whereas here that cost increases by $29.8 million. Likewise, the climate benefits in the Framework Rule RIA were $5.21 billion in 2024, whereas here that benefit increases by $0.3 million. These incremental increased costs and benefits in those years result from the need to adopt additional, higher-cost abatement options (that is, “higher” on the MAC curve) in order to achieve the additional reductions needed to comply with the 60% cap at the new, lower baseline.

[13] Although the method for determining the HFC consumption baseline is prescribed in the AIM Act, and therefore finalizing a new, lower baseline does not depend on demonstrating a net benefit for the regulatory change, this chapter nonetheless provides an estimate of the incremental impact of this change relative to EPA’s prior estimates.

Table 5-1: Summary of Annual Values, Present Values, and Equivalent Annualized Values for the 2024–2050 Timeframe for Estimated Incremental Abatement Costs, Benefits, and Net Benefits for This Rule (millions of 2020$, discounted to 2022)[a,b,c,d,e]

Year	Climate Benefits (3%)[c]	Costs (annual)		Net Benefits (3% Benefits, 3% or 7% Costs)	
2024	$0.3	$29.8		-$29.7	
2025	$0.5	$85.9		-$85.4	
2026	$0.7	$89.8		-$89.1	
2027	$0.9	$94.9		-$94.0	
2028	$1.1	$100.8		-$99.7	
2029	$0	$0.4		-$0.4	
2030	$0	$0.4		-$0.4	
2031	$0	$0.4		-$0.4	
2032	$0	$0.4		-$0.4	
2033	$0	$0.4		-$0.4	
2034	$0	$0.4		-$0.4	
2035	$0	$0.4		-$0.4	
2036	$0	$0.4		-$0.4	
2037	$0	$0.4		-$0.4	
2038	$0	$0.4		-$0.4	
2039	$0	$0.4		-$0.4	
2040	$0	$0.4		-$0.4	
2041	$0	$0.4		-$0.4	
2042	$0	$0.4		-$0.4	
2043	$0	$0.4		-$0.4	
2044	$0	$0.4		-$0.4	
2045	$0	$0.4		-$0.4	
2046	$0	$0.4		-$0.4	
2047	$0	$0.4		-$0.4	
2048	$0	$0.4		-$0.4	
2049	$0	$0.4		-$0.4	
2050	$0	$0.4		-$0.4	
Discount rate	**3%**	**3%**	**7%**	**3%**	**7%**
PV	**$2.9**	**$347**	**$282**	**-$344**	**-$279**
EAV	**$0.2**	**$20**	**$27**	**-$20**	**-$27**

[a] Rows may not appear to add correctly due to rounding.
[b] The annualized present value of costs and benefits are calculated as if they occur over a 27-year period from 2024 to 2050.
[c] Climate benefits are based on changes (reductions) 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). For purposes of this table, we show the benefits (climate benefits and net benefits) associated with the model average at a 3 percent discount rate, but the Agency does not have a single central SC-HFC point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-HFC estimates. As discussed in Chapter 4, a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, is also warranted when discounting intergenerational impacts.
[d] These estimates are year-specific estimates.
[e] For the years 2029 through 2050 the abatement options modeled previously using the higher baseline had already lowered consumption below the maximum consumption allowed. This overshoot reached a level of consumption

that is already below the maximum consumption that would be allowed with the lowered baseline, so no additional abatement options are needed in these years and no incremental costs are accrued.

5.2 Updated Comparison of Costs and Benefits for the HFC Phasedown

Because of the update to the estimated compliance costs detailed in Chapter 2, updated estimates of the climate benefits, compliance costs, and net benefits of all provisions of the HFC phasedown due to finalizing a lowered baseline requires accounting for both the updated costs from Chapter 2 and the incremental changes in benefits and costs of this rule. Adding the estimated incremental costs of lowering the baseline to the updated cost estimate for the entire HFC phasedown, all provisions of the HFC phasedown from 2022–2050 are estimated to have compliance costs of -$8 billion discounted at 3 percent and -$4.0 billion at 7 percent, in 2020 dollars discounted to 2022. Note that the negative compliance costs indicate savings. Considering the incremental climate benefits of lowering the HFC baseline as well, the net benefits of all provisions of the HFC phasedown from 2022 through 2050 are estimated to be $269.9 billion with a 3 percent discount rate and $265.8 billion with a 7 percent discount rate, in 2020 dollars and discounted to 2022, a decrease of less than 1 percent from the Framework Rule RIA.

Chapter 6: Environmental Justice

6.1 Introduction and Background

The environmental justice analysis that was conducted as part of the Framework Rule RIA addressed issues associated with the impacts of changes in the production of HFCs and possible substitutes of HFCs on communities near facilities identified as producers of these chemicals. EPA could not identify specific effects of the phasedown on individual communities, but the Agency did identify eight facilities with emissions likely to be affected by the Framework Rule. EPA was also able to analyze demographic characteristics of the fence-line communities in the Census Block Groups within 1-, 3-, 5-, and 10-mile radii of the affected facilities. Chapter 6 – the environmental justice analysis – of the Framework Rule RIA concluded, in part, that:

- *Higher percentages of low income and Black or African American individuals live near HFC production facilities compared to the overall or rural average at the national level;*
- *Multiple HFC substitutes are available, some of which have toxic profiles for the chemicals used as feedstocks in their production.*
- *Given limited information regarding which substitutes will be produced where, it is unclear to what extent this rule will impact baseline risks from hazardous air toxics for communities living near HFC and HFC substitute production facilities.*

This chapter provides an update to the environmental justice analysis that was done as part of the Framework Rule RIA.[14] While this analysis uses more recent data than the previous analysis carried out as part of the Framework Rule RIA, it is largely similar with its focus on cumulative risks within communities and still uses data predating implementation of the Framework Rule. As such, this analysis, like the Framework Rule analysis, still can be considered a characterization of the baseline environmental conditions faced by communities living near HFC production facilities subject to the rule. This rule has the effect of establishing the allocation of HFC production and consumption allowances after 2023. Since EPA is reducing the consumption baseline by about 0.44 percent, this rule results in a slight reduction in the consumption and emissions of HFCs beyond that required by the Framework Rule. The climate benefits are discussed in chapter 5 of this addendum. The climate benefits from the Framework Rule were estimated to avoid 4,560 MMTEVe of HFCs in the United States for the years 2022–2050. Lowering the HFC baseline is expected to reduce total HFC emissions between 2024–2050 by an additional 0.05 MMTEVe. The HFC Allocation Program could result in potential changes in chemical emissions that may be locally hazardous. EPA has identified facilities that are likely to be affected by this rule (and prior Framework Rule) and has conducted an updated environmental justice analysis of the communities near these identified facilities that produce regulated HFCs.

The updated environmental justice analysis uses the same analytical approach used previously in the Framework Rule RIA. This analysis includes the addition of a facility that reported HFC

[14] EPA, 2021. Regulatory Impact Analysis for Phasing Down Production and Consumption of Hydrofluorocarbons (HFCs). Available at https://www.epa.gov/system/files/documents/2021-09/ria-w-works-cited-for-docket.pdf.

production and provides updated data on the total number of Toxics Release Inventory (TRI) facilities near HFC production facilities and the cancer and respiratory risks to surrounding communities. This analysis also includes updates on reported emissions under the Toxic Release Inventory (TRI) Program for the period of 2019-2021, by facility, for chemicals potentially associated with HFC production, including catalysts, feedstocks, coproducts, or byproducts that EPA anticipates may be associated with HFC production.

The chapter also includes, in Appendix E, a demonstration analysis using a geospatially disaggregated "microsimulation" model to assess these communities in more detail. The tool used is an example of microsimulation approaches using recent advancements in data science, and which can offer insight into the characteristics of communities by statistically representing "synthetic populations." These techniques show promise for improving analysis for many issues, including environmental justice. We include the demonstration analysis, which identifies communities for which further environmental justice analysis may be warranted, and we continue to evaluate the use of microsimulation techniques for potential future environmental justice analyses.

This chapter does not update the following: quantities of HFCs emitted by facility; risk evaluations for existing chemicals under Toxic Substances Control Act (TSCA) of relevant feedstock chemicals used in the production of HFCs; geographical dispersion of RSEI toxicity concentration by facility; number of informal and formal enforcement actions in last five years; and quarters of non-compliance (out of 12). The initial analysis on these topics is included in chapter 6 of the Framework Rule RIA, which is available in the docket for this rulemaking.

6.2 Environmental Justice at EPA

Executive Order 12898 (59 FR 7629; February 16, 1994) establishes federal executive policy on environmental justice. Its main provision directs federal agencies, to the greatest extent practicable and permitted by law, to make environmental justice part of their mission by identifying and addressing, as appropriate, disproportionately high and adverse human health or environmental effects of their programs, policies, and activities on people of color and low-income populations in the United States. EPA defines environmental justice as the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies.[15] Executive Order 14008 (86 FR 7619; January 27, 2021) also calls on Agencies to make achieving environmental justice part of their missions "by developing programs, policies, and activities to address the disproportionately high and adverse human health, environmental, climate-related and other cumulative impacts on disadvantaged communities, as well as the accompanying economic challenges of such impacts." It also declares a policy "to secure environmental justice and spur economic opportunity for disadvantaged communities that have been historically marginalized and overburdened by pollution and under-investment in housing, transportation, water and wastewater infrastructure and health care." EPA also released its "Technical Guidance for Assessing Environmental Justice in Regulatory Analysis" (U.S. 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.

As noted in the 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 this rule may affect baseline risks from hazardous air toxics for communities living near HFC production facilities. We do understand that communities neighboring facilities that currently produce HFCs and those that are likely to produce HFC substitutes are often overburdened and disadvantaged. The Agency has a strong interest in mitigating undue burden on underserved communities.

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

[15] Fair treatment occurs when "no group of people should bear a disproportionate burden of environmental harms and risks, including those resulting from the negative environmental consequences of industrial, governmental, and commercial operations or programs and policies" (U.S. EPA, 2011). Meaningful involvement occurs when "1) potentially affected populations have an appropriate opportunity to participate in decisions about a proposed activity [i.e., rulemaking] that will affect their environment and/or health; 2) the population's contribution can influence [the EPA's] rulemaking decisions; 3) the concerns of all participants involved will be considered in the decision-making process; and 4) [the EPA will] seek out and facilitate the involvement of population's potentially affected by EPA's rulemaking process" (U.S. EPA, 2015). A potential environmental justice concern is defined as "actual or potential lack of fair treatment or meaningful involvement of [people of color], low-income populations, tribes, and indigenous peoples in the development, implementation and enforcement of environmental laws, regulations and policies" (U.S. EPA, 2015). See also https://www.epa.gov/environmentaljustice.

move 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. In addition to other rules which address emissions under the Clean Air Act, the Agency continues to evaluate chemicals under TSCA. For certain chemicals for which risk evaluations are complete that are used in the manufacture of HFC and HFC substitutes, including carbon tetrachloride, methylene chloride, tetrachloroethylene (perchloroethylene), and trichloroethylene, EPA, under section 6 of TSCA will be addressing the unreasonable risks identified.[16]

6.3 Environmental Justice Analysis for this HFC Allocation Rule

In the 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 Framework Rule, the environmental justice benefits of reducing climate change are significant. The HFCs themselves are not a local pollutant and have low toxicity to humans. However, chemicals used as feedstocks or catalysts in the production of HFCs or produced as byproducts may have localized effects if released into the environment, and these may have environmental justice implications. The HFCs regulated under the HFC Allocation Program use a wide array of chemicals as feedstocks or catalysts for

[16] More information on EPA's risk evaluation and risk management activities under TSCA is available at: https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-evaluations-existing-chemicals-under-tsca and https://www.epa.gov/assessing-and-managing-chemicals-under-tsca/risk-management-existing-chemicals-under-tsca.

production or produce them as byproducts, some of which are hazardous when released into the environment or when workers or other occupational non-users are exposed to them. More information on these chemicals, their toxicities, and their health effects can be found in section 6.4, and in the Framework Rule RIA.

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 production facilities). EPA used data from reports required under the HFC Allocation Program,[17] TRI,[18] GHGRP,[19] Chemical Data Reporting (CDR) Program,[20] and information provided by industry stakeholders to identify the facilities producing HFCs. Once production locations were identified, EPA retrieved the Facility Registry Service (FRS) IDs for each production facility using the Agency's FRS national dataset.[21] This step was conducted to facilitate extracting 1) an environmental profile and 2) demographic information within 1, 3, 5 and 10 miles for each facility using EPA's Enforcement and Compliance History Online (ECHO) database.[22]

In considering the allocation of allowances, EPA identified nine HFC facilities where emissions might change and impact neighboring communities. These nine include the eight facilities analyzed for the Framework Rule RIA environmental justice analysis. One additional facility has been identified in the reporting of data required under the Framework Rule. This analysis is

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[17] EPA reviewed first quarter production reports required under the Framework Rule to determine facilities that will need to reduce HFC production to comply with the exchange value weighted HFC production and consumption caps.

[18] TRI tracks the management of certain toxic chemicals that may pose a threat to human health and the environment. U.S. facilities in different industry sectors must report annually how much of each chemical is released to the environment and/or managed through recycling, energy recovery and treatment. Facilities submit a TRI Form R for each TRI-listed chemical it manufactures, processes, or otherwise uses in quantities above the reporting threshold.

[19] The GHGRP requires reporting of GHG data and other relevant information from large GHG emission sources, fuel and industrial gas suppliers, and CO_2 injection sites in the United States. The program generally requires reporting when emissions from covered sources are greater than 25,000 pounds of CO_2e per year.[19] Publicly available information[19] includes facility names, addresses, and lat/long information.

[20] The CDR program, under the Toxic Substances Control Act, requires manufacturers (including importers) to provide EPA with information on the production and use of chemicals in commerce. Under the CDR rule, EPA collects information on the types, quantities, and uses of chemical substances produced domestically and imported into the United States. The information is collected every four years from manufacturers of certain chemicals in commerce generally when production volumes are 25,000 pounds or greater for a specific reporting year.[20] Publicly available information[20] includes facility name, addresses, lat/long information on production facilities, and additional information about the chemicals and downstream uses.

[21] FRS National Data Set available at https://www.epa.gov/frs/epa-frs-facilities-state-single-file-csv-download

[22] https://echo.epa.gov/.

updated from the Framework Rule RIA to include the additional facility, and it uses updated data from the most recent AirToxScreen Assessment.

As discussed later in section 6.4, and in the Framework Rule RIA, there are many toxic and potentially toxic chemicals involved in the manufacturing processes that may be impacted by this rule, and fenceline communities are impacted by emissions from facilities of the type identified here. These analyses detail the reported emissions and assessments of the risks that some of the substances may pose, but they also note several limits to our ability to assess the impact this rule on the exposure that specific communities may face:

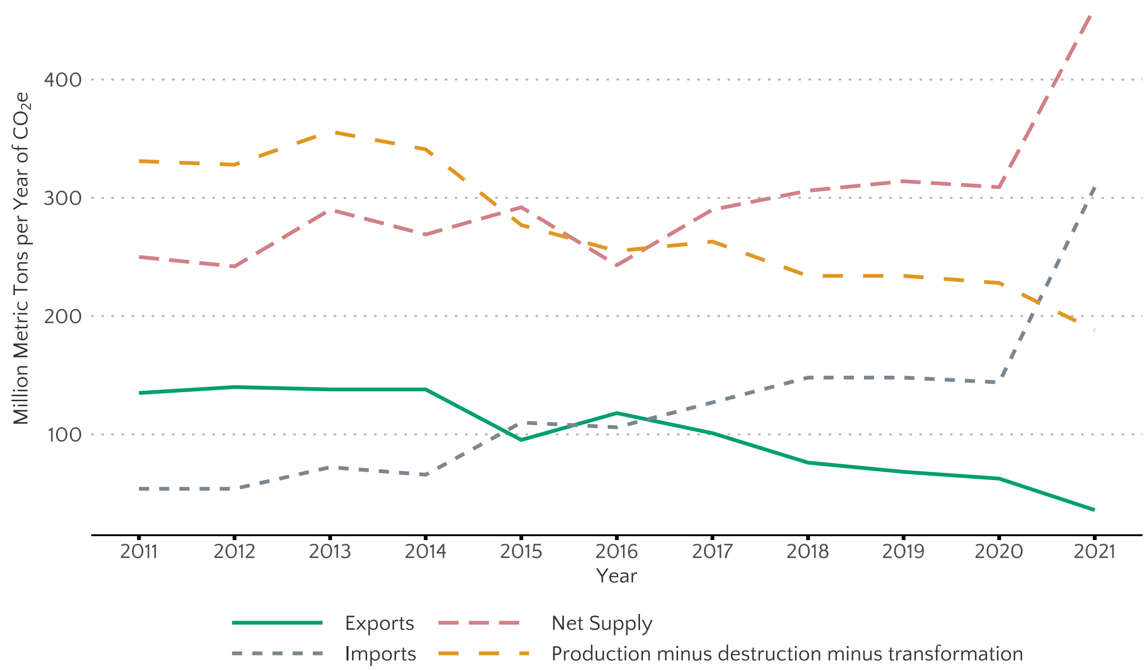
- These facilities generally produce several chemical products, individual facilities use different production methods with differing emissions characteristics, and processes and feedstocks may change. It is unknown how emissions and risks may change as a result of the Framework Rule, and this uncertainty extends to the potential emission impacts of this rule
- Many of the emissions resulting from production are poorly understood given a lack of data on the choices that producers of impacted chemicals will make in the future in response to the Framework Rule and this rule.
- Many of the communities near the facilities expected to be affected by the HFC Phasedown and this rule are also near other sources of toxic emissions which contribute to environmental justice concerns.
- Some companies with multiple production facilities may choose to consolidate production of regulated substances at a subset of facilities as the phasedown continues, which could lead to an increase in regulated substance production at a single facility, despite the overall phasedown.

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

6.4 Net Supply of HFCs and Toxic Release Inventory Data at HFC Production Facilities

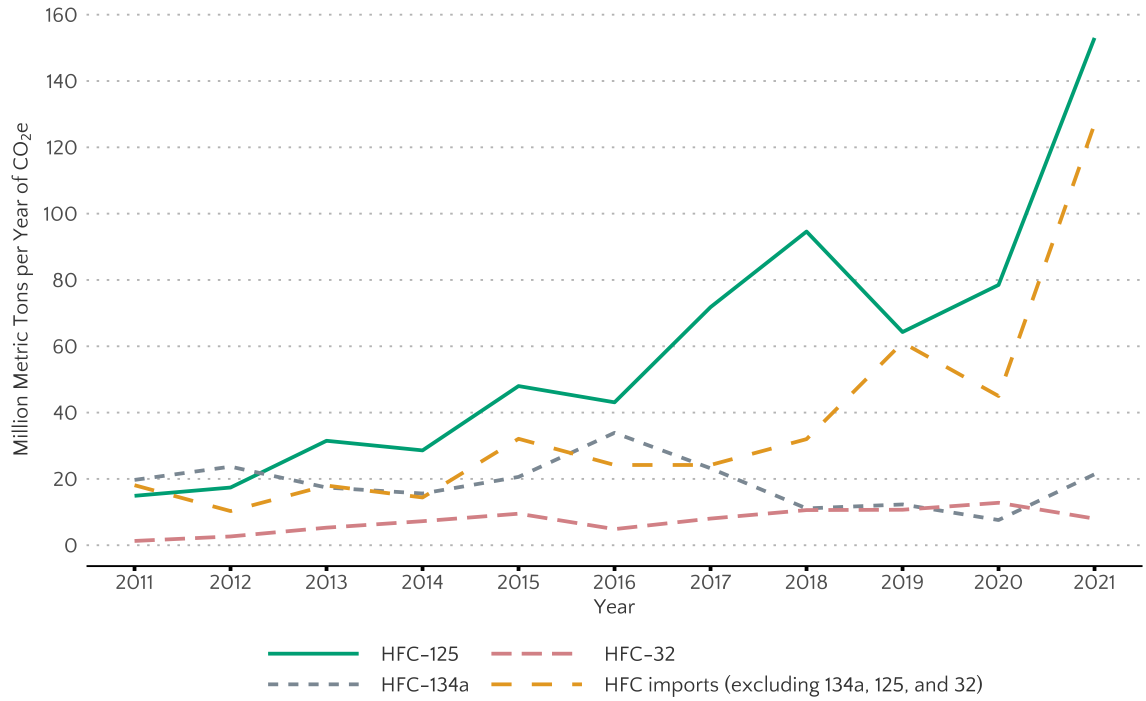
Although the initial AIM Act regulations did not go into effect until 2022, they are likely to have induced anticipatory responses in HFC markets in 2021, after the passage of the AIM Act on December 27, 2020. Production and consumption of HFCs were not subject to a cap in 2021 and, therefore, did not require the expenditure of allowances. However, bulk HFCs are not perishable, so HFCs produced or imported prior to 2022 can be stored and sold in 2022 and beyond without being subject to the cap. Figures 1 and 2 show a time series of HFC production and imports from the most recent GHGRP data through 2021. Based on the reported data, HFC production as measured by global warming potential (GWP-weighted basis) has fallen by more than a third since 2011, while imports have increased substantially, particularly in 2021 likely in anticipation of the regulations initiating the HFC phasedown in 2022. While data are not available, it is reasonable to expect that facilities also continue to transition production to HFC substitutes. Production of some substitutes has the potential to release some of the same chemicals associated with HFC production (see Table 6.22 in the Framework Rule RIA), while production of other substitutes like hydrocarbons have different emissions profiles. For these reasons, it is useful to analyze the changes in toxic air releases between 2019 and 2021. These trends also set a baseline for toxic emissions before the caps on HFC production and consumption took effect in 2022.

Figure 6-1: Net Supply of AIM-Listed HFCs Reported to GHGRP (2011-2021).



Notes: Trends in HFC supply were relatively constant in the decade leading up to the AIM Act's Framework rule (2022). In 2021, however, there was a notable increase in the amount of HFC's being reported as imports (grey dashed line), driving a notable increase in overall net supply (pink dashed line). The term "net supply" means the quantities of bulk HFC produced + imported – exported – transformed – destroyed. "Net supply" is near equivalent to the term "consumption", but these values are not equivalent to consumption, e.g., they do not include HFC-23 production.

Figure 6-2: Imports of AIM-Listed HFCs Reported to GHGRP (2011-2021)



Notes: Looking into which species of HFCs were driving the imports trend in 2021, we see HFC-125 as a major contributor (green solid line), as well as other (suppressed for CBI) species (yellow dashed line).

TRI data. The HFC production facilities that are regulated under the AIM Act also report toxic air releases under the TRI Program. TRI facilities must annually report releases of TRI Chemicals into Air, Water, and Land, and transfers off-site (note that "transfers off-site" is related to the transfer of material and not the transfer of allowances).[23] The most recent TRI emissions data available is for the 2021 reporting year. The release data reported by TRI facilities in TRI is assigned TRI Facility Identification Number. A facility that has a single FRS ID or GHGRP ID can have one or more TRI IDs assigned to it.

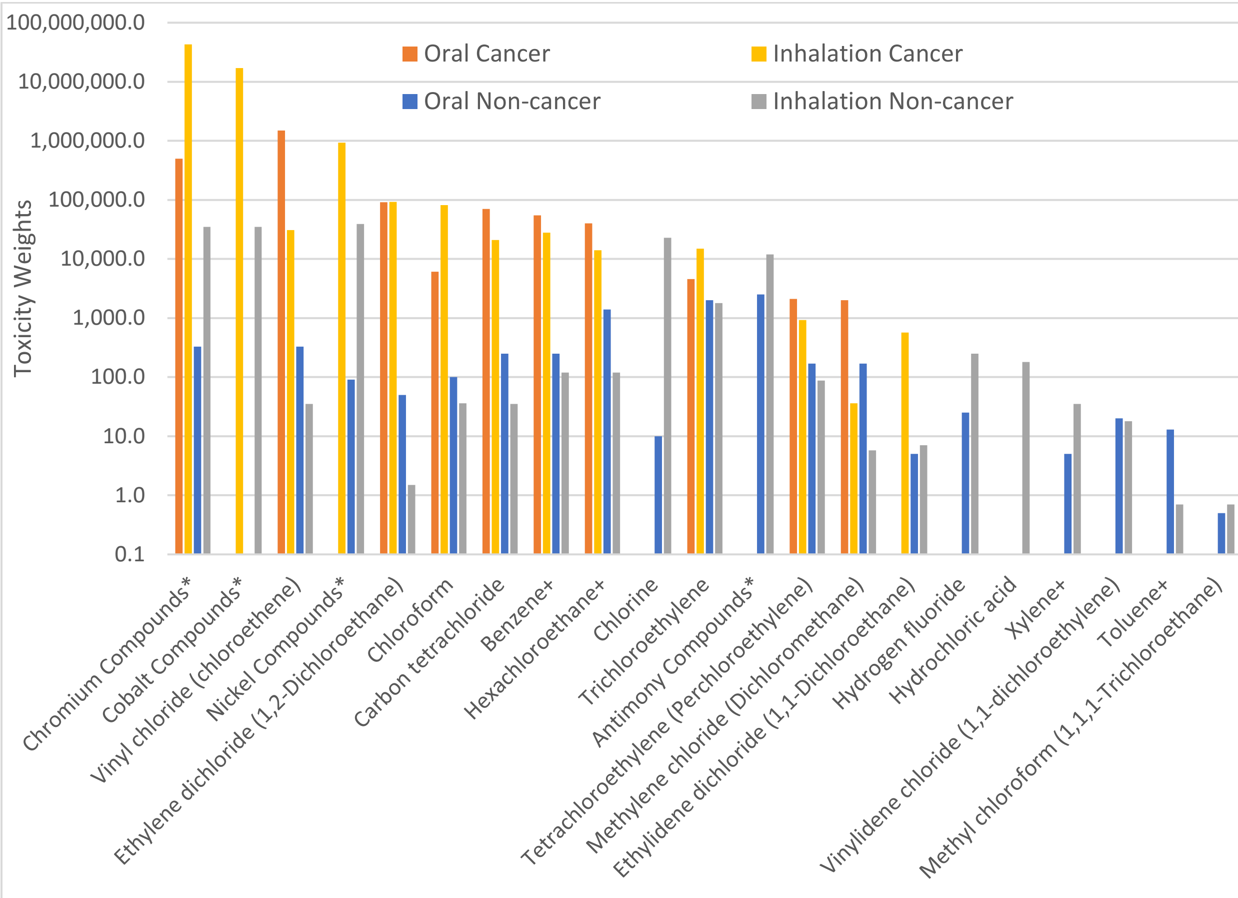
HFC production-related chemicals. HFC production facilities regulated under this rulemaking may also manufacture other non-HFC chemicals. For example, a facility may have multiple production lines, and total emissions are all reported together for that TRI facility and associated TRI ID. For this reason, the reported emissions may not be just from the production of HFCs. To filter out non-HFC-related chemicals, we used a list of chemicals that EPA anticipates are related

[23] Note that an "off-site transfer" under TRI is the transfer of chemical-containing waste to a facility that is geographically or physically separate from the facility reporting under TRI not the transfer of allowances. Chemicals reported to TRI as transferred are sent to off-site facilities for the purposes of recycling, energy recovery, treatment, or disposal.

to HFC production. For the purposes of the analysis below, we specifically used a list of chemicals originally presented in Table 6-3 of the Framework Rule RIA. This list was then supplemented based on an additional set of chemicals reported by companies to EPA in their HFC producer one-time reports submitted under 40 CFR 84.31. The list includes catalysts, feedstocks, coproducts, or byproducts that EPA anticipates may be associated with HFC production. Importantly, these HFC-related chemicals may also be used, produced, or released in the manufacture of non-HFC chemicals, including non-HFC refrigerant substitutes. Therefore, the releases reported in this section are TRI facility total aggregate on-site releases of chemicals potentially related to HFC production and should not be interpreted as releases solely from HFC production.

Toxicity Weights. Figure 3 presents the toxicity weights associated with cancer and non-cancer risks for the toxic chemicals from EPA's Risk-Screening Environmental Indicators (RSEI) model. The vertical axis (log scale) provides a relative measure of the toxicity associated with two endpoints (cancer and non-cancer health effects) via two potential routes of exposure (oral and inhalation). Higher bars in the graph indicate a greater risk associated with the endpoint or route indicated. EPA uses the toxicity weights for the oral route of exposure for water releases and the inhalation route for air releases to describe each chemical's toxicity relative to other TRI-reported chemicals. To present a single toxicity weight, the EPA RSEI hazard uses the maximum of the non-cancer and cancer toxicity weights.

Figure 6-3: RSEI toxicity weights for chemicals potentially used as a feedstock or catalyst or potentially released as a byproduct of HFC production.



Notes: * Denotes toxic chemicals that are potentially used as a catalyst in HFC production. + Denotes toxic chemicals reported to EPA as coproducts, byproducts, or emissions from an HFC production line.
The 21 chemicals included in this figure are derived from two sources: a) a list originally compiled and presented in the Allocation Framework Rule RIA; and, b) additional data reported to EPA by HFC producers under 40 CFR 84.31(b)(1). These chemicals are believed to be related to the production of HFCs and are presented along with their relevant toxicity-weight. This is the list of chemicals that was used to filter EPA's Toxic Release Inventory for each of the HFC production facilities and used to create the tables presented in this RIA Addendum.

Trends in Air Releases. TRI air releases are reported as either Fugitive Air Emissions or Stack Air Emissions of the TRI chemical. For this analysis, they are combined (added together) into a single summary metric of total reported air releases for analyzing trends in aggregate releases over time. To give insight into the toxicity of releases, an analyst could toxicity-weight air releases (also called the "RSEI hazard") by multiplying the RSEI inhalation toxicity-weight (the maximum of the cancer and non-cancer weight) times the pounds emitted of each HFC-related chemical reported as a TRI chemical (Figure 3). The toxicity-weighted pounds for all chemicals would then be added together for each HFC production facility. This analysis presents total pounds, not toxicity weighted.

Table 6-1 lists the total reported TRI releases into Air, Water, Land, and Offsite Transfers by Production Facility (in pounds). Table 6-2 presents the quantities of on-site air and water releases, and quantities transferred offsite for disposal for the subset of toxic chemicals that are used as feedstocks or catalysts or are produced as byproducts of HFC production (Figure 3). Table 6-3 disaggregates the HFC production-related air releases (in Table 6-2) into the individual chemicals listed in Figure 3 for each facility.

In Table 6-2, the facilities can be categorized into three groups based on the changes in air releases: 1) declined releases, 2) generally constant releases, and 3) increased releases. The first group of facilities (Chemours – Corpus Christi, Chemours El Dorado, Daikin America, and Mexichem Fluor) generally had declining releases in this period. The second group of facilities (Arkema, and Honeywell International – Geismar Complex) had generally constant releases in 2019-2021. The third group of facilities (Chemours Louisville Works, and Islechem LLC) showed increased HFC-related air releases from 2019 and 2020 to 2021, mostly in 2021. Additional context on trends at this third group of facilities is provided below. At this time, EPA is not able to discern whether these increases are related specifically to HFC production, the production of HFC substitutes, or other chemicals or compounds also produced at these facilities.

Chemours Louisville Works. In 2021, the Chemours Louisville Works facility reported an increase (10%) in HFC-related air emissions over 2019 (Table 6-2). When the air emissions are disaggregated by chemical (Table 6-3), a single chemical (chloroform) is seen to be the primary cause of this increase. Between 2019 and 2021, chloroform releases increased 192%.

Islechem LLC. Between 2019 and 2020, Islechem reported no releases of HFC production-related chemicals (nor did they report HFC production), although it reported releases of other chemicals (Table 6-1). In 2021, it reported the release of one HFC-related chemical (Table 6-3), methylene chloride (dichloromethane). Overall, while the facility reported an increase (from zero) of HFC-related chemicals (Table 6-3), it experienced a decline of 35% in its air releases for all TRI chemicals between 2019 and 2021 (Table 6-1).

Trends in Water Releases. For this analysis, water releases are combined across chemicals (added together) into a single summary metric of total reported water releases for analyzing trends in aggregate releases over time. To give insight into the toxicity of releases, an analyst could toxicity-weight water releases (also called the "RSEI hazard") by multiplying the RSEI oral toxicity-weight (the maximum of the cancer and non-cancer weight) times the pounds emitted of each HFC-related chemical reported as a TRI chemical (Figure 3). The toxicity-weighted pounds for all chemicals would then be added together for each HFC production facility. This analysis presents total pounds, not toxicity weighted. Table 6-2 summarizes the HFCrelated water releases from 2019 to 2021. Total Water releases, as reported in the TRI, are also reported in Table 6-1 to compare facility-wide trends alongside trends in water releases related to HFC production.

Similar to air releases, facilities can be loosely categorized into three categories based on the changes in water releases for HFC production related chemicals: 1) declined releases, 2) generally constant releases, and 3) increased releases. The first category of facilities (Mexichem Fluor) had generally declining water releases in this period. The second category (Daikin America) had generally constant water releases. The third category (Arkema, and Honeywell International – Geismar Complex) had increases in water releases from 2020 to 2021. The remaining facilities did not report any HFC-related water releases.

Trends in Land Releases and Off-site Transfers. Land releases and off-site transfers are also reported in the TRI. Table 6-1 summarizes the total land releases and off-site transfers from 2019 to 2021. Table 6-2 reports the HFC-related off-site transfers.

Between 2019 and 2021, only two of the HFC production facilities reported land TRI releases: Arkema and Honeywell International - Geismar Complex). One facility (Honeywell International - Geismar Complex) had fairly constant land releases between 2019 and 2021. The other facility (Arkema) reported significant decreases between 2019 and 2021, with only a small increase in land releases between 2020 and 2021.

For off-site transfers reported to the TRI, four facilities (Arkema, Chemours Louisville Works, Daikin America, and Honeywell International – Geismar Complex) reported decreases between

2019 and 2021. Two facilities (Iofina Chemical, and Islechem LLC) remained relatively constant in off-site transfers between 2019 to 2021. The last facility (Mexichem Fluor) had a significant increase in off-site transfers from 2020 to 2021, but this is consistent with a large peak for this facility every 3 years over the period from 2011 to 2021.

Table 6-1: Reported Total Releases into Air, Water, Land, and Offsite Transfers by Production Facility (in pounds)

Facility (TRI year)	**Air Releases**	**Water Releases**	**Land Disposal**	**Off-site Transfers**
Arkema, Inc.; Calvert City, KY				
2019	243194	896	5845	501
2020	225532	742	767	53
2021	220122	945	1070	0
Chemours - Corpus Christi; Gregory, TX				
2019	63568	0	0	0
2020	53925	0	0	0
2021	83582	0	0	0
Chemours El Dorado; El Dorado, AR				
2019	33240	0	0	0
2020	3974	0	0	0
2021	5926	0	0	0
Chemours Louisville; Louisville, KY				
2019	657191	0	0	196
2020	515837	0	0	47
2021	591540	0	0	31
Daikin America; Decatur, AL				
2019	169339	18607	0	30
2020	148733	4222	0	0
2021	148867	6354	0	0
Honeywell - Geismar Complex; Geismar, LA				
2019	122651	4722	12786	158858
2020	115378	4415	12024	101122
2021	122568	5431	11237	118640
Iofina Chemical Inc.; Covington, KY				
2019	20	0	0	125
2020	20	0	0	125
2021	20	0	0	125
IsleChem Facility – Grand Isle, NY				
2019	2029	0	0	0
2020	1178	0	0	5
2021	1313	0	0	0
Mexichem Fluor Inc.; Saint Gabriel, LA				
2019	22593	40	0	73
2020	4622	30	0	193
2021	3246	23	0	230049

Source: U.S. EPA. Toxic Releases Inventory, 2019-2021.

Notes: These emissions are for all TRI reported chemicals, not just those potentially associated with HFC production.

Table 6-2: Reported Toxic Releases Potentially Associated with HFC Production (in pounds)

Facility (TRI year)	Air releases for toxic HFC production chemicals	Ratio of toxic HFC-related to total air releases	Water releases for toxic HFC production chemicals	Ratio of toxic HFC-related to total water releases	Off-site transfers of toxic HFC production chemicals	Ratio of toxic HFC-related to total off-site transfers
Arkema, Inc.; Calvert City, KY						
2019	58043	0.24	250	0.28	1	0
2020	55530	0.25	212	0.29	3	0.06
2021	58369	0.27	479	0.51	0	
Chemours - Corpus Christi; Gregory, TX						
2019	35011	0.55	0		0	
2020	28678	0.53	0		0	
2021	28082	0.34	0		0	
Chemours El Dorado; El Dorado, AR						
2019	17070	0.51	0		0	
2020	3974	1	0		0	
2021	5926	1	0		0	
Chemours Louisville; Louisville, KY						
2019	3724	0.01	0		196	1
2020	3859	0.01	0		47	1
2021	4095	0.01	0		31	1
Daikin America; Decatur, AL						
2019	3313	0.02	22	0	30	1
2020	3216	0.02	14	0	0	
2021	3129	0.02	18	0	0	
Honeywell - Geismar Complex; Geismar, LA						
2019	51282	0.42	499	0.11	62543	0.39
2020	46741	0.41	453	0.1	15649	0.15
2021	47628	0.39	576	0.11	13642	0.11
Iofina Chemical Inc.; Covington, KY						
2019	0	0	0		0	0
2020	0	0	0		0	0
2021	0	0	0		0	0
IsleChem Facility – Grand Isle, NY						
2019	0	0	0		0	
2020	0	0	0		0	0
2021	410	0.31	0		0	
Mexichem Fluor Inc.; Saint Gabriel, LA						
2019	4369	0.19	28	0.7	73	1
2020	2573	0.56	28	0.93	178	0.92
2021	2227	0.69	19	0.83	213801	0.93

Source: U.S. EPA. Toxic Releases Inventory, 2019-2021.

Table 6-3a: 2019-2021 TRI Air Releases (in pounds) for Toxic Chemicals Potentially Associated with HFC Production

Chemical (TRI year)	Maximum RSEI Toxicity Weight*	Arkema, Inc.	Chemours - Corpus Christi	Chemours El Dorado	Chemours Louisville	Daikin America	Honeywell - Geismar Complex	Iofina Chemical Inc.	IsleChem LLC	Mexichem Fluor Inc.
Chromium Compounds	43,000,000									
2019							0.30			1
2020							0.30			1
2021							1.01			1
Vinyl chloride	1,500,000									
2019			939			1853				
2020			942			1820				
2021			942			1820				
Chloroform	82,000									
2019			385		233	64	383			
2020			604		226	53				
2021			425		680	57				
Carbon tetrachloride	70,000									
2019			16808	3631						
2020			12132							
2021			11729	848						
Hexachloroethane	40,000									
2019			135							
2020			103							
2021			54							
Chlorine	23,000									
2019		5298	740		282		6752			
2020		5277	741		284		6031			
2021		5270	995		235		6049			
Trichloroethylene	15,000									
2019		1905								6
2020		1454								7
2021		1426								7

Continued on next page

Source: U.S. EPA. Toxic Releases Inventory 2019-2021. * The maximum RSEI toxicity weight is the highest weight of the four presented in Figure 3: oral cancer, inhalation cancer, oral non-cancer, and inhalation non-cancer.

Table 6-3b: 2019-2021 TRI Air Releases (in pounds) for Toxic Chemicals Potentially Associated with HFC Production

Chemical	Maximum RSEI Toxicity Weight*	Arkema, Inc.	Chemours - Corpus Christi	Chemours El Dorado	Chemours Louisville	Daikin America	Honeywell - Geismar Complex	Iofina Chemical Inc.	IsleChem LLC	Mexichem Fluor Inc.
Antimony Compounds	12,000									
2019		0			0		26			
2020		13			0		22			
2021		1			0		22			
Tetrachloroethylene	2,100									
2019			3806				8013			
2020			3921				8005			
2021			4059				8091			
Methylene chloride	2,000									
2019		791								
2020		483								
2021		714							410	
Ethylidene dichloride (1,1-Dichloroethane)	570									
2019		1								
2020		1								
2021		1								
Hydrogen fluoride	250									
2019		8004	5760	6237	506	772	23138			3095
2020		8099	4044	3974	480	582	21174			1944
2021		7877	3560	4679	465	589	21323			1623
Hydrochloric acid	180									
2019		39717	6437	7202	2703	624	12970			1267
2020		38132	6191		2869	761	11509			621
2021		38909	6320	399	2715	663	12143			596
Methyl chloroform	0.7									
2019		2327								
2020		2071								
2021		4171								
Total for HFC-Related Subset by year										
2019		58043	35011	17070	3724	3313	51282	**0**	0	4369
2020		55530	28678	3974	3859	3216	46741	**0**	0	2573
2021		58369	28082	5926	4095	3129	47628	**0**	410	2227

Source: U.S. EPA. Toxic Releases Inventory 2019-2021. * The maximum RSEI toxicity weight is the highest weight of the four presented in Figure 3: oral cancer, inhalation cancer, oral non-cancer, and inhalation non-cancer.

6.5 Aggregate Average Characteristics of Communities Near Potentially Affected Production Facilities

The RIA for the 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 substitutes. As described earlier, as part of risk evaluations conducted under section 6 of TSCA, EPA has evaluated risks to workers and occupational non-users for several chemicals used as feedstocks for HFCs or HFC substitutes (e.g., carbon tetrachloride, methylene chloride, tetrachloroethylene (perchloroethylene), and trichloroethylene). These risks are characterized in the 2020 risk evaluations for each chemical.[24] The rulemakings under TSCA to address unreasonable risks for each chemical aim to incorporate reasonably available information on demographics of workers in affected industries who live near these facilities in order to identify potential environmental justice concerns.

EPA has not undertaken an analysis of how the emissions of various HFC or HFC substitute feedstocks, catalysts, and byproducts affect nearby communities (e.g., through use of a fate and transport model or the modeling of main exposure pathways). However, a proximity-based approach can identify correlations between the location of these identified production facilities and potential effects on nearby communities. Specifically, this approach assumes that individuals living within a specific distance of an HFC production facility are more likely to be exposed to releases from feedstocks, catalysts, or byproducts. 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 production facility compared to the national average. The national average for

[24] The risks evaluations for these chemicals can be found in the following dockets: EPA-HQ-OPPT-2019-0499 (carbon tetrachloride); EPA-HQ-OPPT-2019-0437 and EPA-HQ-OPPT-2016-0742 (methylene chloride); EPA-HQ-OPPT-2019-0502 and EPA-HQ-OPPT-2016-0732 (tetrachloroethylene (perchloroethylene)); EPA-HQ-OPPT-2016-0737 and EPA-HQ-OPPT-2019-0500E (trichloroethylene).

rural areas is also presented since four of the nine production facilities expected to be impacted by this rule are classified as rural.[25]

In addition, AirToxScreen data from 2019 (the most recent year available) 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 production 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 individual risk values for all the chemicals evaluated in the AirToxScreen database. Note that these risks are not necessarily only associated with a specific HFC production facility. Industrial activity is often concentrated (i.e., multiple plants located within the same geographic area).

Table 6-4 presents the density of TRI facilities (nearby facilities that could contribute to the cumulative AirToxScreen cancer and respiratory risk in HFC production communities) located within 1-, 3-, 5-, and 10-mile radii of the nine facilities. Seven of the nine facilities have fewer than five neighboring TRI facilities within a 1-mile radius. Expanding the radius to 3 miles increases the number of neighboring TRI facilities substantially for seven of the nine facilities. Expanding the radii to 5 and 10 miles increases the number of neighboring facilities even further. Compared to the previous environmental justice analysis for the Framework Rule, there has been minimal change in the density of surrounding TRI facilities. Many facilities were found to have one fewer TRI facility in the radii examined, and one facility – Iofina Chemical – was found to have five fewer facilities within the 10-mile radius. Chemours Louisville, Honeywell – Geismar Complex, and Mexichem Fluor were found to have one additional TRI facilities in the various radii examined.

Table 6-4: Total Number of Neighboring TRI Facilities within 1, 3, 5 and 10 miles of Identified Facilities

[25] The US Census definition of "rural" is used. The term rural is applied to census areas that are not classified as urbanized areas or urban clusters and have a population density below 2,500 people per square mile. Census also looks at other factors before classifying an area as rural including adjacency to an urban area. For the 1-mile radius, population density near an HFC production facility ranges from 40 people per square mile to 306 people per square mile for each of the seven facilities in rural areas. For the 3-mile radius, population density near a facility ranges from 46 people per square mile to 1,262 people per square mile. However, if the majority of census blocks within our buffer are urban-adjacent, we continue to use the overall national or state level average as a basis of comparison.

Facility	Location	TRI Facilities within a 1-Mile Radius	TRI Facilities within a 3-Mile Radius	TRI Facilities within a 5-Mile Radius	TRI Facilities within a 10-Mile Radius
Arkema, Inc.	Calvert City, KY	3	11	11	12
Chemours - Corpus Christi	Gregory, TX	2	4	5	6
Chemours El Dorado	El Dorado, AR	2	2	2	11
Chemours Louisville	Louisville, KY	13	18	33	67
Daikin America	Decatur, AL	3	15	21	27
Honeywell - Geismar Complex	Geismar, LA	4	20	30	38
Iofina Chemical	Covington, KY	2	2	14	41
IsleChem	Grand Isle, NY	1	6	11	36
Mexichem Fluor Inc.	Saint Gabriel, LA	5	17	22	38

Source: Toxic Releases Inventory (2021)

Table 6-5 presents summary information for the demographic data and AirToxScreen risks averaged across the nine communities near the identified production facilities compared to the overall and rural national average. Note that this analysis of the demographics of communities near these HFC production facilities is identical to that presented in the Framework Rule RIA[26] with two exceptions. The first is the inclusion of the IsleChem Inc. facility in Grand Island, NY. The second is the use of updated 2019 AirToxScreen data instead of 2014 NATA data.

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 cancer and respiratory risk in communities within 1, 3, 5 or 10 miles of an identified production facility is markedly greater than either the overall or rural national average.

Table 6-5: Overall Community Profile and AirToxScreen Risks for Communities Near Identified Facilities

	Overall National Average	***Rural Areas National Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*72*	*84*	*82*	*68*	*70*	*74*
% Black or African American (race)	*13*	*7.6*	*14*	*26*	*24*	*19*
% Other (race)	*15*	*8.2*	*4.0*	*5.3*	*5.4*	*7.1*

[26] Note that EPA issued a corrigendum for Chapter 6 of the Framework Rule RIA. The corrigendum corrects inadvertent errors in certain tables and accompanying narrative text in Section 6.4 of the Framework Rule RIA. The corrigendum is available in docket EPA-HQ-OAR-2021-0044, accessible at www.regulations.gov.

% Hispanic (ethnic origin)	*18*	*10*	*6.9*	*6.7*	*7.8*	*6.8*
Median Household Income (1k 2019$)	*71*	*67*	*74*	*63*	*55*	*63*
% Below Poverty Line	*7.3*	*6.8*	*5.7*	*8.0*	*9.3*	*8.0*
% Below Half the Poverty Line	*5.8*	*5.1*	*5.7*	*6.7*	*8.0*	*7.0*
Total Cancer Risk (per million)	*26*	*23*	*36*	*33*	*32*	*31*
Total Respiratory Risk (hazard quotient)	*0.31*	*0.27*	*0.35*	*0.35*	*0.35*	*0.34*

Notes: Demographic definitions are as described in the 2019 American Community Survey (US Census 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).

Results by race and ethnicity are often sensitive to how the comparison group (i.e., overall versus rural national average) and the distance to an HFC production facility are defined.

Looking across all nine facilities (Table 6-5), a higher percentage of Black or African American individuals live in the communities near HFC production facilities compared to the national average or the rural areas national average. In these communities, the percentage of White residents is higher within one mile of the facilities than farther away. (Within one mile, 82% of the residents are white, which is higher than the national average of 72%, but slightly lower than the rural national average of 84%.) There is a higher percentage of Black or African American individuals near these locations, compared to the averages, and lower percentages of people of other racial minorities or persons of Hispanic Ethnicity. The analysis indicates that the percentage of Black individuals is higher at the 10-mile radius (18%), 5-mile radius (22%) and 3-mile radius (27%) than at the 1-mile radius (15%), compared to the national average of 13%. The rural national average population is 7.6%. While median income is generally lower for the communities near these facilities compared to the national average or rural national average, there is an exception for communities nearest the facilities on average. Within the 1-mile radius, the median income is $75,000 per year, compared to the national average of $71,000, or the rural national average of $67,000. There is a higher percentage of households with very low incomes in closest proximity to these facilities. The national percentage of rural households with incomes less than half of the poverty line is 5.1%, and the overall national average is 5.8%. Within 1 mile of these specific facilities, the average percentage of rural households with incomes less than half of the poverty line is 6.0%. At the 3- and 5-mile distances, the number rises to 6.8% and 7.9%—it is 7.2% in the average 10-mile radius.

For this analysis, we use the most recent 2019 AirToxScreen data for total cancer risk and total respiratory risk. Comparing the data for the whole country to the 2014 NATA data (that were available at the time the Framework Rule RIA was written) it is important to note that total cancer and total respiratory risk have dropped for both rural and urban areas. The overall national average and rural areas average total cancer risk using the newest data are shown to have dropped to 26 and 23 per million, respectively, from 32 and 29 per million, compared to the 2014 data averages. A similar drop for total respiratory risk to 0.31 and 0.27 per million for the overall national average and rural areas national average respectively, from 0.44 and 0.38 per million. Likewise, proximity analyses to the identified facilities generally show lower risks at 1, 3, 5, and 10 miles using the 2019 data than was presented in the Framework Rule RIA. Still, the average aggregate risks in communities near these facilities are higher than either the rural national average or the overall national average. The analysis shows that the risks are higher for those within the 1-mile average radius and decrease at the 3-, 5-, and 10-mile radii.

It is worth noting that the averages reported in Table 6-5 may obfuscate potentially large differences in the community characteristics surrounding individual production facilities. It is important, therefore, to examine the socioeconomic and demographic community characteristics for each facility separately, using the appropriate applicable national- and state-level averages for comparison.[27]

6.6 Characteristics of Communities Near Identified Individual Facilities

For eight of the nine facilities identified here, the demographic data is identical to that published in the Framework Rule RIA in September of 2021. The racial, ethnic, and income figures for these eight communities within 1, 3, 5, and 10 miles of the respective facilities are drawn from the American Community Survey's 2019 dataset. The facility-by-facility discussion in the Framework Rule RIA used the 2014 NATA Database. This analysis updates that analysis using

[27] The relatively small number of facilities directly affected by this rule enabled EPA to assemble a uniquely granular assessment of the characteristics of these facilities and the communities where they are located.

the newest (2019) AirToxScreen Database. We discuss the demographics of the community near the IsleChem Inc facility, which was identified after the publication of the Framework Rule RIA, and highlight the results of comparing the 2019 AirToxScreen dataset results for the other eight analyses with the 2014 NATA data. The individual updated tables are presented for convenience.

As shown in Table 6-6, the community profile of the population near the IsleChem, Inc. facility, which is near the Canadian border on Grand Island, a large percentage of White individuals—but the rural average percent White in New York State itself is slightly higher (at 92%), than at the 1-, 3-, 5-, and 10-mile radii (91%, 88%, 81%, 81%). Nearest the facility, there are lower percentages of Black or African American individuals, Hispanic individuals, and people of other races than at the 5- and 10-mile radii. The median household income within one mile of the facility is $68,000 per year—lower than the rural state average of $74,000, but the median income is lower at the 3-, 5-, and 10-mile radii. The population within 10 miles of the site below the poverty line and below 50% of the poverty line is higher than the rural state or national average, but there is a lower percentage of very low-income households nearer the facility. The 2019 AirToxScreen data show that the total cancer risk and total respiratory risk are lower for these communities than the national average and similar to the rural state average.

Table 6-6: Community Profiles and AirToxScreen Risks for IsleChem, Inc. – Grand Island, NY

	Rural Areas National Average	***Rural Areas State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*84*	*92*	*91*	*88*	*81*	*81*
% Black or African American (race)	*7.6*	*2.6*	*5.1*	*4.8*	*12*	*9.1*
% Other (race)	*8.2*	*5.1*	*3.6*	*6.7*	*7.2*	*9.7*
% Hispanic (ethnic origin)	*10*	*4.7*	*0.4*	*2.3*	*3.8*	*5.8*
Median Household Income (1k 2019$)	*67*	*74*	*68*	*64*	*56*	*59*
% Below Poverty Line	*6.8*	*5.3*	*4.8*	*6.5*	*9.9*	*7.7*
% Below Half the Poverty Line	*5.1*	*4.3*	*6.1*	*6.2*	*8.2*	*7.4*
Total Cancer Risk (per million)	*23*	*18*	*20*	*20*	*20*	*20*

Total Respiratory Risk (hazard quotient)	*0.27*	*0.18*	*0.20*	*0.20*	*0.20*	*0.20*

For the other eight facilities, comparing these tables with those provided in the Framework Rule RIA using the newer (2019 AirToxScreen) data shows that, in general, total cancer risk and total respiratory risk has dropped for these communities.

Table 6-7: Community Profiles and AirToxScreen Risks for Arkema, Inc. – Calvert, KY

	Rural Areas National Average	***Rural Areas State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*84*	*94*	*99*	*99*	*98*	*96*
% Black or African American (race)	*7.6*	*3.2*	*0*	*0.36*	*0.57*	*1.8*
% Other (race)	*8.2*	*3.2*	*0.85*	*1.0*	*1.1*	*1.8*
% Hispanic (ethnic origin)	*10*	*2.4*	*1.8*	*3.1*	*2.8*	*2.0*
Median Household Income (1k 2019$)	*67*	*51*	*53*	*55*	*56*	*54*
% Below Poverty Line	*6.8*	*10*	*5.7*	*4.7*	*4.2*	*5.6*
% Below Half the Poverty Line	*5.1*	*7.7*	*8.2*	*7.2*	*6.8*	*6.0*
Total Cancer Risk (per million)	*23*	*23*	*30*	*30*	*30*	*28*
Total Respiratory Risk (hazard quotient)	*0.27*	*0.30*	*0.36*	*0.34*	*0.34*	*0.31*

Table 6-8: Community Profiles and AirToxScreen Risks for Chemours Corpus Christi – Gregory, TX

	Overall National Average	***Overall State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*72*	*74*	*95*	*91*	*92*	*91*
% Black or African American (race)	*13*	*12*	*1.6*	*2.3*	*2.2*	*2.1*
% Other (race)	*15*	*14*	*3.6*	*6.3*	*6.2*	*7.1*
% Hispanic (ethnic origin)	*18*	*39*	*40*	*41*	*44*	*40*

Median Household Income (1k 2019$)	*71*	*69*	*78*	*79*	*69*	*61*
% Below Poverty Line	*7.3*	*8.2*	*1.4*	*4.1*	*3.4*	*6.0*
% Below Half the Poverty Line	*5.8*	*6.2*	*1.0*	*2.8*	*3.7*	*4.9*
Total Cancer Risk (per million)	*26*	*28*	*17*	*19*	*19*	*19*
Total Respiratory Risk (hazard quotient)	*0.31*	*0.30*	*0.20*	*0.20*	*0.18*	*0.18*

Table 6-9: Community Profiles and AirToxScreen Risks for Chemours El Dorado – El Dorado, AR

	Rural Areas National Average	***Rural Areas State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*84*	*83*	*94*	*94*	*82*	*62*
% Black or African American (race)	*7.6*	*11*	*1.4*	*1.4*	*15*	*35*
% Other (race)	*8.2*	*5.9*	*4.7*	*4.7*	*2.9*	*3.4*
% Hispanic (ethnic origin)	*10*	*5.3*	*2.4*	*2.4*	*3.4*	*4.5*
Median Household Income (1k 2019$)	*67*	*51*	*66*	*66*	*54*	*45*
% Below Poverty Line	*6.8*	*9.7*	*8.0*	*8.0*	*11*	*13*
% Below Half the Poverty Line	*5.1*	*6.2*	*5.2*	*5.2*	*4.2*	*7.7*
Total Cancer Risk (per million)	*23*	*29*	*50*	*50*	*47*	*51*
Total Respiratory Risk (hazard quotient)	*0.27*	*0.36*	*0.50*	*0.50*	*0.50*	*0.51*

Table 6-10: Community Profiles and AirToxScreen Risks for Chemours Louisville – Louisville, KY

	Overall National Average	***Overall State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*72*	*87*	*59*	*30*	*51*	*70*
% Black or African American (race)	*13*	*8.1*	*37*	*64*	*43*	*24*
% Other (race)	*15*	*5*	*4.0*	*5.3*	*6.1*	*5.7*

% Hispanic (ethnic origin)	*18*	*3.7*	*4.7*	*4.2*	*4.5*	*5.5*
Median Household Income (1k 2019$)	*71*	*55*	*40*	*35*	*37*	*51*
% Below Poverty Line	*7.3*	*9.5*	*13*	*15*	*14*	*9.7*
% Below Half the Poverty Line	*5.8*	*7.3*	*12*	*11*	*12*	*8.0*
Total Cancer Risk (per million)	*26*	*26*	*30*	*30*	*31*	*30*
Total Respiratory Risk (hazard quotient)	*0.31*	*0.32*	*0.36*	*0.37*	*0.38*	*0.36*

Table 6-11: Community Profiles and AirToxScreen Risks for Daikin America, Inc. – Decatur, AL

	Overall National Average	***Overall State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*72*	*68*	*35*	*53*	*64*	*74*
% Black or African American (race)	*13*	*27*	*59*	*39*	*25*	*18*
% Other (race)	*15*	*5.3*	*5.7*	*8.3*	*11*	*8.6*
% Hispanic (ethnic origin)	*18*	*4.3*	*18*	*14*	*14*	*9.4*
Median Household Income (1k 2019$)	*71*	*55*	*36*	*42*	*51*	*58*
% Below Poverty Line	*7.3*	*9.1*	*21*	*17*	*12*	*10*
% Below Half the Poverty Line	*5.8*	*7.2*	*13*	*8.1*	*6.4*	*5.7*
Total Cancer Risk (per million)	*26*	*34*	*67*	*49*	*42*	*37*
Total Respiratory Risk (hazard quotient)	*0.31*	*0.43*	*0.67*	*0.53*	*0.47*	*0.43*

Table 6-12: Community Profiles and AirToxScreen Risks for Honeywell Geismar Complex – Geismar, LA

	Rural Areas National Average	***Rural Areas State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*84*	*70*	*57*	*63*	*62*	*66*
% Black or African American (race)	*7.6*	*25*	*38*	*34*	*36*	*27*

% Other (race)	*8.2*	*4.7*	*5.4*	*2.5*	*3.0*	*7.1*
% Hispanic (ethnic origin)	*10*	*3.6*	*3.8*	*2.7*	*2.9*	*5.1*
Median Household Income (1k 2019$)	*67*	*53*	*79*	*84*	*80*	*79*
% Below Poverty Line	*6.8*	*9.8*	*2.3*	*2.5*	*2.8*	*5.7*
% Below Half the Poverty Line	*5.1*	*7.8*	*7.2*	*5.0*	*5.5*	*4.9*
Total Cancer Risk (per million)	*23*	*33*	*67*	*67*	*65*	*54*
Total Respiratory Risk (hazard quotient)	*0.27*	*0.37*	*0.42*	*0.43*	*0.43*	*0.42*

Table 6-13: Community Profiles and AirToxScreen Risks for Iofina Chemical, Inc. – Covington, KY

	Overall National Average	***Overall State Average***	***Within 1 mile of production facility***	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	*72*	*87*	*96*	*94*	*90*	*81*
% Black or African American (race)	*13*	*8.1*	*0.85*	*2.3*	*4.3*	*13*
% Other (race)	*15*	*5*	*2.9*	*4.0*	*5.2*	*5.8*
% Hispanic (ethnic origin)	*18*	*3.7*	*1.6*	*1.9*	*3.4*	*3.3*
Median Household Income (1k 2019$)	*71*	*55*	*100*	*85*	*71*	*66*
% Below Poverty Line	*7.3*	*9.5*	*3.3*	*3.0*	*5.5*	*7.5*
% Below Half the Poverty Line	*5.8*	*7.3*	*3.3*	*4.1*	*5.5*	*7.6*
Total Cancer Risk (per million)	*26*	*26*	*28*	*29*	*29*	*29*
Total Respiratory Risk (hazard quotient)	*0.31*	*0.32*	*0.33*	*0.36*	*0.37*	*0.35*

Table 6-14: Community Profiles and AirToxScreen Risks for Mexichem,Fluor – St Gabriel, LA

	Rural Areas National Average	Rural Areas State Average	Within 1 mile of production facility	Within 3 miles of production facility	Within 5 miles of production facility	Within 10 miles of production facility
% White (race)	84	70	25	55	58	62

% Black or African American (race)	7.6	25	75	42	40	31
% Other (race)	8.2	4.7	0.24	2.6	2.2	7.4
% Hispanic (ethnic origin)	10	3.6	4.6	2.6	2.5	5.2
Median Household Income (1k 2019$)	67	53	31	65	78	82
% Below Poverty Line	6.8	9.8	4.6	3.3	2.8	6.2
% Below Half the Poverty Line	5.1	7.8	35	4.4	4.6	5.3
Total Cancer Risk (per million)	23	33	60	65	66	54
Total Respiratory Risk (hazard quotient)	0.27	0.37	0.50	0.45	0.44	0.45

6.7 Conclusion

This rule is expected to result in changing emissions of various air pollutants associated with HFC production. However, how producers transition from high-GWP HFCs could drive changes in potential risk for communities living near HFC and HFC substitute production facilities due to the use of feedstock chemicals that could have local effects if released into the environment. The nature and location of the emission changes are uncertain. Moreover, there is insufficient information about which facilities will change production or production processes. However, EPA finds evidence of environmental justice concerns near HFC production facilities from cumulative exposure to existing environmental hazards in these communities, and that further investigation is warranted, potentially as part of a future rulemaking. The proximity analysis of these communities demonstrates that:

- The characteristics of the communities near facilities are heterogeneous;
- Total baseline cancer risk and total respiratory risk from air toxics (not all of which stem from HFC production) varies, but is generally higher, and in some cases much higher within 1-3 miles of an HFC production facility;
- Higher percentages of low income and Black or African American individuals live near HFC production facilities compared to the overall or rural average at the national level;

- It is not clear the extent to which these baseline risks are directly related to HFC production, but some feedstocks and byproducts are toxic; and
- Since multiple HFC substitutes are available, some of which have toxic profiles for the chemicals used as feedstocks in their production, continued analysis of HFC and HFC substitute production facilities and associated environmental justice concerns is appropriate.

Given limited information regarding which substitutes will be produced where, it is unclear to what extent this rule will impact existing disproportionate adverse effects on communities living near HFC and HFC substitute production facilities. EPA continues to seek information to help better characterize these changes and their implications for nearby communities.[28] The Agency will continue to evaluate the impacts of this program on communities with environmental justice concerns and consider further action, as appropriate, to protect health in communities affected by HFC production.

Appendices

Appendix A: HFCs Regulated Under the AIM Act

The AIM Act instructs EPA to phase down the production and import of the following 18 HFCs and their isomers. The act assigns to each of the 18 listed HFCs an exchange value, which is equivalent to the 100-year GWP of that HFC listed in the 2007 IPCC AR4 synthesis report.[29]

[28] 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 Economic Perspectives; Hernandez-Cortes, D. and Meng, K.C., 2020. 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.; U.S. EPA. 2011. Plan EJ 2014. Washington, DC: U.S. EPA, Office of Environmental Justice.; U.S. 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.

[29] 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* [Core Writing Team, Pachauri, R.K and Reisinger, A. (eds.)]. IPCC, Geneva, Switzerland, 104 pp.

Chemical Name	Common Name	Exchange Value
CHF_2CHF_2	HFC-134	1,100
CH_2FCF_3	HFC-134a	1,430
CH_2FCHF_2	HFC-143	353
$CHF_2CH_2CF_3$	HFC-245fa	1,030
$CF_3CH_2CF_2CH_3$	HFC-365mfc	794
CF_3CHFCF_3	HFC-227ea	3,220
$CH_2FCF_2CF_3$	HFC-236cb	1,340
CHF_2CHFCF_3	HFC-236ea	1,370
$CF_3CH_2CF_3$	HFC-236fa	9,810
$CH_2FCF_2CHF_2$	HFC-245ca	693
$CF_3CHFCHFCF_2CF_3$	HFC-43-10mee	1,640
CH_2F_2	HFC-32	675
CHF_2CF_3	HFC-125	3,500
CH_3CF_3	HFC-143a	4,470
CH_3F	HFC-41	92
CH_2FCH_2F	HFC-152	53
CH_3CHF_2	HFC-152a	124
CHF_3	HFC-23	14,800

Appendix B: Mitigation Options Modeled

This appendix lists the mitigation options that are included in each modeling time step in order to meet the reduction levels specified by the phasedown schedule. Additional options were required to meet the 2024 and 2036 reduction levels based on the finalized, lower baseline. These additional options are shown in italics.

2022

- IPR CS - NH_3/CO_2
- non-MDI Aerosols HFC-152a to NIK
- Large Retail Food - DX R-407A/R-407F
- Large Retail Food - CO_2 Transcritical
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCs
- Flooding Agents - Inert Gas
- PU and PIR Rigid: Boardstock - HFC-245fa Blend to HC
- R-12 Small Retail Food (Low Temperature) - HCs
- Flooding Agents - Water Mist
- non-MDI Aerosols - HFC-134a to NIK
- Commercial Unitary A/C - R-32 and MCHE

- Commercial Unitary A/C - MCHE
- CFC-12 Refrigerated Appliances - HFC-134a to R-600a
- non-MDI Aerosols - HFC-134a to HFC-152a
- Medium Retail Food - CO_2
- non-MDI Aerosols - HFC-134a to HC
- Commercial Unitary A/C - R-32
- Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) - HFC-134a to HCs
- Leak Repair for Large Equipment
- Window AC, Dehumidifiers - R-32
- Large Retail Food - R-407A/R-407F SLS
- Medium Retail Food - DX R-407A/R-407F
- Precision Cleaning applications - retrofitted HFC to HFE
- Electronic Cleaning applications - retrofitted HFC to HFE
- Ice Makers - R-290
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-134a to HCs
- non-MDI Aerosols - HFC-152a to HC
- Flooding Agents - FK-5-1-12
- Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) - HFC-245fa to HCFO-1233zd(*E*)
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-245fa/CO_2 to HCFO-1233zd(*E*)
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCFO-1233zd(*E*)
- PU Rigid: Spray Foam (High-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)
- HP - R-32/R-452B
- PU Rigid: Spray Foam (Low-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HFO-1234ze(*E*)

2024

- IPR CS - NH_3/CO_2
- non-MDI Aerosols - HFC-152a to NIK
- Large Retail Food - DX R-407A/R-407F
- Large Retail Food - CO_2 Transcritical
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCs
- Flooding Agents - Inert Gas
- PU and PIR Rigid: Boardstock - HFC-245fa Blend to HC
- R-12 Small Retail Food (Low Temperature) - HCs
- Flooding Agents - Water Mist
- non-MDI Aerosols - HFC-134a to NIK
- Commercial Unitary A/C - R-32 and MCHE
- Commercial Unitary A/C - MCHE
- CFC-12 Refrigerated Appliances - HFC-134a to R-600a
- non-MDI Aerosols - HFC-134a to HFC-152a

- Medium Retail Food - CO_2
- non-MDI Aerosols - HFC-134a to HC
- Commercial Unitary A/C - R-32
- Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) - HFC-134a to HCs
- Leak Repair for Large Equipment
- Window AC, Dehumidifiers - R-32
- Large Retail Food - R-407A/R-407F SLS
- Medium Retail Food - DX R-407A/R-407F
- Precision Cleaning applications - retrofitted HFC to HFE
- Electronic Cleaning applications - retrofitted HFC to HFE
- Ice Makers - R-290
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-134a to HCs
- non-MDI Aerosols - HFC-152a to HC
- Flooding Agents - FK-5-1-12
- Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) - HFC-245fa to HCFO-1233zd(*E*)
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-245fa/CO_2 to HCFO-1233zd(*E*)
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCFO-1233zd(*E*)
- PU Rigid: Spray Foam (High-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)
- HP - R-32/R-452B
- PU Rigid: Spray Foam (Low-Pressure) - HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)
- R-12 Small Retail Food (Low Temperature) - R-448A/R-449A
- Residential Unitary A/C - R-454B and MCHE
- non-MDI Aerosols - HFC-134a to HFO-1234ze(*E*)
- Screw Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- Reciprocating Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- PU Rigid: One Component Foam - HFC-134a to HFO-1234ze(*E*)
- Polystyrene: Extruded Boardstock and Billet - HFC-134a/CO_2 to HFO-1234ze*(E)*/HCFO-1233zd*(E)*
- Recovery at Disposal for All Equipment
- Scroll Chillers - R-410A/R-407C replaced w/ R-452B
- Vending Machines - R-450A/R-513A
- Transport - R-452A
- R-12 Small Retail Food (Low Temperature) - R-450A/R-513A
- R-12 Small Retail Food (Medium Temperature) - R-448A/R-449A
- Recovery at Service for Small Equipment
- CFC-114 Chillers - HFC-134a replaced w/ R-450A/R-513A
- CFC-11 Centrifugal Chillers - HFC-134a replaced w/ R-450A/R-513A
- CFC-12 Centrifugal Chillers - HFC-134a replaced w/ R-450A/R-513A
- *R-500 Chillers - HFC-134a replaced with R-450A/R-513A*

2029

- IPR CS - NH_3/CO_2
- non-MDI Aerosols - HFC-152a to NIK
- Large Retail Food - DX R-407A/R-407F
- Large Retail Food - CO_2 Transcritical
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCs
- Flooding Agents - Inert Gas
- PU and PIR Rigid: Boardstock - HFC-245fa Blend to HC
- R-12 Small Retail Food (Low Temperature) - HCs
- Flooding Agents - Water Mist
- non-MDI Aerosols - HFC-134a to NIK
- Commercial Unitary A/C - R-32 and MCHE
- Commercial Unitary A/C - MCHE
- CFC-12 Refrigerated Appliances - HFC-134a to R-600a
- non-MDI Aerosols HFC-134a to HFC-152a
- Medium Retail Food - CO_2
- non-MDI Aerosols HFC-134a to HC
- Commercial Unitary A/C - R-32
- Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) - HFC-134a to HCs
- Leak Repair for Large Equipment
- Window AC, Dehumidifiers - R-32
- Large Retail Food - R-407A/R-407F SLS
- Medium Retail Food - DX R-407A/R-407F
- Precision Cleaning applications - retrofitted HFC to HFE
- Electronic Cleaning applications - retrofitted HFC to HFE
- Ice Makers - R-290
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-134a to HCs
- non-MDI Aerosols - HFC-152a to HC
- Flooding Agents - FK-5-1-12
- Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) - HFC-245fa to HCFO-1233zd(*E*)
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-245fa/CO_2 to HCFO-1233zd(*E*)
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCFO-1233zd(*E*)
- PU Rigid: Spray Foam (High-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)
- HP - R-32/R-452B
- PU Rigid: Spray Foam (Low-Pressure) - HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)
- R-12 Small Retail Food (Low Temperature) - R-448A/R-449A
- Residential Unitary A/C - R-454B and MCHE
- non-MDI Aerosols - HFC-134a to HFO-1234ze(*E*)
- Screw Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- Reciprocating Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- PU Rigid: One Component Foam - HFC-134a to HFO-1234ze(*E*)
- Polystyrene: Extruded Boardstock and Billet - HFC-134a/CO_2 to HFO-1234ze*(E)*/HCFO-1233zd*(E)*

- Recovery at Disposal for All Equipment

2034

- IPR CS - NH_3/CO_2
- non-MDI Aerosols - HFC-152a to NIK
- Large Retail Food - DX R-407A/R-407F
- Large Retail Food - CO_2 Transcritical
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCs
- Flooding Agents - Inert Gas
- PU and PIR Rigid: Boardstock - HFC-245fa Blend to HC
- R-12 Small Retail Food (Low Temperature) - HCs
- Flooding Agents - Water Mist
- non-MDI Aerosols - HFC-134a to NIK
- Commercial Unitary A/C - R-32 and MCHE
- Commercial Unitary A/C - MCHE
- CFC-12 Refrigerated Appliances - HFC-134a to R-600a
- non-MDI Aerosols - HFC-134a to HFC-152a
- Medium Retail Food - CO_2
- non-MDI Aerosols - HFC-134a to HC
- Commercial Unitary A/C - R-32
- Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) - HFC-134a to HCs
- Leak Repair for Large Equipment
- Window AC, Dehumidifiers - R-32
- Large Retail Food - R-407A/R-407F SLS
- Medium Retail Food - DX R-407A/R-407F
- Precision Cleaning applications - retrofitted HFC to HFE
- Electronic Cleaning applications - retrofitted HFC to HFE
- Ice Makers - R-290
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-134a to HCs
- non-MDI Aerosols - HFC-152a to HC
- Flooding Agents - FK-5-1-12
- Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) - HFC-245fa to HCFO-1233zd(*E*)
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-245fa/CO_2 to HCFO-1233zd(*E*)
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCFO-1233zd(*E*)
- PU Rigid: Spray Foam (High-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)
- HP - R-32/R-452B
- PU Rigid: Spray Foam (Low-Pressure) - HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)
- R-12 Small Retail Food (Low Temperature) - R-448A/R-449A
- Residential Unitary A/C - R-454B and MCHE
- non-MDI Aerosols - HFC-134a to HFO-1234ze(*E*)

- Screw Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- Reciprocating Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- PU Rigid: One Component Foam - HFC-134a to HFO-1234ze(*E*)
- Polystyrene: Extruded Boardstock and Billet - HFC-134a/CO_2 to HFO-1234ze*(E)*/HCFO-1233zd*(E)*
- Recovery at Disposal for All Equipment
- Scroll Chillers - R-410A/R-407C replaced w/ R-452B
- Vending Machines - R-450A/R-513A
- Transport - R-452A

2036

- IPR CS - NH_3/CO_2
- non-MDI Aerosols - HFC-152a to NIK
- Large Retail Food - DX R-407A/R-407F
- Large Retail Food - CO_2 Transcritical
- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCs
- Flooding Agents - Inert Gas
- PU and PIR Rigid: Boardstock - HFC-245fa Blend to HC
- R-12 Small Retail Food (Low Temperature) - HCs
- Flooding Agents - Water Mist
- non-MDI Aerosols - HFC-134a to NIK
- Commercial Unitary A/C - R-32 and MCHE
- Commercial Unitary A/C - MCHE
- CFC-12 Refrigerated Appliances - HFC-134a to R-600a
- non-MDI Aerosols - HFC-134a to HFC-152a
- Medium Retail Food - CO_2
- non-MDI Aerosols - HFC-134a to HC
- Commercial Unitary A/C - R-32
- Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) - HFC-134a to HCs
- Leak Repair for Large Equipment
- Window AC, Dehumidifiers - R-32
- Large Retail Food - R-407A/R-407F SLS
- Medium Retail Food - DX R-407A/R-407F
- Precision Cleaning applications - retrofitted HFC to HFE
- Electronic Cleaning applications - retrofitted HFC to HFE
- Ice Makers - R-290
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-134a to HCs
- non-MDI Aerosols - HFC-152a to HC
- Flooding Agents - FK-5-1-12
- Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) - HFC-245fa to HCFO-1233zd(*E*)
- Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous and Discontinuous) - HFC-245fa/CO_2 to HCFO-1233zd(*E*)

- Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) - HFC-245fa to HCFO-1233zd(*E*)
- PU Rigid: Spray Foam (High-Pressure) - HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)
- HP - R-32/R-452B
- PU Rigid: Spray Foam (Low-Pressure) - HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)
- R-12 Small Retail Food (Low Temperature) - R-448A/R-449A
- Residential Unitary A/C - R-454B and MCHE
- non-MDI Aerosols - HFC-134a to HFO-1234ze(*E*)
- Screw Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- Reciprocating Chillers - R-410A/R-407C replaced w/ HFO-1234ze(*E*)
- PU Rigid: One Component Foam - HFC-134a to HFO-1234ze(*E*)
- Polystyrene: Extruded Boardstock and Billet - HFC-134a/CO_2 to HFO-1234ze*(E)*/HCFO-1233zd*(E)*
- Recovery at Disposal for All Equipment
- Scroll Chillers - R-410A/R-407C replaced w/ R-452B
- Vending Machines - R-450A/R-513A
- Transport - R-452A
- R-12 Small Retail Food (Low Temperature) - R-450A/R-513A
- R-12 Small Retail Food (Medium Temperature) - R-448A/R-449A
- Recovery at Service for Small Equipment
- CFC-114 Chillers - HFC-134a replaced w/ R-450A/R-513A
- CFC-11 Centrifugal Chillers - HFC-134a replaced w/ R-450A/R-513A
- CFC-12 Centrifugal Chillers - HFC-134a replaced w/ R-450A/R-513A
- R-500 Chillers - HFC-134a replaced w/ R-450A/R-513A
- Electronic Cleaning applications - retrofitted Not-in-kind Aqueous
- Electronic Cleaning applications - retrofitted Not-in-kind Semi-aqueous
- CFC-12 Centrifugal Chillers - HFC-245fa replaced w/ HCFO-1233zd(*E*)
- R-500 Chillers - HFC-245fa replaced w/ HCFO-1233zd(*E*)
- CFC-11 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)

Appendix C: Summary of Mitigation Technologies Modeled by End Use

Table C-1: Market Penetration by year

Sector	End Use	Abatement Option	Option Lifetime (years)	2020	2025	2030	2035	2040	2045	2050
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HC	10	0%	20%	20%	20%	20%	20%	20%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFC-152a	10	0%	10%	10%	10%	10%	10%	10%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFO-1234ze	10	8%	14%	20%	20%	20%	20%	20%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to NIK	10	20%	20%	20%	20%	20%	20%	20%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HC	10	10%	20%	20%	20%	20%	20%	20%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HFO-1234ze	10	8%	14%	20%	20%	20%	20%	20%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to NIK	10	40%	40%	40%	40%	40%	40%	40%
Fire	Flooding Agents	Flooding Agents – FK-5-1-12	20	18%	35%	35%	35%	35%	35%	35%
Fire	Flooding Agents	Flooding Agents - Inert Gas	20	0%	10%	19%	29%	29%	29%	29%
Fire	Flooding Agents	Flooding Agents - Water Mist	20	0%	1%	3%	4%	4%	4%	4%
Foam	Commercial Refrigeration Foam	Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) – HFC-245fa to HCFO-1233zd(*E*)	25	33%	100%	100%	100%	100%	100%	100%
Foam	Flexible PU Foam: Integral Skin Foam	Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) – HFC-134a to HCs	25	33%	100%	100%	100%	100%	100%	100%
Foam	PU and PIR Rigid: Boardstock	PU and PIR Rigid: Boardstock – HFC-245fa Blend to HC	25	33%	100%	100%	100%	100%	100%	100%
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCFO-1233zd(*E*)	25	50%	50%	50%	50%	50%	50%	50%
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCs	25	50%	50%	50%	50%	50%	50%	50%
Foam	PU Rigid: One Component Foam	PU Rigid: One Component Foam – HFC-134a to HFO-1234ze(*E*)	25	5%	30%	30%	30%	30%	30%	30%
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuous	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-134a to HCs	25	33%	100%	100%	100%	100%	100%	100%
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuous	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-245fa/CO_2 to HCFO-1233zd(*E*)	25	33%	100%	100%	100%	100%	100%	100%
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (High-Pressure) – HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)	25	12%	70%	70%	70%	70%	70%	70%
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (Low-Pressure) – HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)	25	5%	30%	30%	30%	30%	30%	30%

Foam	XPS: Boardstock Foam	Polystyrene: Extruded Boardstock and Billet (XPS: Boardstock Foam) - 134a/CO_2 to HCFO/HFO blend	25	0%	51%	85%	85%	85%	85%	85%
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	25	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233(*E*)	25	20%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	CFC-114 Chillers – HFC-134a replaced w/ R-450A/R-513A	20	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	27	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	27	20%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-134 replaced w/ R-450A/R-513A	27	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	27	20%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - MCHE	15	50%	83%	39%	16%	0%	0%	0%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32	15	0%	0%	50%	50%	50%	50%	50%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32 and MCHE	15	0%	0%	50%	50%	50%	50%	50%
Refrigeration & A/C	Disposal	Recovery at Disposal for ALL Equipment	7	100%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Heat Pumps	HP - R-32/R-452B	15	0%	0%	50%	50%	50%	50%	50%
Refrigeration & A/C	Ice Makers	Ice Makers - R-290	8	0%	19%	50%	50%	50%	50%	50%
Refrigeration & A/C	Industrial Process/Cold Storage (CS)	IPR CS - NH_3/CO_2	25	17%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Large Retail Food	Large Retail Food – R-407A/R-407F SLS	18	33%	33%	33%	33%	33%	33%	33%
Refrigeration & A/C	Large Retail Food	Large Retail Food - CO_2 Transcritical	18	33%	33%	33%	33%	33%	33%	33%
Refrigeration & A/C	Large Retail Food	Large Retail Food - DX R-407A/R-407F	18	34%	34%	34%	34%	34%	34%	34%
Refrigeration & A/C	Leak Repair	Leak Repair for Large Equipment	5	17%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - CO_2	20	33%	33%	33%	33%	33%	33%	33%
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - DX R-407A/R-407F	20	67%	67%	67%	67%	67%	67%	67%
Refrigeration & A/C	PD Chillers	Reciprocating Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	20	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	PD Chillers	Screw Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	20	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	PD Chillers	Scroll Chillers – R-410A/R-407C replaced w/ R-452B	20	0%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Refrigerated Appliances	CFC-12 Refrigerated Appliances – HFC-134a to R-600a	14	50%	100%	100%	100%	100%	100%	100%
Refrigeration & A/C	Residential Unitary	Residential Unitary A/C - R-454B and MCHE	15	0%	75%	100%	100%	100%	100%	100%
Refrigeration & A/C	Service	Recovery at Service for Small Equipment	7	40%	40%	40%	40%	40%	40%	40%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) – HCs	10	10%	10%	10%	10%	10%	10%	10%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-448A/R-449A	10	0%	70%	70%	70%	70%	70%	70%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-450A/R-513A	10	0%	20%	20%	20%	20%	20%	20%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Medium Temperature) - R-448A/R-449A	10	0%	30%	30%	30%	30%	30%	30%
Refrigeration & A/C	Transport	Transport - R-452A	12	0%	0%	50%	50%	50%	50%	50%
Refrigeration & A/C	Vending Machines	Vending Machines – R-450A/R-513A	10	29%	100%	100%	100%	100%	100%	100%

Refrigeration & A/C	Vending Machines	Vending Machines - R-290	11	3%	10%	10%	10%	10%	10%	10%
Refrigeration & A/C	Window AC, Dehumidifiers	Window AC, Dehumidifiers - R-32	12	5%	27%	50%	50%	50%	50%	50%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted HFC to HFE	15	40%	53%	67%	80%	80%	80%	80%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Aqueous	15	2%	5%	7%	10%	10%	10%	10%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Semi-aqueous	15	2%	5%	7%	10%	10%	10%	10%
Solvents	Precision Cleaning	Precision Cleaning applications - retrofitted HFC to HFE	15	60%	73%	87%	100%	100%	100%	100%

Table C-2: Percent reduction Off baseline

Sector	End Use	Abatement Option	Reduction Efficiency	Percent Reduction off Baseline (i.e., Technical Effectiveness) (%), Relative to Consumption from Model Facility Type						
				2020	**2025**	**2030**	**2035**	**2040**	**2045**	**2050**
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HC	100%	0%	13%	13%	13%	13%	13%	13%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFC-152a	91%	0%	6%	6%	6%	6%	6%	6%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFO-1234ze	100%	5%	9%	13%	13%	13%	13%	13%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to NIK	100%	13%	13%	13%	13%	13%	13%	13%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HC	95%	4%	7%	7%	7%	7%	7%	7%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HFO-1234ze	95%	3%	5%	7%	7%	7%	7%	7%
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to NIK	100%	15%	15%	15%	15%	15%	15%	15%
Fire	Flooding Agents	Flooding Agents – FK-5-1-12	100%	33%	40%	43%	44%	25%	25%	25%
Fire	Flooding Agents	Flooding Agents - Inert Gas	100%	0%	13%	27%	44%	50%	47%	39%
Fire	Flooding Agents	Flooding Agents - Water Mist	100%	0%	2%	4%	6%	7%	6%	5%
Foam	Commercial Refrigeration Foam	Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) – HFC-245fa to HCFO-1233zd(*E*)	99%	33%	99%	99%	99%	99%	99%	99%
Foam	Flexible PU Foam: Integral Skin Foam	Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) – HFC-134a to HCs	100%	33%	100%	100%	100%	100 %	100%	100%
Foam	PU and PIR Rigid: Boardstock	PU and PIR Rigid: Boardstock – HFC-245fa Blend to HC	99%	33%	100%	100%	100%	100 %	100%	100%
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCFO-1233zd(*E*)	99%	16%	0%	0%	0%	0%	0%	0%
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCs	99%	17%	0%	0%	0%	0%	0%	0%
Foam	PU Rigid: One Component Foam	PU Rigid: One Component Foam – HFC-134a to HFO-1234ze(*E*)	100%	31%	94%	94%	94%	94%	94%	94%

Sector	End Use	Abatement Option	Reduction Efficiency	Percent Reduction off Baseline (i.e., Technical Effectiveness) (%), Relative to Consumption from Model Facility Type						
				2020	2025	2030	2035	2040	2045	2050
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuou s	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-134a to HCs	100%	20%	59%	59%	59%	59%	59%	59%
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuou s	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-245fa/CO_2 to HCFO-1233zd(*E*)	99%	14%	41%	41%	41%	41%	41%	41%
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (High-Pressure) – HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)	99%	12%	69%	69%	69%	69%	69%	69%
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (Low-Pressure) – HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)	99%	5%	30%	30%	30%	30%	30%	30%
Foam	XPS: Boardstock Foam	Polystyrene: Extruded Boardstock and Billet (XPS: Boardstock Foam) – HFC-134a/CO_2 to HCFO/HFO blend	100%	0%	51%	84%	84%	84%	84%	84%
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	57%	0%	48%	55%	64%	67%	93%	45%
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	99%	6%	31%	34%	38%	38%	45%	20%
Refrigeration & A/C	Chillers	CFC-114 Chillers – HFC-134a replaced w/ R-450A/R-513A	57%	0%	0%	100%	100%	100 %	57%	57%
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	57%	0%	54%	61%	70%	77%	85%	74%
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	99%	3%	19%	20%	23%	24%	26%	15%
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-134a replaced w/ R-450A/R-513A	57%	0%	54%	61%	71%	77%	85%	74%
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	99%	3%	19%	20%	23%	24%	26%	15%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - MCHE	38%	13%	22%	11%	1%	0%	0%	0%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32	68%	0%	0%	28%	37%	45%	34%	34%
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32 and MCHE	68%	0%	0%	26%	36%	46%	40%	40%
Refrigeration & A/C	Disposal	Recovery at Disposal for ALL Equipment	85%	4%	9%	10%	11%	5%	4%	4%
Refrigeration & A/C	Heat Pumps	HP - R-32/R-452B	67%	0%	0%	53%	65%	63%	59%	51%
Refrigeration & A/C	Ice Makers	Ice Makers - R-290	100%	0%	25%	72%	61%	50%	50%	50%
Refrigeration & A/C	Industrial Process/Cold Storage	IPR CS - NH_3/CO_2	100%	9%	60%	71%	94%	100 %	100%	100%
Refrigeration & A/C	Large Retail Food	Large Retail Food – R-407A/R-407F SLS	50%	1%	2%	3%	3%	3%	3%	3%
Refrigeration & A/C	Large Retail Food	Large Retail Food - CO_2 Transcritical	100%	1%	2%	4%	4%	4%	4%	4%
Refrigeration & A/C	Large Retail Food	Large Retail Food - DX R-407A/R-407F	50%	1%	1%	2%	2%	2%	2%	2%
Refrigeration & A/C	Leak Repair	Leak Repair for Large Equipment	40%	1%	5%	4%	4%	4%	4%	4%
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - CO_2	100%	19%	24%	33%	38%	32%	32%	32%

Sector	End Use	Abatement Option	Reduction Efficiency	Percent Reduction off Baseline (i.e., Technical Effectiveness) (%), Relative to Consumption from Model Facility Type						
				2020	2025	2030	2035	2040	2045	2050
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - DX R-407A/R-407F	50%	20%	25%	34%	38%	33%	33%	33%
Refrigeration & A/C	PD Chillers	Reciprocating Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	100%	0%	87%	100%	100%	100 %	100%	100%
Refrigeration & A/C	PD Chillers	Screw Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	100%	0%	92%	100%	100%	100 %	100%	100%
Refrigeration & A/C	PD Chillers	Scroll Chillers – R-410A/R-407C replaced w/ R-452B	64%	0%	62%	100%	100%	100 %	63%	63%
Refrigeration & A/C	Refrigerated Appliances	CFC-12 Refrigerated Appliances – HFC-134a to R-600a	100%	100%	100%	100%	100%	100 %	100%	100%
Refrigeration & A/C	Residential Unitary	Residential Unitary A/C - R-454B and MCHE	78%	0%	39%	73%	96%	92%	86%	86%
Refrigeration & A/C	Service	Recovery at Service for Small Equipment	95%	7%	6%	4%	2%	1%	1%	1%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) – HCs	100%	18%	16%	7%	7%	7%	7%	7%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-448A/R-449A	65%	0%	37%	28%	21%	22%	22%	21%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-450A/R-513A	57%	0%	20%	15%	8%	8%	8%	8%
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Medium Temperature) - R-448A/R-449A	57%	0%	1%	1%	1%	1%	1%	1%
Refrigeration & A/C	Transport	Transport - R-452A	20%	0%	0%	9%	16%	20%	19%	19%
Refrigeration & A/C	Vending Machines	Vending Machines – R-450A/R-513A	63%	29%	87%	80%	70%	70%	70%	70%
Refrigeration & A/C	Vending Machines	Vending Machines - R-290	100%	10%	29%	27%	23%	23%	23%	23%
Refrigeration & A/C	Window AC, Dehumidifiers	Window AC, Dehumidifiers - R-32	68%	3%	26%	51%	47%	38%	34%	34%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted HFC to HFE	85%	34%	46%	57%	68%	68%	68%	68%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Aqueous	100%	2%	5%	7%	10%	10%	10%	10%
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Semi-aqueous	100%	2%	5%	7%	10%	10%	10%	10%
Solvents	Precision Cleaning	Precision Cleaning applications - retrofitted HFC to HFE	85%	31%	38%	44%	51%	51%	51%	51%

Table C-3: Summary of Costs and Revenue of Abatement options

Sector	End Use	Abatement Option	Capital Cost (2015 USD)	Annual Revenue (2015 USD)	Annual O&M Costs (2015 USD)	Abatement Amount ($mtCO_2e$)	Break-even Cost (2015 USD / $mtCO_2e$)
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HC	$325,000	$2,551,500	$0	807,124.5	($3.10)
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFC-152a	$500,000	$2,551,500	$0	740,502.0	($3.34)
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to HFO-1234ze(*E*)	$500,000	$0	$4,252,500	807,408.0	$5.37
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-134a to NIK	$250,000	$4,536,000	$500,000	810,810.0	($4.93)
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HC	$325,000	$0	$0	66,622.5	$0.79
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to HFO-1234ze(*E*)	$500,000	$0	$6,804,000	66,906.0	$102.90
Aerosols	Non-MDI Aerosols	non-MDI Aerosols HFC-152a to NIK	$250,000	$1,984,500	$500,000	70,308.0	($20.54)
Fire	Flooding Agents	Flooding Agents – FK-5-1-12	$9.49	$0.00	$4.72	2.0	$2.86
Fire	Flooding Agents	Flooding Agents - Inert Gas	$11.21	$15.18	$0.20	2.0	($6.72)
Fire	Flooding Agents	Flooding Agents - Water Mist	$13.24	$15.18	$0.40	2.0	($6.50)
Foam	Commercial Refrigeration Foam	Rigid PU: Commercial Refrigeration (Commercial Refrigeration Foam) – HFC-245fa to HCFO-1233zd(*E*)	$0	$0	$280,000	71,610.0	$3.91
Foam	Flexible PU Foam: Integral Skin Foam	Integral Skin Polyurethane (Flexible PU Foam: Integral Skin Foam) – HFC-134a to HCs	$405,000	$135,000	$0	42,705.0	($2.13)
Foam	PU and PIR Rigid: Boardstock	PU and PIR Rigid: Boardstock – HFC-245fa Blend to HC	$695,500	$520,000	$0	66,527.5	($6.68)
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCFO-1233zd(*E*)	$0	$0	$2,147,162	549,136.6	$3.91
Foam	PU Rigid: Domestic Refrigerator and Freezer Insulation	Rigid PU: Appliance (PU Rigid: Domestic Refrigerator and Freezer Insulation) – HFC-245fa to HCs	$5,610,000	$4,351,836	$0	549,405.0	($6.81)
Foam	PU Rigid: One Component Foam	PU Rigid: One Component Foam – HFC-134a to HFO-1234ze(*E*)	$399,000	$0	$1,320,480	185,780.7	$7.34
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuous	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-134a to HCs	$201,500	$2,038,500	$2,490,000	644,845.5	$0.73
Foam	PU Rigid: Sandwich Panels: Continuous & Discontinuous	Rigid PU: Sandwich Panels (PU Rigid: Sandwich Panels: Continuous & Discontinuous) – HFC-245fa/CO_2 to HCFO-1233zd(*E*)	$0	$0	$1,812,000	463,419.0	$3.91
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (High-Pressure) – HFC-245fa and HFC-245fa/CO_2 blend to HCFO-1233zd(*E*)	$250,000	$0	$230,124	58,854.2	$4.37
Foam	PU Rigid: Spray Foam	PU Rigid: Spray Foam (Low-Pressure) – HFC-245fa and HFC-245fa/CO_2 to HFO-1234ze(*E*)	$550,000	$0	$230,124	58,911.7	$4.92
Foam	XPS: Boardstock Foam	Polystyrene: Extruded Boardstock and Billet (XPS: Boardstock Foam) – HFC-134a/CO_2 to HCFO/HFO blend	$5,856,000	$4,770,000	$915,000	1,007,942.4	($3.19)

Sector	End Use	Abatement Option	Capital Cost (2015 USD)	Annual Revenue (2015 USD)	Annual O&M Costs (2015 USD)	Abatement Amount ($mtCO_2e$)	Break-even Cost (2015 USD / $mtCO_2e$)
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	$12,695	$0	$762	74.2	$28.84
Refrigeration & A/C	Chillers	CFC-11 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	$53,800	$0	$168	71.8	$83.62
Refrigeration & A/C	Chillers	CFC-114 Chillers – HFC-134a replaced w/ R-450A/R-513A	$16,793	$0	$1,008	111.3	$26.53
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-134a replaced w/ R-450A/R-513A	$13,057	$0	$783	73.2	$29.70
Refrigeration & A/C	Chillers	CFC-12 Centrifugal Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	$53,880	$0	$173	71.7	$82.51
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-134a replaced w/ R-450A/R-513A	$13,057	$0	$783	73.2	$29.70
Refrigeration & A/C	Chillers	R-500 Chillers – HFC-245fa replaced w/ HCFO-1233zd(*E*)	$53,880	$0	$173	71.7	$82.51
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - MCHE	($27)	$2	$0	1.7	($3.53)
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32	($30)	$3	$0	2.1	($3.08)
Refrigeration & A/C	Commercial Unitary	Commercial Unitary A/C - R-32 and MCHE	($46)	$4	$0	2.1	($4.72)
Refrigeration & A/C	Disposal	Recovery at Disposal for ALL Equipment	$2,026	$445	$1,084	79.6	$13.23
Refrigeration & A/C	Heat Pumps	HP - R-32/R-452B	$4	$0	$1	0.3	$4.64
Refrigeration & A/C	Ice Makers	Ice Makers - R-290	$107,125	$9,587	$0	14,213.1	$0.73
Refrigeration & A/C	Industrial Process/Cold Storage	IPR CS - NH_3/CO_2	$193,000	$50,180	$0	711.6	($41.09)
Refrigeration & A/C	Large Retail Food	Large Retail Food – R-407A/R-407F SLS	$36,932	$4,574	$0	429.4	($0.30)
Refrigeration & A/C	Large Retail Food	Large Retail Food - CO_2 Transcritical	$19,610	$13,445	$0	1,096.4	($10.11)
Refrigeration & A/C	Large Retail Food	Large Retail Food - DX R-407A/R-407F	$0	$10,365	$0	695.4	($14.91)
Refrigeration & A/C	Leak Repair	Leak Repair for Large Equipment	$1,870	$1,224	$0	533.4	($1.37)
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - CO_2	($108)	$13	$0	8.1	($3.16)
Refrigeration & A/C	Medium Retail Food	Medium Retail Food - DX R-407A/R-407F	$0	$0	$0	5.2	$0.00
Refrigeration & A/C	PD Chillers	Reciprocating Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	$2,048	$0	$123	66.8	$5.39
Refrigeration & A/C	PD Chillers	Screw Chillers – R-410A/R-407C replaced w/ HFO-1234ze(*E*)	$1,950	$0	$117	63.6	$5.39
Refrigeration & A/C	PD Chillers	Scroll Chillers – R-410A/R-407C replaced w/ R-452B	$3,334	$0	$200	40.9	$14.33
Refrigeration & A/C	Refrigerated Appliances	CFC-12 Refrigerated Appliances – HFC-134a to R-600a	($201,075)	$3,156	$0	8,798.0	($3.43)
Refrigeration & A/C	Residential Unitary	Residential Unitary A/C - R-454B and MCHE	$28	$0	$2	1.2	$5.18
Refrigeration & A/C	Service	Recovery at Service for Small Equipment	$4,050	$351	$870	62.8	$21.43
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) – HCs	($4)	$0	$0	0.1	($6.54)
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-448A/R-449A	$6	$0	$1	0.3	$5.04

Sector	End Use	Abatement Option	Capital Cost (2015 USD)	Annual Revenue (2015 USD)	Annual O&M Costs (2015 USD)	Abatement Amount ($mtCO_2e$)	Break-even Cost (2015 USD / $mtCO_2e$)
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Low Temperature) - R-450A/R-513A	$9	$0	$1	0.1	$21.04
Refrigeration & A/C	Small Retail Food	R-12 Small Retail Food (Medium Temperature) - R-448A/R-449A	$9	$0	$1	0.1	$21.04
Refrigeration & A/C	Transport	Transport - R-452A	$86	$0	$28	2.0	$20.44
Refrigeration & A/C	Vending Machines	Vending Machines – R-450A/R-513A	$5	$0	$0	0.1	$17.31
Refrigeration & A/C	Vending Machines	Vending Machines - R-290	$305,950	$191	$0	554.0	$88.76
Refrigeration & A/C	Window AC, Dehumidifiers	Window AC, Dehumidifiers - R-32	($0)	$0	$0	0.1	($0.83)
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted HFC to HFE	$0	$0	$0	159.0	$0.00
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Aqueous	$50,000	$1,000	$700	186.0	$33.33
Solvents	Electronics Cleaning	Electronic Cleaning applications - retrofitted Not-in-kind Semi-aqueous	$55,000	$0	$5,900	186.0	$70.16
Solvents	Precision Cleaning	Precision Cleaning applications - retrofitted HFC to HFE	$0	$0	$0	159.0	$0.00

Appendix D: Annual SC-HFC Estimates

Note that the tables in this appendix are replicated from Appendix E in the Framework Rule RIA.

Table D-1: SC-HFC-32 (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	49786.59	38382.85	101492.44	18352.27
2021	51413.109	39762.257	105300.205	19177.965
2022	53039.625	41141.666	109107.972	20003.655
2023	54666.141	42521.076	112915.739	20829.346
2024	56292.657	43900.486	116723.505	21655.036
2025	57919.173	45279.895	120531.272	22480.727
2026	59668.379	46770.953	124530.702	23384.736
2027	61417.586	48262.010	128530.133	24288.746
2028	63166.793	49753.068	132529.563	25192.755
2029	64916.000	51244.125	136528.993	26096.764
2030	66665.207	52735.183	140528.424	27000.774
2031	68704.221	54500.880	145708.294	28120.592
2032	70743.235	56266.578	150888.165	29240.411
2033	72782.249	58032.275	156068.035	30360.229
2034	74821.262	59797.972	161247.906	31480.048
2035	76860.276	61563.670	166427.777	32599.866
2036	79039.580	63453.666	171852.464	33805.174
2037	81218.884	65343.662	177277.151	35010.483
2038	83398.188	67233.659	182701.838	36215.792
2039	85577.491	69123.655	188126.525	37421.100
2040	87756.795	71013.652	193551.212	38626.409
2041	90054.034	73050.354	199639.692	40012.789
2042	92351.273	75087.056	205728.172	41399.170
2043	94648.512	77123.758	211816.651	42785.551
2044	96945.751	79160.460	217905.131	44171.931
2045	99242.990	81197.162	223993.611	45558.312
2046	101685.333	83363.003	229987.399	47034.247
2047	104127.677	85528.844	235981.188	48510.182
2048	106570.020	87694.685	241974.976	49986.118
2049	109012.364	89860.526	247968.764	51462.053
2050	111454.707	92026.367	253962.552	52937.988

Table D-2: SC-HFC-125 (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	287355.72	210911.81	551978.95	82898.26
2021	294887.556	217085.503	569594.501	86120.505
2022	302419.397	223259.193	587210.048	89342.751
2023	309951.238	229432.882	604825.595	92564.996
2024	317483.079	235606.572	622441.142	95787.241
2025	325014.920	241780.261	640056.689	99009.487
2026	333092.365	248424.768	657741.554	102515.118
2027	341169.809	255069.275	675426.418	106020.750
2028	349247.254	261713.782	693111.283	109526.382
2029	357324.698	268358.289	710796.148	113032.013
2030	365402.142	275002.796	728481.012	116537.645
2031	373919.994	282163.781	748470.546	120583.985
2032	382437.846	289324.765	768460.080	124630.326
2033	390955.698	296485.750	788449.614	128676.666
2034	399473.550	303646.735	808439.148	132723.006
2035	407991.402	310807.719	828428.682	136769.347
2036	417251.781	318564.552	849636.684	141137.117
2037	426512.159	326321.385	870844.685	145504.888
2038	435772.537	334078.219	892052.687	149872.658
2039	445032.916	341835.052	913260.688	154240.429
2040	454293.294	349591.885	934468.690	158608.199
2041	463371.229	357367.866	955473.401	163321.348
2042	472449.163	365143.847	976478.111	168034.498
2043	481527.097	372919.828	997482.822	172747.647
2044	490605.032	380695.809	1018487.533	177460.797
2045	499682.966	388471.790	1039492.244	182173.946
2046	509191.467	396671.327	1060081.206	187192.272
2047	518699.968	404870.864	1080670.168	192210.597
2048	528208.468	413070.400	1101259.130	197228.922
2049	537716.969	421269.937	1121848.092	202247.248
2050	547225.470	429469.474	1142437.054	207265.573

Table D-3: SC-HFC-134a (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	115195.66	87119.97	228428.24	38251.06
2021	118631.241	89985.780	236470.182	39855.749
2022	122066.820	92851.589	244512.121	41460.442
2023	125502.399	95717.398	252554.059	43065.136
2024	128937.977	98583.206	260595.998	44669.829
2025	132373.556	101449.015	268637.937	46274.522
2026	136095.427	104560.437	277134.079	48030.441
2027	139817.297	107671.858	285630.222	49786.361
2028	143539.168	110783.280	294126.365	51542.280
2029	147261.038	113894.701	302622.507	53298.200
2030	150982.909	117006.122	311118.650	55054.119
2031	155005.633	120437.385	320909.232	57112.544
2032	159028.356	123868.648	330699.814	59170.968
2033	163051.080	127299.910	340490.396	61229.393
2034	167073.804	130731.173	350280.978	63287.817
2035	171096.528	134162.436	360071.560	65346.242
2036	175389.925	137836.695	370127.217	67566.620
2037	179683.323	141510.954	380182.874	69786.999
2038	183976.720	145185.214	390238.532	72007.377
2039	188270.117	148859.473	400294.189	74227.755
2040	192563.514	152533.732	410349.846	76448.134
2041	196659.573	156123.295	419827.206	78783.486
2042	200755.632	159712.859	429304.565	81118.839
2043	204851.691	163302.422	438781.925	83454.191
2044	208947.750	166891.985	448259.285	85789.543
2045	213043.809	170481.549	457736.644	88124.896
2046	217389.754	174299.885	467468.878	90619.705
2047	221735.699	178118.221	477201.111	93114.514
2048	226081.644	181936.558	486933.344	95609.324
2049	230427.590	185754.894	496665.577	98104.133
2050	234773.535	189573.230	506397.811	100598.942

Table D-4: SC-HFC-143a (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	376193.35	267248.70	699659.97	94760.56
2021	385135.835	274417.932	720658.392	98266.435
2022	394078.320	281587.166	741656.813	101772.315
2023	403020.806	288756.399	762655.234	105278.195
2024	411963.291	295925.632	783653.655	108784.074
2025	420905.777	303094.866	804652.076	112289.954
2026	430387.114	310744.202	824860.325	116084.243
2027	439868.451	318393.538	845068.575	119878.532
2028	449349.789	326042.873	865276.824	123672.821
2029	458831.126	333692.209	885485.074	127467.109
2030	468312.464	341341.545	905693.323	131261.398
2031	478233.222	349525.185	927712.023	135636.429
2032	488153.980	357708.824	949730.723	140011.459
2033	498074.738	365892.464	971749.423	144386.489
2034	507995.497	374076.103	993768.122	148761.520
2035	517916.255	382259.743	1015786.822	153136.550
2036	528472.557	390986.280	1038786.095	157824.770
2037	539028.859	399712.818	1061785.367	162512.990
2038	549585.161	408439.355	1084784.640	167201.210
2039	560141.463	417165.892	1107783.912	171889.431
2040	570697.765	425892.430	1130783.185	176577.651
2041	581211.345	434775.654	1155302.921	181741.799
2042	591724.925	443658.878	1179822.656	186905.946
2043	602238.506	452542.102	1204342.392	192070.094
2044	612752.086	461425.325	1228862.128	197234.242
2045	623265.667	470308.549	1253381.863	202398.390
2046	634393.420	479730.705	1279066.864	207892.147
2047	645521.173	489152.860	1304751.864	213385.904
2048	656648.926	498575.015	1330436.864	218879.662
2049	667776.679	507997.171	1356121.864	224373.419
2050	678904.432	517419.326	1381806.865	229867.176

Table D-5: SC-HFC-152a (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	6928.87	5359.89	14161.65	2624.61
2021	7156.181	5553.929	14701.064	2743.788
2022	7383.489	5747.968	15240.479	2862.965
2023	7610.797	5942.007	15779.895	2982.142
2024	7838.105	6136.046	16319.310	3101.319
2025	8065.412	6330.085	16858.726	3220.497
2026	8311.446	6540.784	17413.200	3351.178
2027	8557.479	6751.482	17967.675	3481.860
2028	8803.513	6962.181	18522.149	3612.542
2029	9049.546	7172.879	19076.624	3743.223
2030	9295.580	7383.578	19631.099	3873.905
2031	9585.902	7636.208	20372.275	4037.234
2032	9876.225	7888.838	21113.452	4200.563
2033	10166.548	8141.468	21854.629	4363.891
2034	10456.871	8394.098	22595.806	4527.220
2035	10747.194	8646.728	23336.983	4690.548
2036	11057.865	8917.251	24105.852	4866.255
2037	11368.537	9187.774	24874.721	5041.962
2038	11679.209	9458.297	25643.590	5217.668
2039	11989.880	9728.820	26412.458	5393.375
2040	12300.552	9999.343	27181.327	5569.081
2041	12670.904	10326.176	28217.415	5790.383
2042	13041.256	10653.009	29253.503	6011.685
2043	13411.608	10979.842	30289.591	6232.987
2044	13781.960	11306.676	31325.678	6454.288
2045	14152.312	11633.509	32361.766	6675.590
2046	14542.565	11978.535	33387.545	6909.980
2047	14932.817	12323.562	34413.324	7144.371
2048	15323.070	12668.589	35439.104	7378.761
2049	15713.322	13013.615	36464.883	7613.151
2050	16103.575	13358.642	37490.662	7847.542

Table D-6: SC-HFC-227ea (2020$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	265356.49	193089.64	506009.35	73736.77
2021	272110.248	198595.466	521308.516	76559.579
2022	278864.004	204101.296	536607.681	79382.390
2023	285617.761	209607.126	551906.846	82205.201
2024	292371.518	215112.956	567206.011	85028.012
2025	299125.275	220618.786	582505.176	87850.823
2026	306344.044	226530.215	598382.520	90917.832
2027	313562.813	232441.643	614259.863	93984.842
2028	320781.582	238353.072	630137.207	97051.852
2029	328000.351	244264.500	646014.550	100118.861
2030	335219.120	250175.928	661891.893	103185.871
2031	342806.814	256528.702	679511.654	106723.214
2032	350394.508	262881.476	697131.415	110260.557
2033	357982.202	269234.249	714751.177	113797.900
2034	365569.896	275587.023	732370.938	117335.243
2035	373157.590	281939.796	749990.699	120872.586
2036	381305.447	288757.900	768267.650	124675.878
2037	389453.303	295576.004	786544.602	128479.170
2038	397601.160	302394.107	804821.553	132282.462
2039	405749.017	309212.211	823098.505	136085.755
2040	413896.874	316030.314	841375.456	139889.047
2041	421916.693	322894.341	858948.745	144016.673
2042	429936.512	329758.368	876522.034	148144.299
2043	437956.331	336622.395	894095.323	152271.926
2044	445976.150	343486.421	911668.612	156399.552
2045	453995.969	350350.448	929241.901	160527.178
2046	462537.979	357669.454	948617.279	164934.047
2047	471079.989	364988.461	967992.657	169340.916
2048	479621.999	372307.467	987368.035	173747.785
2049	488164.010	379626.473	1006743.413	178154.654
2050	496706.020	386945.480	1026118.791	182561.522

Table D-7: SC-HFC-236fa (2020$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	971911.32	635691.68	1671593.41	182719.62
2021	990966.334	650225.941	1712939.154	189003.615
2022	1010021.351	664760.197	1754284.899	195287.611
2023	1029076.368	679294.453	1795630.645	201571.608
2024	1048131.384	693828.709	1836976.391	207855.604
2025	1067186.401	708362.965	1878322.137	214139.600
2026	1087374.004	723836.127	1920231.244	220906.135
2027	1107561.607	739309.289	1962140.352	227672.670
2028	1127749.210	754782.450	2004049.460	234439.205
2029	1147936.813	770255.612	2045958.567	241205.740
2030	1168124.416	785728.774	2087867.675	247972.275
2031	1189329.895	802305.367	2136403.703	255826.244
2032	1210535.374	818881.960	2184939.731	263680.213
2033	1231740.853	835458.553	2233475.759	271534.182
2034	1252946.332	852035.146	2282011.786	279388.152
2035	1274151.811	868611.739	2330547.814	287242.121
2036	1296438.782	886109.188	2381068.457	295594.550
2037	1318725.754	903606.638	2431589.100	303946.979
2038	1341012.726	921104.088	2482109.743	312299.409
2039	1363299.698	938601.538	2532630.386	320651.838
2040	1385586.670	956098.988	2583151.028	329004.267
2041	1408441.699	974359.583	2635485.726	338463.005
2042	1431296.727	992620.177	2687820.423	347921.743
2043	1454151.756	1010880.772	2740155.121	357380.481
2044	1477006.785	1029141.366	2792489.818	366839.219
2045	1499861.814	1047401.961	2844824.516	376297.957
2046	1523747.327	1066577.257	2898382.352	386286.778
2047	1547632.840	1085752.553	2951940.189	396275.599
2048	1571518.353	1104927.849	3005498.026	406264.421
2049	1595403.866	1124103.145	3059055.863	416253.242
2050	1619289.379	1143278.441	3112613.700	426242.064

Table D-8: SC-HFC-245fa (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	79920.92	61300.90	161390.69	28587.55
2021	82459.557	63446.648	167363.131	29847.970
2022	84998.191	65592.394	173335.569	31108.389
2023	87536.826	67738.140	179308.007	32368.807
2024	90075.460	69883.886	185280.445	33629.226
2025	92614.095	72029.632	191252.883	34889.645
2026	95356.029	74354.956	197500.284	36269.117
2027	98097.963	76680.280	203747.684	37648.589
2028	100839.897	79005.603	209995.085	39028.061
2029	103581.831	81330.927	216242.485	40407.533
2030	106323.765	83656.250	222489.886	41787.005
2031	109426.575	86333.922	230330.054	43460.060
2032	112529.385	89011.593	238170.222	45133.114
2033	115632.195	91689.265	246010.390	46806.169
2034	118735.005	94366.936	253850.558	48479.224
2035	121837.815	97044.608	261690.726	50152.278
2036	125196.978	99939.251	269867.222	51961.200
2037	128556.141	102833.894	278043.717	53770.121
2038	131915.305	105728.538	286220.213	55579.043
2039	135274.468	108623.181	294396.709	57387.965
2040	138633.631	111517.824	302573.204	59196.886
2041	141916.845	114417.253	310725.593	61151.160
2042	145200.059	117316.683	318877.982	63105.433
2043	148483.273	120216.112	327030.370	65059.707
2044	151766.487	123115.542	335182.759	67013.980
2045	155049.701	126014.971	343335.148	68968.254
2046	158589.120	129137.145	351770.865	71067.545
2047	162128.539	132259.319	360206.582	73166.836
2048	165667.957	135381.493	368642.300	75266.127
2049	169207.376	138503.667	377078.017	77365.418
2050	172746.795	141625.840	385513.735	79464.709

Table D-9: SC-HFC-43-10mee (2020$)

	Discount rate and statistic			
Year	2.5%	3%	3% 95th Percentile	5%
2020	132976.19	100136.12	262542.58	43232.49
2021	136842.827	103357.628	271504.098	45019.695
2022	140709.459	106579.132	280465.619	46806.902
2023	144576.092	109800.636	289427.140	48594.110
2024	148442.724	113022.139	298388.661	50381.318
2025	152309.357	116243.643	307350.182	52168.526
2026	156513.011	119747.938	317037.761	54124.231
2027	160716.666	123252.233	326725.339	56079.936
2028	164920.320	126756.528	336412.918	58035.642
2029	169123.975	130260.823	346100.496	59991.347
2030	173327.629	133765.118	355788.075	61947.052
2031	177841.943	137606.700	366655.119	64229.658
2032	182356.257	141448.282	377522.163	66512.263
2033	186870.571	145289.863	388389.206	68794.869
2034	191384.885	149131.445	399256.250	71077.474
2035	195899.199	152973.026	410123.294	73360.080
2036	200701.567	157076.690	421305.310	75819.959
2037	205503.935	161180.355	432487.326	78279.838
2038	210306.303	165284.019	443669.342	80739.717
2039	215108.671	169387.683	454851.358	83199.596
2040	219911.039	173491.347	466033.374	85659.475
2041	224514.092	177516.883	476545.962	88252.826
2042	229117.145	181542.419	487058.550	90846.177
2043	233720.198	185567.956	497571.138	93439.528
2044	238323.251	189593.492	508083.726	96032.878
2045	242926.304	193619.028	518596.314	98626.229
2046	247831.642	197913.424	529594.395	101398.496
2047	252736.980	202207.819	540592.477	104170.763
2048	257642.319	206502.215	551590.559	106943.030
2049	262547.657	210796.610	562588.641	109715.298
2050	267452.996	215091.006	573586.723	112487.565

Table D-10: SC-HFC-23 (2020$)

	Discount rate and statistic			
Year	**2.5%**	**3%**	**3% 95th Percentile**	**5%**
2020	1483435.899	965975.482	2566380.066	274829.362
2021	1512334.175	987952.030	2628461.987	284263.718
2022	1541232.452	1009928.578	2690543.907	293698.075
2023	1570130.728	1031905.126	2752625.827	303132.431
2024	1599029.004	1053881.674	2814707.747	312566.788
2025	1627927.280	1075858.222	2876789.667	322001.145
2026	1658460.740	1099209.337	2940999.970	332155.387
2027	1688994.199	1122560.453	3005210.272	342309.629
2028	1719527.659	1145911.568	3069420.575	352463.871
2029	1750061.118	1169262.683	3133630.877	362618.114
2030	1780594.578	1192613.798	3197841.180	372772.356
2031	1812698.086	1217652.379	3271609.673	384571.571
2032	1844801.595	1242690.960	3345378.166	396370.786
2033	1876905.104	1267729.541	3419146.660	408170.001
2034	1909008.612	1292768.122	3492915.153	419969.216
2035	1941112.121	1317806.703	3566683.647	431768.431
2036	1974899.788	1344277.188	3642377.730	444342.072
2037	2008687.454	1370747.673	3718071.814	456915.713
2038	2042475.121	1397218.159	3793765.897	469489.354
2039	2076262.788	1423688.644	3869459.981	482062.995
2040	2110050.455	1450159.130	3945154.065	494636.636
2041	2144715.499	1477788.348	4026205.523	508872.690
2042	2179380.542	1505417.566	4107256.982	523108.744
2043	2214045.586	1533046.785	4188308.441	537344.798
2044	2248710.630	1560676.003	4269359.899	551580.852
2045	2283375.674	1588305.221	4350411.358	565816.905
2046	2319595.263	1617298.516	4433292.967	580829.914
2047	2355814.853	1646291.811	4516174.575	595842.922
2048	2392034.442	1675285.106	4599056.184	610855.931
2049	2428254.032	1704278.401	4681937.793	625868.939
2050	2464473.621	1733271.696	4764819.401	640881.948

Appendix E: Supplemental Approach for the Environmental Justice Analysis

Background

As described in Chapter 6 "Environmental Justice Analysis" of this analysis, EPA seeks to better quantify the impacts of this rule on vulnerable and burdened communities. In seeking to reduce disproportionate negative environmental consequences on overburdened communities, and in our efforts to "conduct the highest quality analysis feasible,"[30] EPA is considering the use of additional analytical tools to understand burdens facing communities.

Section 6.4 "Aggregate Average Characteristics of Communities Near Potentially Affected Production Facilities" provides an analysis of the environmental justice aspects of this rule by discussing the characteristics of Census block groups near the nine identified facilities, as described by the American Community Survey (ACS).

In this supplemental analysis EPA is providing a demonstration of analysis using a statistical technique called "microsimulation" to assess these communities in more detail. EPA continues to evaluate use of microsimulation analyses generally for future application to environmental justice analyses.

Microsimulation techniques have been used for various analyses for decades. By combining data from different surveys with geospatial information, microsimulation provides analytical utility beyond that possible with the respective individual datasets, surveys, and maps. Increases in computing power and the advances in software development have made microsimulation approaches faster and more flexible.[31] Data science has advanced to allow for the identification of populations with multiple characteristics – for the case of environmental justice analysis, for example, it is possible to identify communities facing multiple burdens and multiple vulnerabilities.

The technique employed for this demonstration analysis was used originally by the National Institutes of Health for the National Infectious Disease Study.[32] The method involves using

[30] EPA. Technical Guidance for Assessing Environmental Justice in Regulatory Analysis. 2016. Available at: https://www.epa.gov/environmentaljustice/technical-guidance-assessing-environmental-justice-regulatory-analysis
[31] Lovelace, R., Dumont, M., 2016. Spatial microsimulation with R. CRC Press.
[32] Wheaton WD, Cajka JC, Chasteen BM, Wagener D, Cooley PC, Ganapathi L, et al. *Synthesized population databases: a US geospatial database for agent-based models.* Research Triangle Park, NC: RTI Press; 2009.

statistics to combine two databases[33] to create a population of anonymous "synthetic households." Using the 2010 decennial census, the 2007 – 2011 ACS, and a very fine-scale model of the geographic density of U.S. population,[34] analysts can generate a "synthetic population" of approximately 116 million households. The synthetic households are assigned demographic characteristics according to the population characteristics of their respective Census block group. This microsimulation has additional analytical capability because each of the simulated households are mapped to a 90x90 meter grid of actual physical locations of residences in 2010. In other words, maps using this dataset can show dots on a map representing every known residence in 2010 with an accuracy of 45 meters. (Maps presented in Figures 1-9 show distributions show household locations near the facilities of interest – the points are accurate for residences in 2010 within the dimensions of the printed dots). The techniques employed are reproducible using current data, which while beyond the scope of current efforts, would offer much more detailed proximity analysis of communities near specific facilities.

The dataset used for this supplementary analysis is publicly available.[35] Because it is not up to date, EPA does not represent information in this appendix to be descriptive of current demographic features of communities near the facilities potentially affected by this rule, but rather as a potential tool to identify locations that may merit additional consideration due to population patterns in the recent past. As discussed in the following paragraphs, EPA is investigating the utility of microsimulation for potential use in future environmental justice analyses of atmospheric pollution by combining various geospatial information with the demographic specificity and large sample size of the ACS.

In addition to the synthetic dataset mentioned above, EPA is exploring novel methods to combine the spatial and socio-demographic information of the ACS with estimates of household characteristics from smaller surveys. Whereas the previous method provides a precise location estimate, the novel method provides greater detail on household characteristics. Example surveys include the Consumer Expenditure Survey, the EIA Residential Energy Consumption Survey, the

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[33] Wheaton, W.D. (May, 2014) 2010 U.S. Synthetic Population Ver. 1. *RTI* International.

[34] ICLUSE Tools and Datasets (V1.3 and 1.3.1) U.S. EPA. ICLUS Tools and Datasets (Version 1.3 & 1.3.1). U.S. Environmental Protection Agency, Washington, DC, EPA/600/R-09/143F, 2010. Current and previous version available at https://www.epa.gov/gcx/about-iclus

[35] The dataset is available on request from https://www.rti.org/synthpop-synthetic-population-data-analysis. The SynthPop viewer is accessible at https://synthpopviewer.rti.org/

American Housing Survey, and the National Household Transportation Survey. While these surveys provide useful analytical insight that can inform environmental justice analysis, they are smaller surveys compiled of responses from fewer individuals and they are not as spatially disaggregated as the ACS. Using microsimulation approaches to combine the ACS with other surveys can allow analysis of synthetic populations at finer geographic scale that statistically represent the detail of the smaller, specialized surveys.

Many different surveys and datasets can be incorporated within microsimulation. Existing microsimulation models featuring different datasets provide insight into healthcare availability and inform tax policy.[36] Potential uses of microsimulation by EPA includes identification of communities facing burdens ranging from proximity to manufacturing facilities, environmental hazards such as air quality, and other vulnerabilities including poverty, natural hazard risk, food insecurity, energy insecurity, and inadequate access to medical care. By combining data from surveys, it is likely to be possible in the future, for example, to characterize the demographics of communities not just by their residents, but also considering locations where individuals are likely to work and go to school. It may be that residents of a community, for example, do not live close to specific hazardous facilities, but many work in areas with such facilities. Additionally, by combining data from surveys on employment and jobs, future microsimulation analysis may be able to identify communities at risk of adverse economic impacts both of environmental hazards and, potentially, the unintended impacts of different kinds of policies.

In the past, the approach to analyzing environmental justice for many atmospheric emissions rules has typically been conducted at higher levels of geographic aggregation. With advances in data availability, data science, and computational power, more local detail may be available for actions with regional or national environmental implications. While the utility of microsimulations may be limited by the statistical representation represented by the sample size of the datasets used, the ability to combine different surveys to address novel questions may help identify communities facing multiple, cumulative burdens. This capability may be extremely important in analyses of proximity exposure to certain risks, such as toxics or HAP in which the atmospheric concentration of a pollutant is important. Of course, these methodologies can apply

[36] Including: *Cronin*, Julie-Anne. *1999*. U.S. Treasury *Distributional Analysis Methodology*. OTA Paper 85. Washington, DC: U.S. Department of the Treasury.

to other wide-scale risks with locally vulnerable populations (e.g., clean water, wildfire, and flooding[37]).

The method used in this supplementary analysis has been used by EPA before, in the context of analysis by the Office of Water. In 2011, EPA was able to identify households potentially affected by leaking underground storage tanks.[38] The method identified, with a high degree of statistical likelihood, the number of households using well water potentially affected within the probably plume of contaminants from known underground storage tanks. In addition to estimating the number of affected households, the technique estimated the number of households with certain characteristics relevant to environmental justice, including the number of affected vulnerable households, and the number of households with young children. It is important to note, however, that while the microsimulation methods described in this analysis provide more refined measures of the number of households nearby a facility, evaluating the characteristics of these households relies on a strong assumption that key demographics are uniformly distributed across the number of households in a census block group and, therefore, uniformly distributed within the resulting simulated population. Evaluating exposure and risk using the simulated population across dimensions such as race, ethnicity, and income would, by necessity, assume that these groups are no more or less likely to live in households on the fence line side of a block group than they are to live on the opposite side of that same block group.

Comparing Microsimulation and the ACS/AirToxScreen Analyses

The Framework Rule RIA and Chapter 6 of this addendum to the Framework Rule RIA use the ACS to estimate the percentage of communities that identify as members of specific races/ethnicities and to provide information on income. However, these analyses are based on the "average" characteristics of Census block groups within a specific distance from identified facilities. The analyses include Total Cancer Risk data and Total Respiratory Risk data as reported in the AirToxScreen data as well, and these are also based on the "average" risk characteristics across these Census block groups.

[37] Brouwers, L. 2005. "Microsimulation Models for Disaster Policy Making." Stockholm University.
[38] "Risk Analysis to Support Potential Revisions to Underground Storage Tank (UST) Regulations" prepared by RTI International, December 22, 2010.

Because the demographic characteristics and the risk quantifications are averaged across the geographic area of the Census blocks groups, the ACS and AirToxScreen data cannot identify the distribution of household locations within the boundaries of the block groups. The Census Bureau data divides communities into separate geographic areas called blocks, and the ACS reports data for "block groups" each with populations of a few thousand individuals.[39] While urban Census block groups may be relatively small geographically, more rural blocks may represent many square miles. Consider, for example, a case in which a specific facility is located near one boundary of its Census block, but the actual residences of households within the block are clustered in a town that is miles from the facility. In a case like this, the ACS/AirToxScreen analysis may overstate the actual risks to nearby residents. Conversely, a community may be "at the fence line" of a facility, and these specific households may face higher risks than the averages that are estimated across the Census block group.

As stated above, EPA used the publicly available version of the dataset for this analysis, The dataset allows for detailed maps to be created, showing the (2010) location of households within as mapped to a 90x90 meter grid, and it can assign each household with statistically likely racial, income, age, and education characteristics based on the probabilities of these characteristics as reported for their respective Census block in the ACS.

This analysis shows that there are circumstances in which the use of this specific microsimulation tool can show differences in the number of households estimated to be close to a specific facility. In cases for which the individual households are distributed very differently from the average population density for their respective Census block groups (for example, a town in a relatively rural block group), the tool can show that the ACS/AirToxScreen average calculations are likely to either overstate or understate proximity of populations to the facility. These cases appear to involve geographically large Census block groups. The differences appear most dramatic in the one-mile radius analyses – differences between the Census block group averages and the household location analyses are reduced as the distance from the facility increases.

[39] See https://www2.census.gov/geo/pdfs/reference/GARM/Ch11GARM

Comparison of Demographic Analysis for Each Identified Facility

Following the approach taken in Chapter 6, this analysis assesses the communities within 1-, 3-, 5-, and 10-mile distances of each of the nine affected facilities. For each community, the technique identifies modeled "actual" locations of households. Household locations are modeled using the ICLUS database based on the location of actual residences identified by the 2010 Census, anonymized, and assigned to a grid of 90x90 meter squares, based on actual residences in the 2010 Census. We report the number of households identified in this manner within 1-, 3-, 5-, and 10-miles distances of each facility, and offer tables comparing the results of the microsimulation analysis with the estimates calculated using the ACS data.

This supplemental analysis then, will have different results in cases where a concentration of households – in a town for example – may be within the proximity buffers. For each facility, we present a map showing the communities surrounding the site. The maps show concentric circles centered on the facility location representing the 1-, 3-, 5-, and 10-mile distances used for analysis. The modeled household locations using the 2010 synthetic population are presented as dark grey dots. The dots do not represent current household locations: they merely show locations of residences in 2010 as determined by Census, ACS and population density modeling. While some residential structures may have changed use since 2010, many locations that were household residences in 2010 are likely to be locations of current households. These recent residential patterns may help identify communities where more detailed assessments may be helpful to address environmental justice issues in these communities.

In the data table accompanying each map, each column represents the analysis for the communities within the specified distance of the facility. The number in **bold** is our calculation using the current ACS as presented in Chapter 6. The simulated population numbers based on the modeled households for 2010 are presented for comparison in *(italics).* While potentially helpful for presenting patterns of recent residential locations as a way of identifying communities of concern, the specific numbers are out of date. The percentages of population by race or by relative income, for example, can change rapidly in some communities. In many cases, estimates of the percentage of people living below the federal poverty line, and separately, the percentage living below 50 percent of the poverty line, are different from the assessments of the current ACS.

One example of how the analysis of modeled 2010 household locations differs from that using the current ACS is the community near the Chemours Corpus Christi Facility, located near Gregory, Texas. To understand differences between the microsimulation tool based on modeled 2010 household locations and the ACS analysis for this facility, we present two maps. In Figure 1(a), the modeled 2010 simulated household locations are represented. The facility is at the center of the "bull's eye" of the 1-, 3-, 5-, and 10-mile distance. The dots are the modeled locations of households in 2010 within the 90x90 meter squares of the population density model. Within the one-mile circle, there are a very small number of dots representing residences in 2010. The microsimulation result shows that there were just 3 households within the one-mile radius circle.

Figure 1(b) is a map of the same location showing the boundaries of the relevant ACS Census block groups. (This map is from ArcGIS Hub.[40]) The colored polygons in the map are individual Census block groups mapped from the ACS. The facility is located in the large, medium shaded, block group bounded on the south by Corpus Christi Bay, extending west off the map, with northern boundary the diagonal line running from Taft southeast to Gregory and then to the northeastern corner near Ingleside. (This is block group as 484090107002, showing a 2019 population of 3,220, and a population density of 38.4 per square mile. In 2010, the population was 2666, with a population density of 31.8). Comparing the maps, one notes that the dots representing the locations of residences in 2010 were clustered to the west side of this region, in Portland, and to the east, near Ingleside. The facility is near the center of the rectangle. In 2010 the area was a large industrial area with essentially no residences. Analysis at the level of the block group, as done in Chapter 6 and in many other demographic studies using survey data, geometrically calculates the area at a given distance from the given coordinates (in this case, of the Chemours facility) and assumes that the population of the block group is distributed evenly. In this case, the one-mile circle represents a fraction of the area of the block group, and with a population density of 38.4 per square mile, that calculation yields an estimate of 120 people living within one mile of the site. Since the AirToxScreen database associates risk disaggregated to the Census tract level, the risk is assumed to be constant across the area of the polygon. Note

[40] ArcGIS Hub data referenced for GEOID 484090107002 https://hub.arcgis.com/datasets/TEA-Texas::census-block-group-map/explore?location=27.906983%2C-97.233085%2C11.43

in Table 1, the discrepancy between the **bold** numbers estimated using the previous ACS methodology, and the *(italicized)* numbers from the 2010 microsimulation.

In this case, household location model suggests that the ACS Census block group average approach overestimates the number of individuals living within the one-mile distance. EPA is not modeling the transport nor does the Agency have sufficient information on emissions to measure the health impacts at specific distances, but the modeling shows that, as of 2010, fewer households were likely within a one-mile radius of the facility than are estimated using the averaging method.

Chemours Corpus Christi – Gregory, TX

Figure 1(a) Chemours Corpus Christi: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

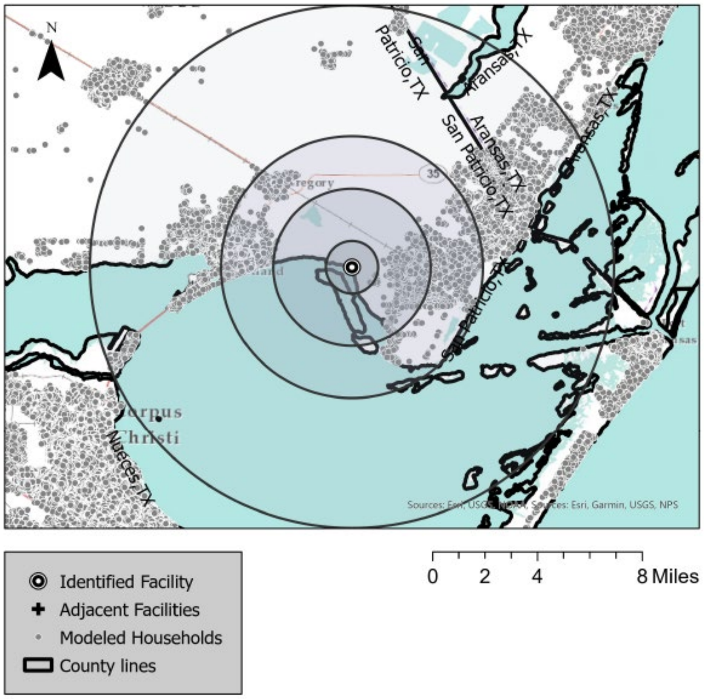

Figure 1(b). San Patricio and Aransas Counties, TX, showing Gregory, Portland, and Ingleside

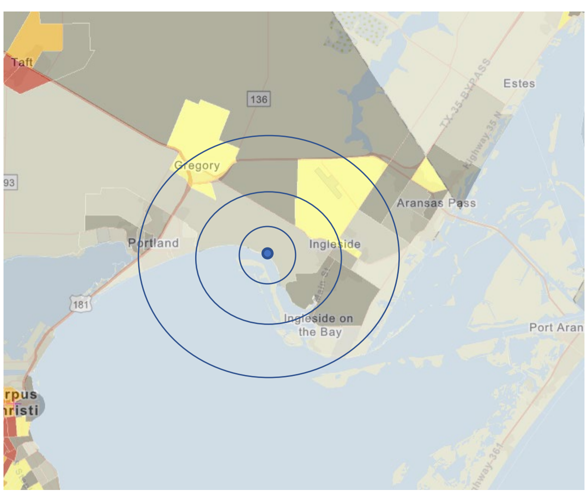

Table 1. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: Chemours Corpus Christi

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**95** *(100)*	**91** *(91.9)*	**92** *(91.0)*	**91** *(91.0)*
% Black or African American (race)	**1.6** *(0)*	**2.3** *(2.5)*	**2.2** *(1.9)*	**2.1** **(***2.2)*
% Other (race)	**3.6** *(0)*	**6.3** *(5.6)*	**6.2** *(7.1)*	**7.1** *(6.8)*
% Below Poverty Line	**1.4** *(0)*	**4.1** *(7.3)*	**3.4** *(7.4)*	**6.0** *(9.4)*
% Below Half the Poverty Line	**1** *(0)*	**2.8** *(3.3)*	**3.7** *(4.1)*	**4.9** *(4.1)*

IsleChem Facility – Grand Isle, NY

The IsleChem facility is on the Grand Isle in the Niagara River, a few miles upstream from Niagara Falls. The Canadian border falls within the one-mile radius from the facility. The ACS and the simulated datasets do not assess households outside of the United States. The 2010 synthetic population modeled households in close proximity to the facility and distributed in nearby Niagara and Erie Counties.

Figure 2. IsleChem, Grand : Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

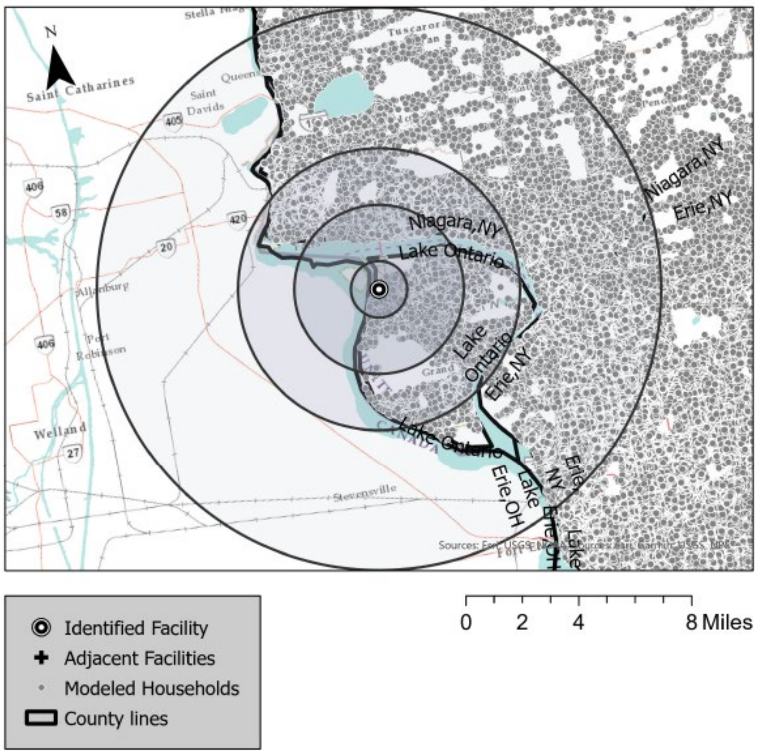

Table 2. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: IsleChem

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**91.0** *(94.3)*	**88.0** *(93.1)*	**81.0** *(85.3)*	**81.0** *(89.4)*
% Black or African American (race)	**5.1** *(1.9)*	**4.8** *(3.3)*	**12** *(11.2)*	**9.1** *(6.5)*
% Other (race)	**3.6** *(3.8)*	**6.7** *(3.5)*	**7.2** *(3.5)*	**9.7** *(4.1)*
% Below Poverty Line	**4.8** *(3.6)*	**6.5** *(5.5)*	**9.9** *(9.6)*	**7.7** *(8.9)*
% Below Half the Poverty Line	**6.1** *(1.4)*	**6.2** *(1.7)*	**8.2** *(4.0)*	**7.4** *(5.0)*

Arkema Inc.; Calvert – KY

The Arkema Inc. facility is on the Tennessee River in Kentucky, approximately five miles from the Ohio River and Illinois. There were no households modeled in the 2010 population density data within a one-mile radius of the facility, and no synthetic households represented on the map in Figure 3. The ACS analysis of the area, as indicated of the first column of Table 3, shows the figures in **bold** for the "average" of the block groups, compared to the microsimulation result for the 2010 synthetic households shown as *(n/a)* because the calculation is not applicable.

Figure 3. Arkema Inc.: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

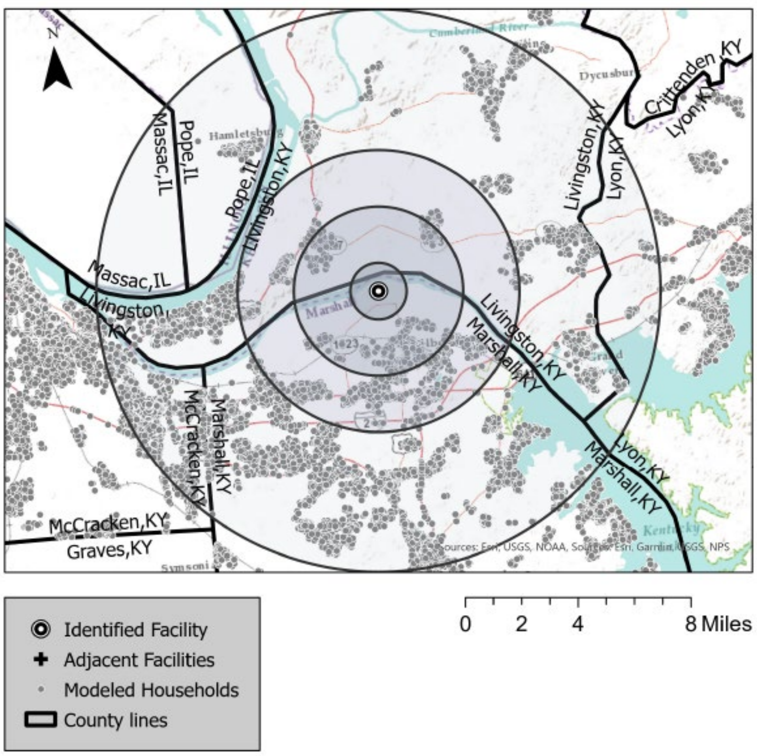

Table 3. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: Arkema

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**99** *(n/a)*	**99** *(99.3)*	**98** *(99.2)*	**96** *(99.2)*
% Black or African American (race)	**0** *(n/a)*	**0.36** *(0)*	**0.57** *(0)*	**1.8** *(0)*
% Other (race)	**0.85** *(n/a)*	**1** *(.7)*	**1.1** *(.8)*	**1.8** *(.7)*
% Below Poverty Line	**5.7** *(n/a)*	**4.7** **(***13.8)*	**4.2** *(11.4)*	**5.6** *(7.7)*

% Below Half the Poverty Line	**8.2** *(n/a)*	**7.2** *(7.2)*	**6.8** *(5.4)*	**6** *(2.9)*

Chemours El Dorado – El Dorado AR

The Chemours El Dorado facility is about 7 miles from the Louisiana state line. Figure 4 shows that households are distributed unevenly in this semi-rural area with the largest concentrations to the North and East. Table 4 shows that the demographics are generally similar between the two approaches.

Figure 4. Chemours El Dorado: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

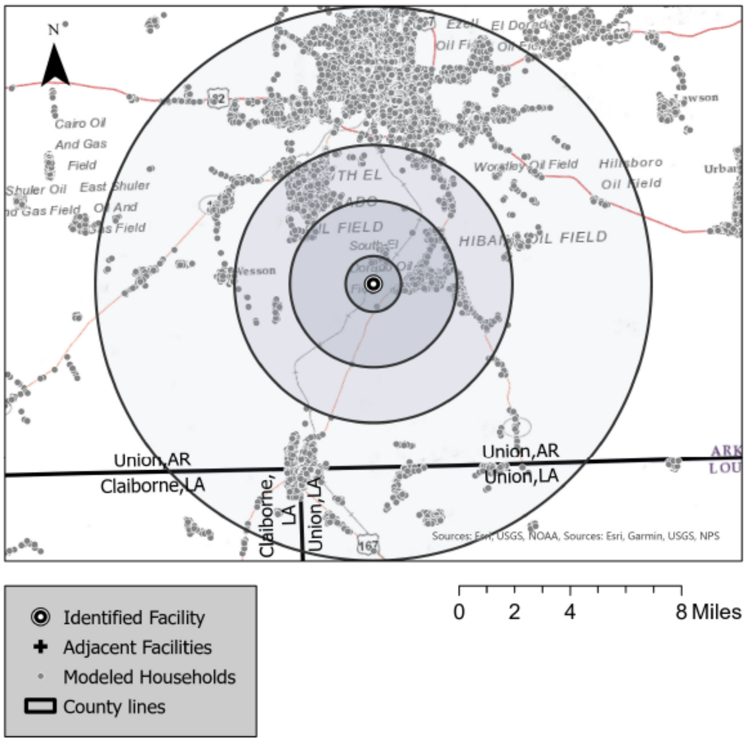

Table 4. Comparison **ACS Census Block** and (*2010 Synthetic Households*): Chemours El Dorado

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**94** *(92.7)*	**94** *(96.8)*	**82** *(93.9)*	**62** *(62.1)*
% Black or African American (race)	**1.4** *(4.9)*	**1.4** *(2.9)*	**15** *(4.5)*	**35** *(36.4)*
% Other (race)	**4.7** *(2.4)*	**4.7** *(0.3)*	**2.9** *(1.6)*	**3.4** *(1.5)*
% Below Poverty Line	**8.0** *(9.8)*	**8.0** *(6.4)*	**11** *(5.6)*	**13** *(15.0)*
% Below Half the Poverty Line	**5.2** *(0)*	**5.2** *(1.9)*	**4.2** *(2.3)*	**7.7** *(8.0)*

Chemours Louisville Plant – Louisville, KY

The Chemours Louisville plant is situated on the Ohio river. The City of Louisville lies north and east, and the Indiana Counties of Clark, Floyd and Harrison lie north and west. Figure 5 shows the area to be densely populated, and Table 5 shows some differences between the modeled household data at the 1 mile radius distance and the ACS census block averages. Specifically, the percentage of white residents is 9 percentage points higher (68 vs 59) and the percentages of black or African American and other race categories is correspondingly lower. Also, the percentages of households below the poverty line, or half the poverty line, is higher in the modeled household data.

Figure 5. Chemours Louisville: Modeled Household Locations (in 2010) within 1, 3, 5, 10 mile

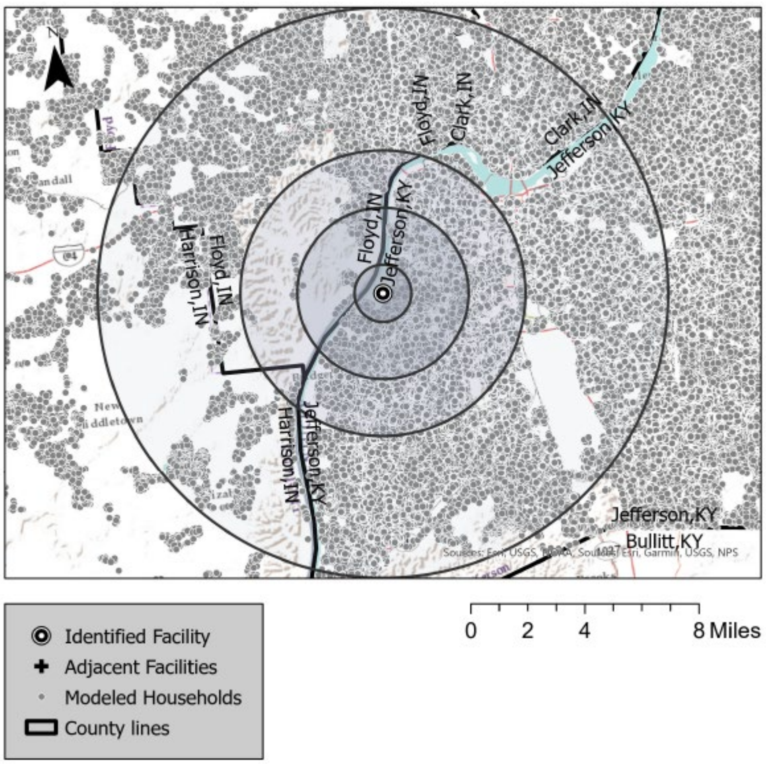

Table 5. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: Chemours Louisville

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 mles of production facility***	***Within 10 miles of production facility***
% White (race)	**59** *(67.8)*	**30** *(32.2)*	**51** *(52.3)*	**70** *(73.2)*
% Black or African American (race)	**37** *(24.2)*	**64** *(65.5)*	**43** *(45.2)*	**24** *(23.4)*
% Other (race)	**4.0** *(8.1)*	**5.3** *(2.3)*	**6.1** *(2.5)*	**5.7** *(3.4)*
% Below Poverty Line	**13** *(18.6)*	**15** *(16.2)*	**14** *(15.2)*	**9.7** *(11.3)*
% Below Half the Poverty Line	**12** (*17.7*)	**11** *(10.1)*	**12** *(11.8)*	**8.0** *(8.0)*

Daikin America – Decatur, AL

The Daikin America facility, is near Wheeler Reservoir on the Tennessee River, near another facility EPA has analyzed in connection with the AIM Act. The other is the Linde Decatur facility to the east of the Daikin site. The overlapping concentric rings of the analyses are shown in Figure 6. The synthetic household analysis identified 22 households within one mile of the Daikin Facility in 2010, clustered to the south as indicated on the map.

Figure 6. Daikin America: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

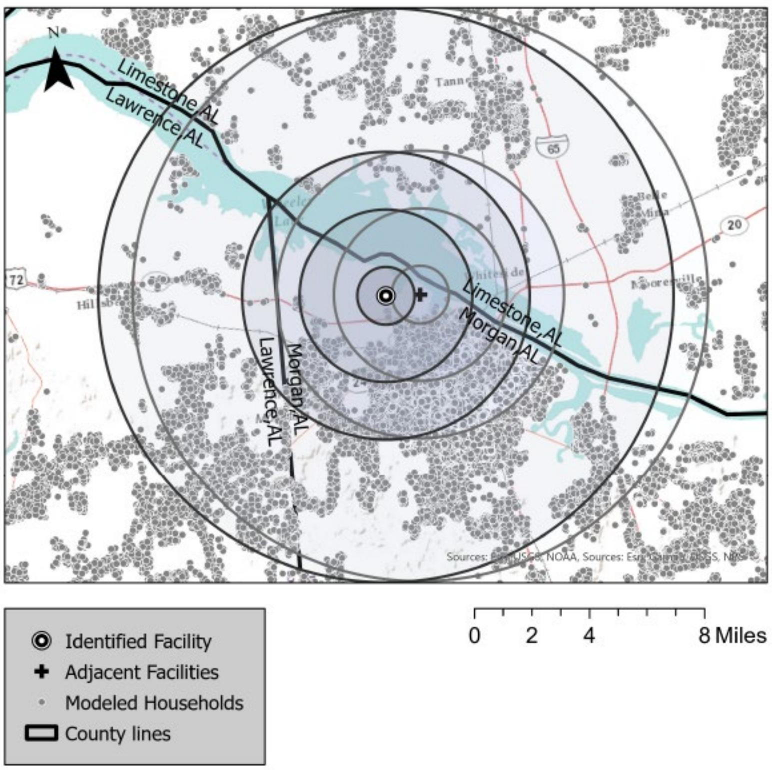

Table 6. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: Daikin America

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**35** *(63.6)*	**53** *(36.9)*	**64** *(67.8)*	**74** *(74.6)*
% Black or African American (race)	**59** *(27.3)*	**39** *(58.2)*	**25** *(25.2)*	**18** *(19.8)*
% Other (race)	**5.7** (9.1)	**8.3** *(5.0)*	**11** *(7.0)*	**8.6** *(5.6)*
% Below Poverty Line	**21** *(9.1)*	**17** *(17.6)*	**12** *(11.2)*	**10** *(10.3)*
% Below Half the Poverty Line	**13** *(0)*	**8.1** *(8.7)*	**6.4** *(5.2)*	**5.7** *(5.0)*

Honeywell Geismar Complex – Geismar, LA

The Honeywell Geismar Complex, in Ascension Parish, LA, near the border with Iberville Parish, is one of three facilities EPA has analyzed in connection with the AIM Act, the other two being the Mexichem Fluor Plant to the west in San Gabriel, Iberville, and the Air Products facility to the west in Geismar. The overlapping concentric rings of the analyses are shown in Figure 7. The 2010 synthetic household analysis shows no residences within one mile of the Honeywell Complex, as indicated in the comparison between the ACS calculations and the 2010 household model in the first column of Table 7.

Figure 7. Honeywell Geismar Complex: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

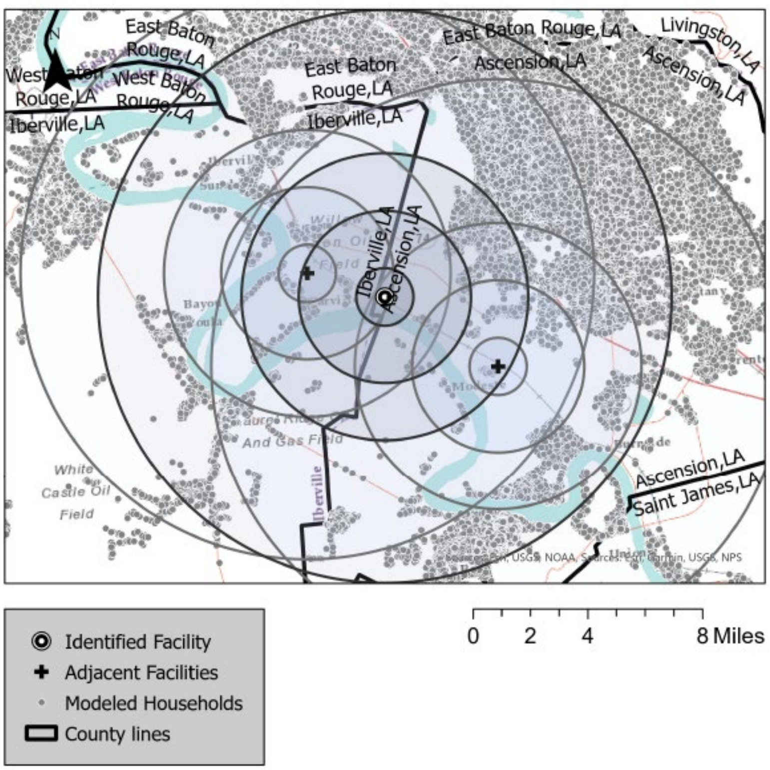

Table 7. Comparison **ACS Census Block** and (*2010 Synthetic Households*): Honeywell Geismar

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**57** *(n/a)*	**63** *(52.8)*	**62** *(62.8)*	**66** *(69.8)*
% Black or African American (race)	**38** *(n/a)*	**34** *(33.4)*	**36** *(33.4)*	**27** *(26.6)*
% Other (race)	*5.4* *(n/a)*	**2.5** *(3.9)*	**3.0** *(3.9)*	**7.1** *(3.6)*
% Below Poverty Line	**2.3** *(n/a)*	**2.5** *(10.6)*	**2.8** *(8.1)*	**5.7** *(6.2)*

% Below Half the Poverty Line	**7.2** *(n/a)*	**5.0** *(4.7)*	**5.5** *(4.9)*	**4.9** *(3.8)*

Iofina Chemical Inc. – Covington, KY

Figure 8 shows that Iofina Chemical Inc. is in Covington, KY, a densely populated area a little more than 5 miles south of the Ohio river and the City of Cincinnati, OH. Table 8 shows that the demographics of the modeled household data generally follow the Census block group averages at the 1,2,5, and 10 mile radius distances.

Figure 8. Iofina Chemical: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

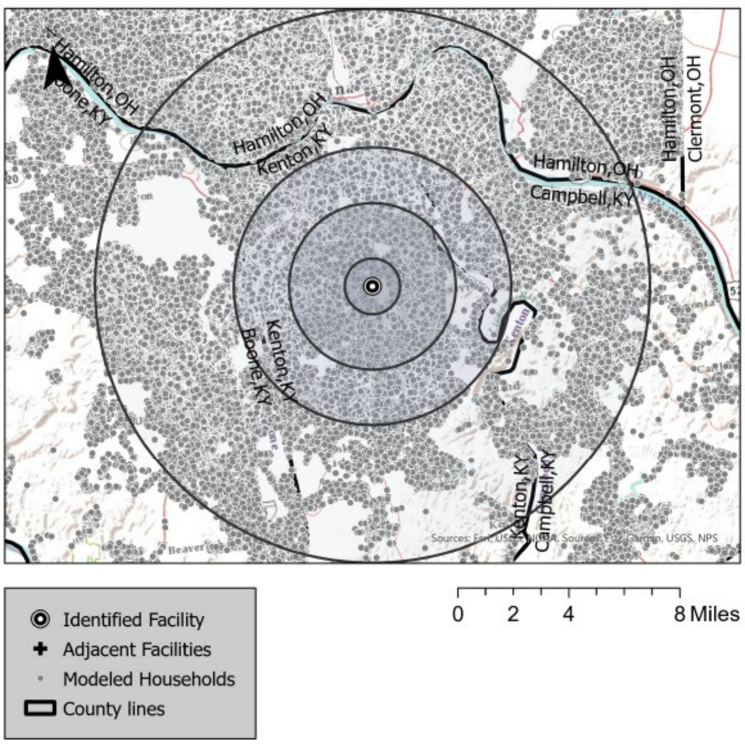

Table 8. Comparison **ACS Census Block** and (*2010 Synthetic Households*): Iofina Chemical

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**96** *(97.9)*	**94** *(96.3)*	**90** *(93.7)*	**81** *(82.5)*
% Black or African American (race)	**0.85** *(1.1)*	**2.3** *(1.7)*	**4.3** *(3.6)*	**13** *(13.7)*
% Other (race)	**2.9** *(1.0)*	**4.0** *(2.0)*	**5.2** *(2.7)*	**5.8** *(3.9)*
% Below Poverty Line	**3.3** *(2.9)*	**3.0** *(3.5)*	**5.5** *(6.6)*	**7.5** *(9.0)*
% Below Half the Poverty Line	**3.3** *(1.9)*	**4.1** *(2.0)*	**5.5** *(4.1)*	**7.6** *(6.9)*

Mexichem Fluor – St Gabriel, LA

The Mexichem Fluor facility in Iberville Parish, LA, is another of three facilities EPA has analyzed in connection with the AIM Act. The Honeywell Geismar Complex and the Air Products facilities are to the west in Geismar. The overlapping concentric rings of the analyses are shown in Figure 9. The 2010 synthetic household analysis shows a community within the mile radius the facility. A small number of households appear to be within the one-mile radius of Mexichem Fluor and within three miles of the Honeywell Complex.

Figure 9. Mexichem Fluor St Gabriel: Modeled Household Locations (in 2010) within 1, 3, 5, 10 miles

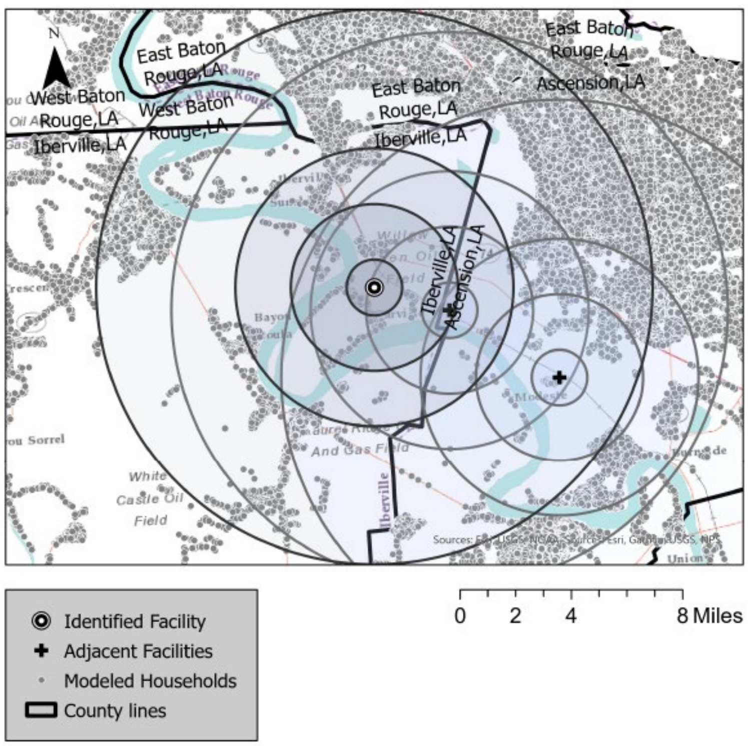

Table 9. Comparison **ACS Census Block** and (*2010 Synthetic Households)*: Mexichem Fluor St Gabriel

	Within 1 mile of production facility	***Within 3 miles of production facility***	***Within 5 miles of production facility***	***Within 10 miles of production facility***
% White (race)	**25** (*32.8)*	**55** *(35.5)*	**58** *(45.5)*	**62** *(66.6)*
% Black or African American (race)	**75** *(60.9)*	**42** *(58.9)*	**40** *(51.5)*	**31** *(29.2)*
% Other (race)	**0.24** *(6.3)*	**2.6** *(5.6)*	**2.2** *(3.0)*	**7.4** *(4.2)*
% Below Poverty Line	**4.6** *(14.4)*	**3.3** *(11.1)*	**2.8** *(8.1)*	**6.2** *(7.1)*
% Below Half the Poverty Line	**35** *(9.2)*	**4.4** *(6.1)*	**4.6** *(4.9)*	**5.3** *(5.0)*

Conclusion

Using microsimulation techniques can provide additional analytical information by using advanced data science and statistics to combine data from different surveys and geospatial datasets. The dataset used here, with a synthetic population featuring modeled locations of residences in 2010 combined with information from the 2010 Decennial Census and the ACS can show statistically representative demographic information for household locations in 2010. We are not presenting the demographic results as these are considered to be more out-of-date than the location of residences. The current version of the household location database used here is not publicly available. The publicly available data results presented here may, by showing patterns of residence in the recent past, show communities that merit more environmental justice analysis. In the time available, EPA is not pursuing additional analysis of communities for this rule.

Other synthetic datasets are available and being developed. These have additional analytic capabilities and may be useful in identifying overburdened communities.