State of California
AIR RESOURCES BOARD

Proposed Amendments to the Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses Regulation

Standardized Regulatory Impact Assessment (SRIA)

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Air Resources Board

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A. INTRODUCTION

Hydrofluorocarbons (HFCs) are synthetic gases used in refrigeration and air conditioning (AC) equipment, insulating foams, solvents, aerosol products, and fire protection. They are primarily produced for use as substitutes for ozone-depleting substances (ODS), including chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), which are being phased out under the Montreal Protocol. HFCs are short-lived climate pollutants (SLCPs) with global warming potentials (GWPs) hundreds to thousands of times greater than carbon dioxide.[1] GWP values provide a common unit of measure, which allows for comparison of greenhouse gas (GHG) emissions across different sectors. The larger the GWP value, the more that a given gas warms the Earth compared to carbon dioxide (CO_2) over a given time period. The mix of all HFCs in current use in California, weighted by usage (tonnage), has an average 100-year GWP of 1,700, and an average 20-year GWP of 3,800.[2]

Atmospheric observations show that the volume of HFCs in the atmosphere is increasing rapidly, at 7 to 15 percent annually.[3] If no measures are taken, it is estimated that HFCs will amount to 9 to 19 percent of total greenhouse gas emissions globally by 2050.[4] Studies indicate that replacing high-GWP HFCs with low-GWP alternatives worldwide could avoid 0.1 degree Celsius (°C) of global warming by 2050 and warming of up to 0.5°C by 2100, offering one of the most cost-effective climate mitigation strategies available.[5] In California, HFCs currently comprise 5 percent of greenhouse gas emissions in California, but they are the fastest growing source of GHG emissions, primarily driven by the increased demand for refrigeration and AC and the replacement of Ozone-Depleting Substances (ODS) with HFCs.[6] Even with preliminary HFC

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[1] The Intergovernmental Panel on Climate Change (IPCC) developed the concept of GWP as an index to evaluate the climate impacts of different GHGs, including SLCPs. This metric provides a comparison of the ability of each GHG to trap heat in the atmosphere relative to CO_2 over a specified time horizon. GWP accounts for the lifetime of different GHGs in the atmosphere, and the amount of energy they absorb on a per-kilogram basis, relative to CO_2, to represent the relative climate forcing of a kilogram of emissions when averaged over a time period of interest (for example, 20 years or 100 years). Current practice in most of the world for developing GHG emission inventories, including California's inventory, is to use GWP values from the 4th Assessment Report of the IPCC (AR4), which was released in 2007 (IPCC 2007). This proposed rulemaking and SRIA uses 100-yr GWP values from AR4 to be consistent with current industry practices.

[2] The GWP limits being proposed in this rulemaking are in terms of 100-year GWP values to be consistent with the State's official GHG inventory and for accounting for emissions in programs adopted under Assembly Bill (AB) 32. However, CARB also considers the 20-year GWP values as a part of this analysis which better reflect how damaging SLCPs can be over the short-term.

[3] Carpenter, et al. (2014), Ozone-Depleting Substances (ODSs) and Other Gases of Interest to the Montreal Protocol (web link: https://orbi.uliege.be/handle/2268/175647, Last accessed February 2020). See also Doherty, et al. (2014), Global emissions of HFC-143a (CH3CF3) and HFC-32 (CH2F2) from in situ and air archive atmospheric observations (web link: https://www.atmos-chem-phys.net/14/9249/2014/acp-14-9249-2014.pdf, Last accessed February 2020).

[4] *Ibid.*

[5] Xu Y., et al. (2013), The role of HFCs in mitigating 21st century climate change (web link: https://www.atmos-chem-phys.net/13/6083/2013/acp-13-6083-2013.pdf, Last accessed February 2020).

[6] California Air Resources Board, California Greenhouse Gas Emissions for 2000 to 2017 - Trends of Emissions and Other Indicators, released in 2019 (web link: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf, Last accessed February 2020); See also United Nations Environment Programme (UNEP) (2011), HFCs: A Critical Link in Protecting Climate and the Ozone Layer - A UNEP Synthesis Report (web link: https://www.ccacoalition.org/en/resources/hfcs-critical-link-protecting-climate-and-ozone-layer-synthesis-report, Last accessed February 2020).

emissions reductions measures already in place as a part of early action for AB 32, HFC emissions are still expected to increase in California by approximately 15 percent from 2019 to 2030.[7]

Figure 1 shows HFC emissions in California by end-use sector based on emission estimates conducted by CARB. [8] In 2018, the total HFC emissions in California are estimate to be approximately 19 million metric tons in CO_2-equivalents ($MMTCO_2e$). [9] HFC emissions in 2018 are almost equal amounts from stationary refrigeration, stationary AC, and mobile vehicle AC and transport refrigeration (Mobile R/AC). The remaining 11 percent of HFC emissions are from aerosol propellants, foams, and other sources including solvents, and fire suppressants. By 2030, HFC emissions will have grown approximately 5 percent to 20 $MMTCO_2e$.[10] Although total estimated HFC emissions are not significantly different in 2030 compared to 2018, the sources of HFC emissions are expected to change significantly from 2018 to 2030. HFC emissions from the mobile R/AC sector are expected to decrease significantly due to the increasing use of low-GWP AC refrigerants in new passenger vehicles.[11] HFC emissions from stationary AC are expected to increase, without further HFC measures, as AC equipment[12] built before 2010 using HCFC-22, an ODS refrigerant, continue to be replaced with new equipment using R-410A, a blend of HFC refrigerants. Additionally, residential AC use is increasing, from 63 percent of all households in California in 2011, to 73 percent by 2017.[13]

[7] California Air Resources Board, Short-Lived Climate Pollutant Reduction Strategy, March 2017. Appendix C: California SLCP Emissions. web link https://ww2.arb.ca.gov/resources/documents/final-short-lived-climate-pollutant-reduction-strategy-march-2017, Last accessed February 2020. See also California Air Resources Board, 2019. Analysis conducted by CARB Research Division to estimate growth of HFC emissions under business as usual (BAU) conditions, October 2019.

[8] California Air Resources Board, California Greenhouse Gas Emissions for 2000 to 2017 - Trends of Emissions and Other Indicators, released in 2019 (web link: https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2017/ghg_inventory_trends_00-17.pdf, Last accessed

[9] *Ibid.*

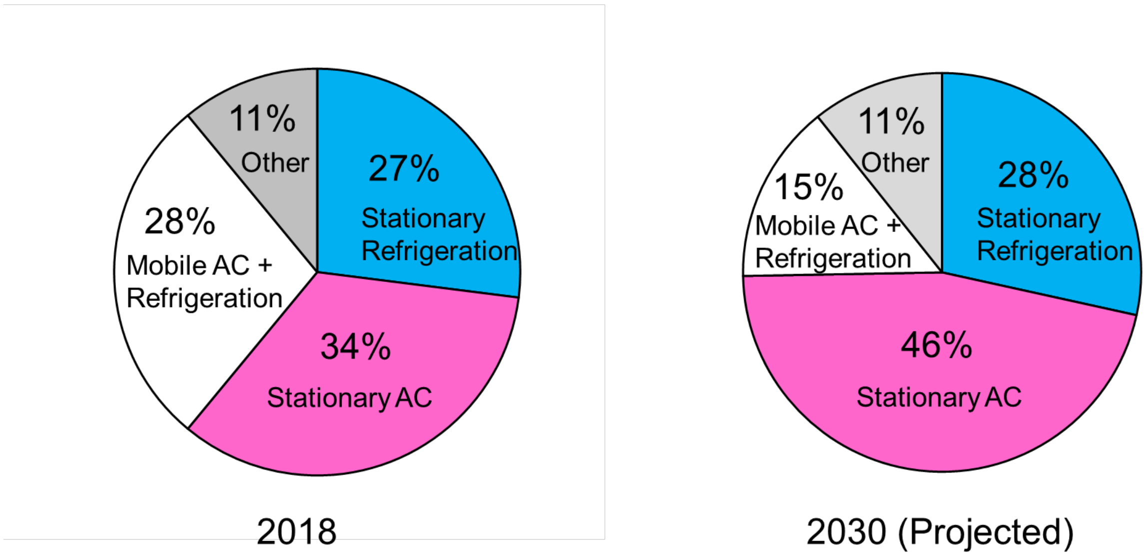
[10] *Ibid.*

[11] United States Environmental Protection Agency (U.S. EPA). The 2018 EPA Automotive Trends Report: Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975. U.S. EPA Report PA-420-R-19-002, March 2019. Web link at: https://nepis.epa.gov/Exe/ZyPDF.cgi/P100W5C2.PDF?Dockey=P100W5C2.PDF (accessed February 2020).

[12] Generally, the terms "equipment" and "systems" are interchangeable. For the purpose of this analysis, CARB refers to AC "equipment" to exclude components of heating ventilation and AC (HVAC) systems such as ductwork which are part of the system but not directly impacted by this regulation.

[13] U.S. Energy Information Administration (U.S. EIA). Residential Energy Consumption Survey (RECS), 2009. Table HC7.11, Air Conditioning in Homes in West Region, Divisions, and States, 2009. web link https://www.eia.gov/consumption/residential/data/2009/#ac (accessed February 2020); See also U.S. Census Bureau, American Housing Survey, 2017. web link https://www.census.gov/programs-surveys/ahs.html (accessed February 2020).

Figure 1. California sources of HFC emissions by sector in 2018 (total of 19 million metric tonnes of carbon dioxide equivalents [MMTCO2E) and projected for 2030 (total of 20 MMTCO2E). Source: California's F Gas Inventory, 2017. IPCC AR4 100-year GWP values used.



Refrigeration and AC equipment also contribute to global warming through indirect emissions due to the electricity consumed in operating the equipment. (Note that "systems" "equipment" and "units" are often used interchangeably in the cooling industry). The relative importance of the direct and indirect contributions depends on the type of system, the refrigerant used, the leak rates, the electricity consumption and the "carbon intensity" of the electricity, which refers to the GHG emissions associated with producing electricity. Globally, indirect emissions from electricity generation account for approximately 74 percent of total emissions from stationary AC systems with the remaining 26 percent from refrigerants.[14] In California, the refrigerant emissions represent an even more significant portion of total emissions because of the lower carbon intensity of electricity in California and the significant improvements in energy efficiency levels.

To further reduce HFC emissions in California, CARB is proposing to amend the regulation: "Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses Regulation" or "CA Significant New Alternatives Policy (SNAP) Regulation," hereafter referred to as the "Proposed Amendments". The Proposed Amendments have four main elements:

- Prohibits the use of high GWP of refrigerants in new refrigeration systems containing more than 50 pounds of refrigerant beginning January 1, 2022

- Requires existing retail food facilities to reduce their company-wide, weighted-average GWP for all refrigeration systems containing more than 50 pounds of refrigerant to less than 1,400 by 2030, with a progress step in 2026 for large companies. An optional

[14] W. Goetzler, M. Guernsey, et. al., 2016. *The Future of Air Conditioning in Buildings* https://www.energy.gov/sites/prod/files/2016/07/f33/The%20Future%20of%20AC%20Report%20-%20Full%20Report_0.pdf (Last accessed February 2020).

compliance pathway for achieving similar emissions reductions by reducing refrigerant amounts (full charge of system) and/or GWP will also be available.

- Prohibits the use of high GWP of refrigerants in all new stationary AC systems beginning January 1, 2023.
- Clarifies requirements of the existing CA SNAP regulation and the "California Cooling Act" (Senate Bill 1013, Lara, Stats. of 2018, Ch. 375; Health & Safety Code § 39734).

The Proposed Amendments will help meet several HFC reduction objectives and recommendations included in California Senate Bill 32 (SB 32),[15] which enhanced "The Global Warming Solutions Act of 2006"also known as Assembly Bill 32 (AB 32),[16] "The Short-lived Climate Pollutants Act," also known as Senate Bill 1383 (SB 1383);[17] and the most recent "California Cooling Act;"[18] the 2008 Climate Change Scoping Plan; the 2014 First Update to the Climate Change Scoping Plan;[19] California's 2017 Climate Change Scoping Plan;[20] and the 2017 Short-Lived Climate Pollutant Reduction Strategy.[21]

1. Regulatory History

Federal

In 1987, the United States signed the Montreal Protocol, an international treaty that requires signatory nations to regulate the production and use of ODS. In 1990, Congress implemented its treaty obligations by amending the Clean Air Act to add Title VI, which addresses stratospheric ozone protection by phasing out the use of ozone-depleting chemicals. Section 612 of the Clean Air Act authorizes U.S. EPA to require direct replacement of these compounds. Listed substances have a specific phase-out schedule. U.S. EPA created the Significant New Alternatives Policy (SNAP) program (42 U.S.C. § 7671k(a)) to require manufacturers to stop using listed chemicals and replace them with listed safe substitute substances. U.S. EPA added HFCs to the list of prohibited substances in 2015 and 2016 but in August 2017 and April 2019, following an industry challenge to U.S. EPA's authority to add HFCs to the prohibited list, the court partially vacated the two rules (known as the *Mexichem I* [22] and *Mexichem II*[23] decisions).

[15] Senate Bill 32 (Pavely, Stats. of 2016, Ch. 249, Health & Saf. Code § 38566).
[16] Global Warming Solutions Act of 2006, Assembly Bill 32 (Nunez, Stats. of 2006, Ch. 488, Health & Saf. Code §§ 38500 et seq).
[17] Short Lived Climate Pollutants, Senate Bill 1383 (Lara, Stats. of 2016, Ch. 395, Health & Saf. Code § 39730.5).
[18] California Cooling Act, Senate Bill 1013 (Lara, Stats. of 2018, Ch. 375, Health & Saf. Code § 39764).
[19] California Air Resources Board, First Update to the Climate Change Scoping Plan, released in May 2014 (web link: https://ww3.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf, Last accessed February 2020).
[20] California Air Resources Board, California's 2017 Climate Change Scoping Plan, released in November 2017 (web link: https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf, Last accessed February 2020).
[21] California Air Resources Board, Short-Lived Climate Pollutant Reduction Strategy, released in March 2017 (web link: https://ww3.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf, Last accessed February 2020).
[22] *Mexichem Fluor, Inc. v. Environmental Protection Agency* (D.C. Cir. 2017) 866 F. 3d 451 (Mexichem I).
[23] *Mexichem Fluor, Inc. v. Environmental Protection Agency* (D.C. Cir. 2019) 760 Fed.Appx. 6 (Mexichem II).

Historically, U.S. EPA regulated[24] HFCs under two separate sections of the Clean Air Act. The existing federal regulations on HFCs include the following provisions:

- *U.S. EPA Rule 612 (40 Code of Federal Regulations, Part 82, Subpart G, Appendices U and V):* U.S. EPA implements the SNAP Program under Section 612 of the Clean Air Act (42 U.S.C. § 7671k, et seq.) to identify and evaluate substitutes for ODS.

- *U.S. EPA Rule 608 (40 Code of Federal Regulations, Part 82, Subpart F):* Section 608 of the Clean Air Act (42 U.S.C. § 7671g, et seq.) prohibits the knowing release of refrigerant during the maintenance, service, repair, or disposal of air-conditioning and refrigeration equipment. The U.S. EPA requires proper refrigerant management practices by owners and operators of refrigeration and air-conditioning systems, technicians, and others.[25]

State

The State of California is required to reduce Greenhouse Gas (GHG) emissions under various laws identified above. AB 32 specifically includes HFCs as one of the classes of GHG emissions and mandates their reduction. Under AB 32, GHG emissions in California must be reduced to 1990 levels by the year 2020. SB 32 builds upon AB 32 to require all GHG emissions be reduced 40 percent below 1990 levels by the year 2030. SB 1383 further requires annual HFC emissions to be reduced to 40 percent below 2013 levels by the year 2030. Additionally, SB 1013 prohibits the use of specific high-GWP HFCs in a wide range of end-use categories, including stationary refrigeration, insulating foam, aerosol propellants, and chillers.

CARB currently implements several regulatory programs to reduce HFC emissions from these sectors:

- *Refrigerant Management Program (RMP):[26]* RMP is modeled after the U.S. Environmental Protection Agency (U.S. EPA) Clean Air Act, Section 608 program to protect the stratospheric ozone layer by reducing usage and emissions of ozone-depleting substances. In addition to ozone-depleting substances, CARB also included non-ozone-depleting substance HFC refrigerants with a 100-year GWP of 150 or greater (considered "high-GWP").

- *California Prohibitions on High-GWP HFCs:[27]* In 2018, California backstopped key U.S. EPA SNAP Program prohibitions on high-GWP HFCs through two avenues. First, by adopting a new CARB HFC regulation ("Prohibitions on Use of Certain Hydrofluorocarbons in

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[24] Due to the *Mexichem* decisions, HFCs are no longer prohibited under the SNAP program but U.S. EPA does continue to approve safe substitutes for CFCs and HCFCs.
[25] U.S. EPA released a proposed rule that would remove HFCs from the 608 requirements. See Protection of Stratospheric Ozone: Revisions to the Refrigerant Management Program's Extension to Substitutes, 83 Fed. Reg. 49332 (Oct. 1, 2018). As of February 10, 2020, U.S. EPA has not finalized the proposed rule.
[26] Cal. Code of Regs., tit. 17, §§ 95380, et seq.
[27] Cal. Code Regs., tit. 17, §§ 95371, et seq.

Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses Regulation"), and secondly, through new legislation—SB 1013.

- *Additional HFC Measures:* California also implements regulations to reduce HFC emissions from consumer product aerosol propellants, semiconductor manufacturing, and small cans of HFC-134a used by at-home "DIYer" mechanics.[28]

Local

The South Coast Air Quality Management District (SCAQMD) regulates stationary commercial AC systems with over 50 pounds of ODS or high-GWP refrigerants:

- *District Rule 1415*: Affected entities must register, conduct leak inspections and keep records on site. Rule 1415 also contains requirements for any person who installs, repairs, maintains, services, relocates, or disposes of any AC system, and for any person who recycles, recovers, reclaims, distributes or sells high-GWP refrigerants. SCAQMD also implements Rule 1415.1, which is equivalents to the statewide RMP.

International

The importance of reducing HFC emissions to alleviate the worst impacts of global warming has also been recognized by the global community. In 2016, representatives from 197 nations signed "The Kigali Amendment" to amend the existing Montreal Protocol (to reduce ODS production and consumption) to include a gradual phase-down in the production of HFCs beginning 2019. The Kigali Amendments were ratified and entered into force on January 1, 2019. As of February 2020, 85 nations have ratified the Kigali Amendment.

Non-Article 5 Parties,[29] including Japan, Australia, Canada and the European Union (EU) have committed to reducing HFCs by 85 percent below 2012-2013 average annual usage baseline levels by the year 2036. Most Article 5 Parties have committed to reducing HFCs 80 percent by the year 2040, as compared to future average annual baseline usage of HFCs in years 2020, 2021, and 2022. Although the U.S. was a signatory, the U.S. has not ratified the Kigali Amendment as of February 2020. The majority of AC and refrigeration equipment manufacturers selling equipment to California are international corporations transitioning product lines away from high-GWP HFC refrigerants and have invested billions to bring next generation refrigerants and equipment to market.[30]

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[28] Contained in various sections, commencing with Cal. Code of Regs., tit. 13, §§ 1900 et seq.

[29] The Montreal Protocol separates countries into two different classifications based on the special situation of developing countries. Pursuant to the Montreal Protocol, Non-Article 5 Parties are developed countries and Article 5 Parties are developing countries whose annual calculated level of consumption of the controlled substance is less than 0.3 kilograms per capita on the date of the entry into force of the Protocol or any time thereafter within ten years of the date of entry into force. Article 5 Parties are entitled to a delay in compliance with certain control measures under the Montreal Protocol.

[30] AHRI & ARAP, Letter to United States Senate and House of Representatives (Oct. 8, 2019), available at: https://images.magnetmail.net/images/clients/AHRI/attach/FINALCEOLetterwithSignaturesFinal.pdf.

Energy Efficiency

The energy efficiency performance of most heating and cooling equipment is regulated by the National Appliance Efficiency Conservation Act (NAECA) and California Appliance Efficiency Regulations (Title 20) which are administered by the U.S. Department of Energy (U.S. DOE) and the California Energy Commission (CEC), respectively. Requirements promulgated under these regulations as well as voluntary labeling and incentive programs have resulted in significant emissions reductions and cost savings for end-users. While energy conservation standards can place upward pressure on equipment prices, the incremental price for efficient products has dropped rapidly along with a long-term decline in baseline prices.[31] In the Proposed Amendments, staff proposes to set the effective date for the 750 GWP limit for new ACs in 2023 in order to align with new efficiency standards taking effect and leverage the existing equipment redesign cycle for energy efficiency standards to reduce costs associated with transitioning refrigerants.

Building Codes and Industry Voluntary Standards

The American National Standards Institute (ANSI) is a private non-profit organization that oversees the development of voluntary consensus standards for products, services, processes, systems, and personnel in the United States. Both the American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) and Underwriters Laboratory (UL) are ANSI-accredited standard setting bodies. UL develops and publishes product safety standards, which contain design criteria for appliances. Manufacturers build products in accordance with these safety standards and submit them to UL for testing. UL provides certification for these products if they meet the safety standards design criteria. ASHRAE develops and publishes application safety standards that describe equipment design and safe installation, often referred to as application safety standards. ASHRAE and UL have representative consensus guidelines for committees that develop standards to engage a diverse set of stakeholders. UL and ASHRAE standards are designed to complement one another and work in conjunction. Provisions from these standards are adopted in into building codes, whereby they become law. [32] In order for a refrigerant to be used in California, it must be allowed for use by these standard and code setting bodies.

2. Proposed Amendments

The Proposed Amendments would prohibit the use of high-GWP refrigerants in two sectors that contribute the most to statewide HFC emissions, namely, stationary refrigeration and AC equipment as well as one equipment type that falls into both stationary and AC sectors (chillers). The Proposed Amendments also includes adding in recordkeeping, reporting, and labeling requirements, and clarifying edits to the regulation. The Proposed Amendments are summarized below.

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[31] Van Buskirk, et al. (2014), A Retrospective investigation of energy efficiency standards: policies may have accelerated long term declines in appliance costs (web link: https://iopscience.iop.org/article/10.1088/1748-9326/9/11/114010/pdf, Last accessed February 2020).

[32] California Mechanical Code, Cal. Code Regs., tit. 24, Part 4.

a. *GWP Limits for New Equipment*

The proposed requirements for new equipment are summarized in Table 1.

Table 1. Summary of Proposed Amendments for New Equipment

General End-Use	Specific End-Use	Prohibited Substances	Effective Date
Stationary Refrigeration	New refrigeration systems containing more than 50 pounds of refrigerant (non-residential) in newly constructed / remodeled facilities	Refrigerants with GWP greater than or equal to 150	January 1, 2022
Stationary AC	All new AC equipment, residential and non-residential	Refrigerants with GWP greater than or equal to 750	January 1, 2023
Chillers	All new chillers	Refrigerants with GWP greater than or equal to 750	January 1, 2024

For new equipment, there are two sectors impacted and one equipment type falling into both sectors (chillers):

- Refrigeration: Refers to the process of cooling products and/or processes, and storing chilled and/or frozen products at the appropriate temperatures. The Proposed Amendments will be applicable only to refrigeration systems containing more than 50 pounds of refrigerant. Facilities that use stationary refrigeration systems above that size threshold typically include, but are not limited to retail food facilities, for example, supermarkets and grocery stores; cold storage warehouses, food preparation and processing facilities; hotels and recreational facilities; facilities with other types of industrial process refrigeration (IPR) equipment. The rationale for the proposed GWP limit in new refrigeration equipment is to reduce the global warming impact of refrigerants inadvertently leaked from the equipment as a part of the equipment wear and fittings fatigue from normal use; average leak rates for even well-maintained refrigeration systems are between 10 and 20 percent of its entire refrigerant charge each year. SB 1013 HFC prohibitions in new refrigeration equipment still allow refrigerants up to 2,100 times more global warming than carbon dioxide. Continuing to use high-GWP refrigerants in new equipment is counter-productive to achieving the HFC emissions goal required by SB 1383.

- Air Conditioning: Refers to the use of a refrigerant to cool, heat or dehumidify air. An AC that uses a refrigerant to provide heating in addition to cooling is referred to as a heat pump and these types of systems are included in the Proposed Amendments. Stationary AC includes room ACs meant to condition air in a single room as well as central ACs used in residential, commercial and other non-residential settings. This includes all types of AC systems including those that use a refrigerant to provide heating in addition to cooling (heat pump), room ACs and dehumidifiers as well as ductless split and ducted split and packaged ACs used in residential, commercial and non-residential settings.[33] The rationale for the proposed GWP limit in new AC equipment is to reduce the significant and growing source of greenhouse gas emissions from AC end-uses. These end-uses represents the fastest growing source of HFC emissions in California; if left unchecked will reach 46 percent of emissions by 2030. Transitioning refrigerants in new equipment, which predominately use R-410A (GWP 2,088) is one of the most effective ways to mitigate the growing bank of high-GWP refrigerants in this sector.

- Chillers: Refers to equipment that uses water or heat transfer fluid to chill. They can be used for AC or refrigeration applications. For refrigeration, they are most commonly used in industrial processing refrigeration (IPR) facilities and sometimes in commercial facilities. The primary refrigerant used in a 'refrigeration chiller' is chosen based on the temperature needs of the facility (i.e., how cold the process and/or products need to be) and is usually coupled with a secondary fluid like glycol that circulates through the facility. Based on RMP data, an estimated 50 percent of the systems registered under IPR facilities are chillers. Larger buildings are often cooled by a central chiller that pumps chilled water to heat exchangers in air handling or fan-coil units that deliver conditioned air. Chillers are typically located in a machinery room or outdoors. Chillers can also be used to provide AC to multiple building by using a centralized plant to deliver chilled water via underground insulated pipes to multiple buildings in a process referred to as district cooling.[34]

The rationale for including chillers in the proposed regulation is to provide additional clarity to existing regulations used to implement SB 1013. The existing regulation contains a list of 24 specific refrigerants banned in new equipment beginning January 1, 2024. The proposed regulation eliminates any mention of specific refrigerants and replaces them with a single GWP limit of 750 in new equipment, which was the de facto previous GWP limit of the existing regulation, although no GWP limit was directly expressed. Using a single GWP limit instead of a list of refrigerants that may be subject to change will add clarity to the regulated community, and the flexibility to be used in the future without numerous changes to list additional prohibited refrigerants as they become available.

b. GWP Limits for Existing Facilities Using Refrigeration Systems

Apart from rules for new refrigeration systems in newly constructed and remodeled facilities, the Proposed Amendments will also require existing facilities to reduce their emissions in the following ways:

[33] In the rest of this document, the term AC is used for ACs and heat pumps that directly cool or heat air.
[34] SB 1013 banned specific refrigerants with high GWP values and the compliant refrigerant options for AC chillers are below the 750 GWP limit. Manufacturers of chillers have already commercialized equipment using next generation refrigerants in accordance with SB 1013's requirement prohibiting high-GWP refrigerants from being used in new chillers starting 2024.

- Due to their high emissions impact, retail food facilities such as supermarkets and grocery stores will be required to reduce their weighted-average GWP[35] to below 1,400 or reduce their Greenhouse Gas Emissions Potential or GHGp[36] (i.e., refrigerant amount multiplied by GWP, summed over all refrigerants used by the company across all their stores) from their existing systems by 55 percent by 2030.

- Across all non-retail food facilities, any new systems being installed in existing facilities must use refrigerants with GWP values less than 1,500. This is a preventative measure to disallow high-GWP refrigerants from being used in any refrigerated facility. For most refrigerated facilities, new systems with high-GWP refrigerants are already prohibited from use. This rule will help cover any remaining facilities.

Table 2. Summary of Proposed Rules for Refrigeration Equipment in Existing Facilities

Regulated Entity	Compliance Requirements	Compliance Date
Refrigerated Facilities excluding Retail Food Facilities	Prohibition on refrigerants with GWP greater than or equal to 1,500 in new systems containing more than 50 pounds of refrigerant	January 1, 2022
Retail Food Companies with greater than or equal to 20 Retail Food Facilities	Attain a company-wide weighted-average GWP below 2,500 or 25% reduction in GHGp below 2018 levels	January 1, 2026
	Attain a company-wide weighted-average GWP below 1,400 or 55% reduction in GHGp below 2018 levels	January 1, 2030
Retail Food Companies with fewer than 20 Retail Food Facilities	Attain a company-wide weighted-average GWP below 1,400 or 55% reduction in GHGp below 2018 levels	January 1, 2030

c. Recordkeeping, Reporting, and Labeling

The Proposed Amendments include labeling and recordkeeping requirements for refrigeration, AC, chillers, as well as some reporting requirements retail food facilities. Existing labels meeting the requirements may be used. For retail food facilities, existing reporting and recordkeeping requirements under the Refrigerant Management Program regulation will help end-users comply with the reporting requirements under the Proposed Amendments. For AC manufacturers, the

[35] Weighted-average GWP is defined as the average GWP of all refrigerants used by a retail food company across all their stores and systems with more than 50 pounds of refrigerant each, weighted by the pounds of each refrigerant. For more information, see Section C.
[36] Greenhouse Gas Emissions Potential (GHGp) is defined as the pounds of each refrigerant multiplied by its GWP, summed over all refrigerants used across all stores owned by a company in systems containing more than 50 pounds of refrigerant. For more information, see Section C.

recordkeeping requirements are not expected to be additional to the standard business practices.

3. Statement of the Need of the Proposed Regulation

Climate scientists agree that global warming and other shifts in the climate system observed over the past century are caused by human activities and that these recorded changes are occurring at an unprecedented rate.[37] California is already feeling the impacts of climate change, and projections show that these effects will continue and worsen. The impacts of climate change on California have been documented by the Office of Environmental Health Hazard Assessment (OEHHA) in the *Indicators of Climate Change Report.*[38]

Californians are experiencing hot days and nights more frequently while California has become drier and more susceptible to drought. Statewide precipitation has become increasingly variable and changes in snowpack have led to less reliable water supply. Extreme weather events such as coastal storm surges, drought, wildfires, floods, and heat waves, are expected to become more frequent and more severe. As GHG emissions continue to accumulate and climate disruption grows, destructive weather events will become more frequent. Climate change is making events like these more frequent, more catastrophic, and costlier. The total statewide economic cost of the 2013–2014 drought was estimated at $2.2 billion, with a total loss of 17,100 jobs.[39] In the Central Valley, the drought cost California agriculture about $2.7 billion and more than 20,000 jobs in 2015.[40] It is imperative that California continue to work to reduce GHG emissions in order to decrease the impacts. California has instituted specific legal mandates to reduce GHG and more specifically, SLCPs, including HFC emissions.

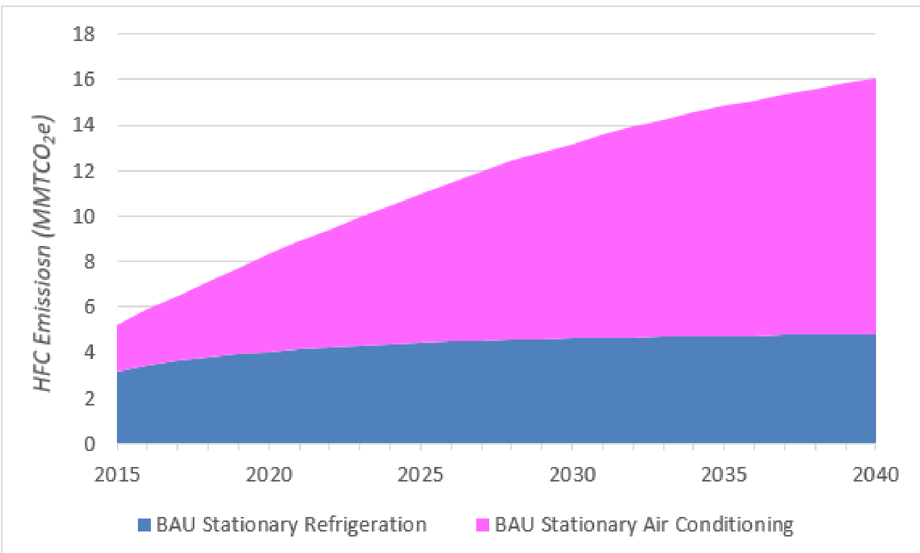
HFCs are powerful climate forcers. While they remain in the atmosphere for a much shorter time than carbon dioxide, their relative global warming potentials can be thousands of times greater than CO_2. The mix of HFCs in current use, weighted by usage (tonnage), has an average atmospheric lifetime of 15 years. The warming impact of any GHG depends on how long the gases stay in the atmosphere. Since the average lifetime of HFCs is 15 years, their warming impact or their GWP values, are higher when considered over a 20-year timeframe compared to a 100-year timeframe. For example, the average 100-year GWP of the current mix of HFCs being used as refrigerants is less than half the average 20-year GWP. This highlights the fact the damage caused HFCs is significantly worse when considered in the near term. Additionally, not only are HFCs thousands of times more potent than CO_2 but they also represent the fastest growing source of greenhouse gas emissions in California, the U.S., and globally.[41] The primary

[37] Cook, et al., 2015. Unprecedented 21st century drought risk in the American Southwest and Central Plains. (web link: https://advances.sciencemag.org/content/advances/1/1/e1400082.full.pdf, Last accessed February 2020).
[38] Office of Environmental Health Hazard Assessment, 2018. Indicators of Climate Change in California. (web link: https://oehha.ca.gov/media/downloads/climate-change/report/2018caindicatorsreportmay2018.pdf, Last accessed February 2020).
[39] Howitt, et al., 2014 Economic Impacts of 2014 Drought on California Agriculture. July 23, 2014. (web link: https://watershed.ucdavis.edu/files/biblio/DroughtReport_23July2014_0.pdf, Last accessed February 2020).
[40] Williams, et al., 2015. Contribution of anthropogenic warming to California drought during 2012–2014. (web link: https://agupubs.onlinelibrary.wiley.com/doi/full/10.1002/2015GL064924, Last accessed February 2020).
[41] Intergovernmental Panel on Climate Change, 2014. Summary for Policymakers. In: Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the

factor driving the large increase of HFC use and emissions in the air-conditioning and refrigeration sectors is that new equipment using HFC refrigerants are replacing older equipment using ozone-depleting substance (ODS) refrigerants. Because ODS emissions are intentionally not included in California's GHG Inventory (by design of the Kyoto Protocol and AB 32), the growth of HFC emissions reflects not only simple growth in the number of new equipment used each year, but also the replacement of ODS equipment with HFC equipment.

As shown in Figure 2., HFC emissions from stationary refrigeration and stationary AC are expected to increase more than 50 percent by 2030 if left unchecked. This growth in HFC emissions would greatly undermine efforts to address climate change.

Figure 2. Business-As-Usual HFC Emissions in California from 2010 to 2040



The first goal of the Proposed Amendments is to take steps towards addressing climate change. Acting now to reduce HFC emissions can have an immediate beneficial impact on climate change. The most recent 2018 IPCC report analyzed the impacts associated with a warming of 1.5°C. The IPCC report indicates that significant changes will need to be made to avoid the most devastating impacts of a 2°C temperature increase.[42]

The second goal of the Proposed Amendments is to meet California's statutory mandates. Recognizing the importance of mitigating climate change, the California Legislature enacted several laws aimed to reduce both GHG and HFC emissions. In 2006, the California Legislature adopted AB 32 requiring a reduction of GHG emissions to 1990 levels by 2020. In 2016, the Legislature adopted SB 32, further strengthening the mandate by requiring GHG reductions to 40 percent below 1990 levels by 2030. That same year, the Legislature adopted SB 1383

Intergovernmental Panel on Climate Change. (web link: https://www.ipcc.ch/site/assets/uploads/2018/02/ipcc_wg3_ar5_summary-for-policymakers.pdf, Last accessed February 2020).

[42] Intergovernmental Panel on Climate Change, Special Report: Global Warming of 1.5°C, 2018. (web link: https://www.ipcc.ch/sr15/, Last accessed February 2020).

requiring a 40 percent reduction in HFC emissions below 2013 baseline levels by the year 2030. CARB adopted several plans and regulations already to meet these mandates.

California Health and Safety Code sections 38510, 38598, 38560, 38562, 38566, 38580, 39600, 39601, and 41511 grant CARB authority to adopt regulations that reduce emissions of GHGs and HFCs and to "do that which is necessary" to carry out CARB's purpose. California Health and Safety Code sections 39730, 39730.5, and 39734 specifically grant CARB authority to regulate HFCs. Under these laws, CARB is authorized to regulate stationary refrigeration and AC as emissions sources.

Despite several HFC emissions reductions programs in place, CARB analysis estimates that the 2030 HFC emissions goal cannot be reached using only current measures. Based on CARB's 2017 F-gas Inventory (published in 2019), with existing regulations in place, annual HFC emissions in California are projected to be approximately 20 million metric tons of carbon dioxide equivalent ($MMTCO_2e$) in 2030.[43] The SB 1383 emissions reduction goal of 40 percent below 2013 emissions by 2030 equates to annual emissions of 10 $MMTCO_2e$ or less by 2030. Thus, on annual basis, by 2030, annual emissions reductions of at least 10 $MMTCO_2e$ are needed from additional regulatory measures and/or incentive programs. New system GWP limits are needed to restrict the banks of high GWP refrigerants in California in both refrigeration and AC equipment. As shown in **Figure *2.***, together, refrigeration and AC end-uses contributed 34 percent of all HFC emissions in California in 2018. Stationary AC is the fastest growing of all sectors that use HFCs as refrigerants and is projected to contribute 46 percent of all HFC emissions in 2030—the largest of any individual sector contribution. Apart from fire suppressants, it is also the only HFC emission sector that is not yet regulated by CARB.

On average, depending on system type and size, the regulated refrigeration systems survive between 15 to 20 years. It is worth noting that some facilities like supermarkets use their systems well past this average lifetime, and by some industry accounts, for up to 30 years. Thus, once a product using HFCs is installed or otherwise placed into use in California, it is difficult to require removal, and "locks in" those HFC emissions over the lifetime of the product. Based on user-reported data from the Refrigerant Management Program in 2018, 30 to 40 percent of all regulated refrigeration systems in the State today use R-404A or R-507; which are HFC refrigerants with very high GWP values of nearly 4,000. Additionally, more than 30 percent of the systems continue to use R-22, an ozone depleting HCFC refrigerant being phased out under the Montreal Protocol. The R-22 systems in particular are aging and nearing their retirement. Under business-as-usual over the next 10 years, they will be replaced by refrigerants like R-407A, which has a GWP of 2,100, higher than that of R-22.

Similarly, AC equipment survives between 15 and 20 years, depending on equipment type. More than half of AC equipment currently uses HCFC-22, an ODS which is scheduled for a complete production and import phase-out in the United States by 2020. The HCFC-22 refrigerant is being replaced with HFCs that have higher GWPs, thus increasing the GHG impact of refrigerants. In anticipation of the HCFC-22 phase-out by 2020, most owners of equipment using HCFC-22 will

[43] California Air Resources Board, 2017. California High GWP Gases Inventory for 2000-2017 – by Sector and Activity. Available at: https://ww3.arb.ca.gov/cc/inventory/data/tables/ghg_inventory_sector_sum_2000-17hgwp.pdf, Last accessed February 2020).

either replace the equipment by 2020, or at a minimum replace the HCFC-22 refrigerant in the same equipment (retrofit) with a high-GWP HFC refrigerant.

A window of opportunity exists in the next five years to accelerate the transition of refrigeration and air-conditioning equipment to lower-GWP refrigerants, before another generation of equipment is locked into using higher-GWP refrigerants. In addition to taking action during a critical time period for preventing the worst impacts of climate change, industry has stressed the importance of regulatory certainty to signify that the time to transition the market to more climate friendly refrigerants is now.

In September 2018, nine chemical and equipment manufacturing companies, the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), which represents companies that produce over 90 percent of equipment in North America, and the Natural Resources Defense Council (NRDC) sent a letter to CARB urging CARB to adopt a regulation prohibiting refrigerants with a GWP of 750 or greater in new stationary AC equipment beginning January 1, 2023.[44] The signatories to the letter identified this date to balance environmental benefit while minimizing cost impacts on consumers, and to provide adequate time for manufacturers, distributors, and contractors to prepare for a safe and efficient transition to lower-GWP technologies. CARB responded immediately to the industry's request for certainty as to the date of the transition to more climate friendly AC in California.

Additional goals are to provide regulatory certainty to businesses in California, clarify the existing regulations, and help advance more sustainable cooling technologies in the State.

4. Major Regulation Determination

CARB staff determined that the Proposed Amendments is a major regulation as the analysis shows a greater than $50 million economic impact over a 12-month period after full implementation. The first equipment prohibitions under the Proposed Amendments will become effective January 1, 2022 and will be fully implemented the following year for new equipment and in 2030 for the existing retail food facilities. This SRIA analyzes the costs from the first compliance date out to one average equipment lifetime for regulated refrigeration and AC equipment i.e., 2022 to 2040. Please see Section D, Macroeconomic Impacts for the analysis.

5. Baseline Information

To estimate the economic impacts of the Proposed Amendments, CARB evaluated the economic and emissions impacts of the proposal relative to the business-as-usual (BAU) or "baseline" scenario each year for the analysis period from 2020 to 2040. CARB maintains a California specific Fluorinated Gas (F-Gas) Inventory as a part of the statewide GHG Emission Inventory that is used for establishing historical emission trends and tracking California's progress in reducing greenhouse gases. To determine the baseline scenario for the economic and emissions analysis,

[44] AHRI, NRDC, Carrier Corporation, Daikin Applied Americas, Inc., Goodman Manufacturing Company, L.P., Lennox International, Nortek Global HVAC LLC, Trane Inc., The Chemours Company, Honeywell International Inc., Letter to Chair Nichols. 14 September 2018. (web link: http://www.ahrinet.org/Portals/_Appleseed/documents/news/AHRI_NRDC_CARB_Letter_regarding_SLCP_HFC_measures.pdf, Last accessed February 2020).

CARB used its F-Gas Inventory and the DOF population forecasts as a basis for the analysis. The regulatory proposal and alternative scenarios result in economic and emissions changes relative to the baseline scenario and those are discussed throughout the document.

For the SRIA, the F-Gas Inventory is used to estimate emissions under BAU and alternative scenarios and to forecast the number of AC and refrigeration units each year through 2040 for which there are direct costs or benefits associated with the Proposed Amendments. For additional information regarding the F-Gas Inventory methodology, see referenced publicly available documents.[45] Unit populations, such as AC and refrigeration units, are assumed to increase proportionally to population, unless data indicate otherwise. CARB staff uses the California Department of Finance (DOF) population projections for estimating growth rates.[46]

Under the BAU scenario, as modeled in the F-Gas Inventory, it is assumed that all entities are in full compliance with current regulations governing the use of fluorinated refrigerants in the state. A description of how policies affecting refrigeration and or air conditioning systems are taken into account in the BAU scenario is provided below:

- *California SNAP*: This includes CARB's HFC Regulation, "Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Stationary Air-conditioning, Chillers, Aerosols, Propellants, and Foam End-Uses" which incorporates SB 1013. California SNAP adopted key federal prohibitions on the use of very high-GWP refrigerants originally issued under the U.S. EPA SNAP Rules 20 and 21 as they read in January 2017 prior to being partially vacated. The BAU GWP utilized in this analysis reflects the use of compliant refrigerants in new and retrofit systems.

- *California Refrigerant Management Program:* The RMP regulation is aimed at minimizing leaks of refrigerants from refrigeration systems containing more than 50 pounds of refrigerants with GWP values greater than 150. RMP data on average refrigerant amount used per system, or "charge size", and annual leak rates are used to update the F-Gas Inventory inputs that are used in this analysis.

- *U.S. DOE Energy Conservation Standards:* U.S. DOE sets minimum energy conservation standards under the NAECA for appliances and equipment used in homes, businesses, and other applications, including small self-contained, commercial and residential AC. The baseline for this analysis incorporates equipment, installation, maintenance and repair costs from the U.S. DOE's Technical Support Documents[47] for the efficiency standards in effect today, some of which have future compliance dates.

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[45] California Air Resources Board, California's High Global Warming Potential Gases Emission Inventory, 15th Ed., 2016. (web link: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf, Last accessed February 2020).
[46] California Department of Finance, 2019. Population Projections. http://www.dof.ca.gov/Forecasting/Demographics/Projections/, Last accessed December 2019).
[47] Energy Conservation Program: Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps, 82 Fed. Reg. 1786 (Jan. 6, 2017); See Technical Support Documents submitted as part of rulemaking available here: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0102; Energy Conservation Standards for Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment, 81 Fed.

Additional information on these policies can be found in **Section** *1*, Regulatory History of this document. The information used in this to develop the baseline emissions on populations for regulated refrigeration and AC systems is discussed below.

a. Stationary Refrigeration Systems

The baseline emissions from this category depend on the projected populations of and the sizes of the systems. The following sections describe the characteristics and population projects of the regulated refrigeration systems that make up the baseline. For the purposes of this analysis, CARB categorizes stationary refrigeration systems containing more than 50 pounds of refrigerant into the three end-use sectors listed below.

- *Commercial Refrigeration:* This end-use sector comprises mainly retail food facilities designed to store and display chilled or frozen goods for commercial sale, for example, in supermarkets and grocery stores. In addition, some commercial systems are used in merchant wholesale facilities, hotels, amusement parks, etc.

- *Industrial Process Refrigeration:* This sector includes systems that cool process streams in industrial applications. This includes, but is not limited to, food and non-food production and manufacturing, respectively. The choice of refrigerant for specific applications depends on ambient and required operating temperatures and pressures.[48]

- *Cold Storage Warehouses:* This sector includes systems in facilities that "store meat, produce, dairy products, and other perishable goods. The majority of cold storage warehouses in the United States use ammonia as the refrigerant in a vapor compression cycle, although some rely on other refrigerants."[49]

This system classification broadly aligns with the U.S.EPA's SNAP end-uses of retail food refrigeration, industrial process refrigeration and cold storage warehouses. These systems are currently subject to CARB's Refrigerant Management Program (RMP) under which they have to provide annual reports on their refrigerant purchase and use and follow best leak management practices.[50] The RMP has three size classes for the refrigeration systems, which are as follows:

Table 3. Refrigeration system size classes in CARB's Refrigerant Management Program

System Size	Full charge of system (amount of high-GWP refrigerant contained)
Large	2,000 pounds and above
Medium	200 to under 2,000 pounds
Small	Over 50 to under 200 pounds

Reg. 2420 (Jan. 15, 2016); See Technical Support Documents submitted s part of rulemaking available here: https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0007 (Hereinafter collectively "U.S. DOE Technical Support Documents").

[48] United States Environmental Protection Agency definitions, (web link: https://www.epa.gov/snap/substitutes-refrigeration-and-air-conditioning, Last accessed February 2020).

[49] *Ibid.*

[50] California Air Resources Board, Refrigerant Management Program, (web link: https://ww2.arb.ca.gov/our-work/programs/refrigerant-management-program, Last accessed February 2020).

The same size classes are used for this analysis. This helps align the implementation of the Proposed Amendments with the already established RMP. Here on, stationary refrigeration systems containing more than 50 pounds of refrigerant are referred to as "regulated refrigeration systems" in this document. Baseline characteristics for regulated refrigeration systems are based on CARB's F-Gas Inventory and the RMP database, and are given in Table 4.

Table 4. Baseline Characteristics for New Stationary Refrigeration Systems

System Type	Baseline Refrigerant for New Systems	Baseline GWP (100-year, AR4[51])	Lifetime (Years)	Average Full Charge (lb.)	Average Annual Leak Rate (%)
Commercial Refrigeration					
Large	R-407A	2,107	15	3,352	24.2%
Medium			15	684	22.9%
Small			20	103	15.6%
Industrial Process Refrigeration					
Large	R-404A, R-507, R-134a	3,066	20	5,873	12.3%
Medium			20	660	12.5%
Small			20	104	9.1%
Cold Storage					
Large	R-448A / R-449A	1,391	20	7,252	14.8%
Medium			20	552	10.3%
Small			20	113	3.7%

For all refrigeration systems, the average end-of-life leak rate is 20 percent.

For commercial refrigeration and cold storage, the baseline GWP for new systems in new construction is the maximum allowable GWP value under the current California SNAP regulation and SB 1013. Industrial process refrigeration systems are not currently included in the original California SNAP regulation or SB 1013; the baseline GWP for new systems in that sector is based on the F-Gas Inventory and is the weighted-average GWP of all the refrigerants used in the sector. The average system lifetimes and refrigerant charge sizes are from the F-Gas Inventory.[52] To reflect the current state of emissions, the average annual leak rates used in this analysis are based on refrigerant leak data reported by end-users to CARB's RMP in 2018. The average end-of-life leak rates are from CARB's F-Gas Inventory and align with the U.S. EPA's estimates.[53]

Based on the F-Gas Inventory, commercial refrigeration systems, most of which are used in supermarkets and grocery stores comprise 74 percent of all high-GWP refrigeration systems, followed by industrial process refrigeration and cold storage, which account for 22 percent and 4 percent of the high-GWP refrigeration systems, respectively. Since the majority of the regulated

[51] AR4: Fourth Assessment Report issued in 2007 by the United Nations Intergovernmental Panel on Climate Change.
[52] California Air Resources Board, 2016, California's High Global Warming Potential Gases Emission Inventory: Emission Inventory Methodology and Technical Support Document, *2015 Edition* (web link: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf, Last accessed February 2020).
[53] Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation, September 2, 2014. Prepared for the Stratospheric Protection Division, Office of Air and Radiation, U.S. EPA by ICF International. Available at https://www.epa.gov/snap/accounting-tool-support-federal-reporting-hydrofluorocarbon-emissions (accessed 7 February 2020).

refrigeration systems are used in retail food industry, that is to say in supermarkets and grocery stores, the Proposed Amendments include additional requirements for existing supermarkets and grocery stores, as outlined in section A.2.

I. Projected Populations of Regulated Refrigeration Systems

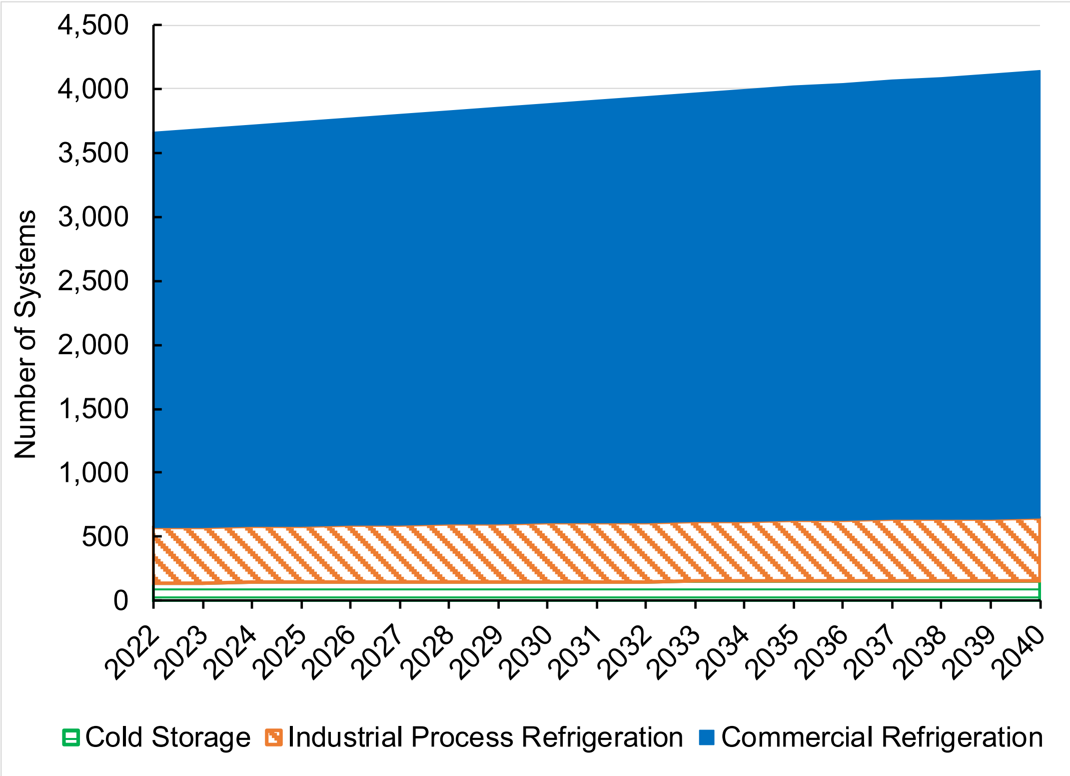
CARB staff used the F-Gas Inventory to estimate the number of new systems entering the California market to quantify baseline emissions and costs related to the Proposed Amendments. The F-Gas Inventory uses data from the following sources to estimate stationary refrigeration system populations:

- Research report by Armines, "Inventory of Direct and Indirect GHG Emissions from Stationary Air conditioning and Refrigeration Sources" for CARB, 2009.[54]
- 2012 Report on Greenhouse Gas Performance Analysis by ICF International.[55]
- Data from CARB's Refrigerant Management Database—Refrigerant Registration and Reporting System or R3.[56]
- Projected population growth from the California Department of Finance.[57]

The number of refrigeration systems within California is growing due to (1) new construction of refrigerated facilities, and (2) due to replacement of retiring equipment in existing facilities. On average, the annual growth in regulated refrigeration equipment correlates with population growth in the state. This is based on the assumption that as population increases, facilities like supermarkets and cold storage warehouses will increase proportionally to serve the additional population. In 2019, DOF projected annual average population growth rates between 0.80 and 0.58 percent between 2020 and 2040. ***Figure* 3.** shows the projected number of new regulated refrigeration systems based on DOF-projected growth rates by end-use sector:

[54] Armines et al., 2009. Inventory of Direct and Indirect GHG Emissions from Stationary Air conditioning and Refrigeration Sources, with Special Emphasis on Retail Food Refrigeration and Unitary Air Conditioning, Final Report, March 2009. CARB research contract 06-325. (web link: https://ww3.arb.ca.gov/research/apr/past/06-325.pdf, Last accessed February 2020).
[55] ICF International, 2012. Greenhouse Gas Performance Analysis for Commercial Buildings with Large Refrigeration and Air Conditioning Systems, Final Report, May 2012. CARB research contract 09-306. (web link: https://ww3.arb.ca.gov/research/apr/past/09-306.pdf, Last accessed February 2020).
[56] California Air Resources Board, 2019. Refrigerant Management Program database, R3. (web link: https://ssl.arb.ca.gov/rmp-r3/, Last accessed February 2020).
[57] California Department of Finance, 2019. Population Projections. (web link: http://www.dof.ca.gov/Forecasting/Demographics/Projections/, Last accessed February 2020).

Figure 3. New refrigeration systems between 2022 and 2040



As mentioned earlier, most refrigeration systems containing more than 50 pounds of HFC refrigerants are used in commercial refrigeration, followed by industrial process refrigeration and cold storage. Annually, new refrigeration systems can either be installed in newly constructed or fully remodeled facilities or they can be used to replace equipment reaching end of their useful life in existing facilities. Based on CARB's F-Gas Inventory, majority of new systems in any given year are used to replace retiring equipment in existing facilities. For example, even though the figure above shows more than 3,500 new regulated refrigeration systems being added in 2020, most of the new units annually are used to replace systems reaching end of life and approximately only 10 to 13 percent of those are used in new construction.[58] In the baseline scenario, the new systems use refrigerants with GWP values between 2,000 and 4,000 depending on the end-use sector. Under the Proposed Amendments, new systems in new facilities will be required to use refrigerants with a GWP less than 150, while existing facilities will be required to use refrigerants with a GWP less than 1,500 across all end-use sectors.

According to the F-Gas Inventory and CARB's RMP program, retail food refrigeration is the largest sub-set of commercial refrigeration. Retail food refrigeration encompasses supermarkets and grocery stores which use 70 percent of the regulated refrigeration systems in California and

[58] Since new construction is assumed to correlate with population growth, in any given year, an average of 0.76 percent of the operational systems are assumed to be added in newly constructed facilities. Depending on average system lifetime, 0.76 percent of operational units equates to 10 to 13 percent of all new systems per year installed in new construction. For this analysis, a similar percentage is assumed to be used in remodeled facilities. See Appendix

Table 63 for more detail.

have the largest amounts of high-GWP refrigerants *banked* inside them. Additionally, systems used for retail food refrigeration have the highest average annual leak rates compared to any other sector.

Table 5 below shows that in 2022, less than 1 percent of the operational systems are expected to be used in new facilities while 99 percent of the systems will be used in existing facilities. Thus, existing facilities hold the highest potential for emissions reductions. Under the baseline scenario, these existing systems would continue to use refrigerants with GWP values between 2,000 and 4,000. Under the Proposed Amendments, new systems in new facilities will be subject to a GWP limit of 150, while existing facilities will be required to reduce their emissions by more than 50 percent. Together, the proposed rules will result in significant emissions reductions while ensuring a greater market adoption of truly sustainable, low-GWP (i.e., GWP < 150) technologies in this sector.

Table 5. Post-Rule Projected Populations of Retail Food Refrigeration Systems

Year	New Systems in New Facilities [a]	Existing Facilities New Systems Replacing Retiring Systems [b]	Existing Facilities Existing Systems (not yet reached end-of-life) [c]	Total Projected Population of Retail Food Systems [d]
2022	256	1,884	34,651	36,791
2023	514	3,783	32,835	37,132
2024	773	5,693	31,001	37,467
2025	1,032	7,598	29,167	37,798
2026	1,290	9,491	27,344	38,124
2027	1,545	11,364	25,540	38,449
2028	1,796	13,206	23,767	38,770
2029	2,041	15,008	22,036	39,086
2030	2,282	16,772	20,345	39,400
2031	2,517	18,495	18,700	39,712
2032	2,745	20,152	17,127	40,023
2033	2,965	21,760	15,608	40,333
2034	3,180	23,324	14,137	40,641
2035	3,382	24,790	12,773	40,946
2036	3,573	26,174	11,500	41,247
2037	3,758	27,511	10,278	41,547
2038	3,934	28,779	9,132	41,844
2039	4,097	29,951	8,091	42,139
2040	4,247	31,021	7,164	42,431

[a] New systems in newly constructed facilities – required to use refrigerants with GWP less than 150, starting 2022 under the Proposed Amendments.
[b] New systems replacing retiring equipment in existing facilities -– required to have an average GWP less than 1,400 under the Proposed Amendments on a company-wide basis.
[c] Existing systems that have not reached their end of life – required to have an average GWP less than 1,400 under the Proposed Amendments on a company-wide basis.
[d] Total population of retail food systems = new systems + existing systems (i.e., footnotes *a* + *b* + *c*).
Projected populations of other regulated refrigeration systems (i.e., cold storage and industrial process refrigeration) are given in Table 63 of the Appendix.

b. *Stationary AC*

The Proposed Amendments affects all types of ACs. For the purpose of this analysis, CARB is categorizing this equipment into the following general categories consistent with the F-Gas Inventory:

Room ACs: This category consists of small AC units that are factory sealed and used for conditioning one room at a time. This includes window-mounted, through-the-wall, portable units, packaged terminal ACs (PTAC), packaged terminal heat pumps (PTHP) typically used in hotels, and dehumidifiers. Due to their small size and relatively low cost, these units are used in private residences, apartments, as well as hotels, small offices, and small shops. While other countries refer to ductless split ACs (mini splits) as room ACs, these types of units are classified as central ACs in the United States and are included in the categories described below.

Residential AC/Heat Pump (HP): This category of equipment is sometimes referred to as "central" or "unitary" AC and includes non-ducted split systems and ducted split and single packaged systems used in residences. In California, the most common type of residential AC is a ducted system that uses a refrigerant to condition air in a central location and the air is distributed to and from rooms by one or more fans and ductwork. Ducted systems can be split systems that connect an indoor and outdoor unit via refrigerant piping or packaged systems that are factory sealed.

CARB tracks residential ACs and residential heat pumps as separate categories in the F-Gas Inventory because of the interest heat pumps have received as a potential strategy for reducing emissions from natural gas use related to heating homes. The main difference between residential and commercial units is the size and capacity of the system to condition larger spaces. Units under 65,000 Btu/hr are categorized as residential, consistent with AHRI certification standards and the U.S. DOE energy equipment categories in their energy conservation standards.[59] According to AHRI shipment data, approximately 96 percent of shipments are residential ACs.[60]

Commercial AC: AHRI certification standards and the U.S. DOE use 65,000 Btu/hr as the size threshold to distinguish between ACs used in residential and commercial and other non-residential settings. For the purpose of this analysis, the commercial AC category includes AC units used in commercial buildings and non-residential uses such as state buildings, schools and hospitals. While commercial ACs make up approximately 4 to 5 percent of AC shipments, CARB distinguishes between two size ranges of commercial equipment because of the difference in baseline cost and the emission profile of these units. This category includes both ACs and heat pumps but they are not disaggregated as separate categories.

[59] 10 C.F.R. § 430.32 2017; 11 C.F.R. § 431.92 2016.
[60] Air-Conditioning, Heating, and Refrigeration Institute (AHRI) monthly shipment data reports. Web link at: http://www.ahrinet.org/statistics (accessed February 2020).

- *Commercial AC (Small to Medium):* Units ≥ 65,000 Btu/hr and < 135,000 Btu/hr are classified as small to medium, consistent with the U.S. DOE equipment categories used in their energy conservation standards. [61]
- *Commercial AC (Large):* Units ≥ 135,000 Btu/hr are classified as large, consistent with the U.S. DOE equipment categories used in their energy conservation standards.[62]

The majority of ACs sold in California today use the refrigerant R-410A, which has a GWP value of 2,088, with the exception of room ACs, which have already begun to transition to a lower-GWP refrigerant. Room ACs such as portable and window/wall ACs are already available on the California market today with R-32, which has a GWP value of 675. While the baseline refrigerant is predominately R-410A across different AC categories, the average unit lifetimes, charge size and leak rates vary by equipment type. ***Table 6*** lists these baseline characteristics from CARB's F-Gas Inventory.[63] Staff use these factors to estimate emissions on a per unit basis and in the cost impact analysis.

Table 6. Baseline characteristics for stationary AC

System Type	Baseline Refrigerant	Baseline GWP (100-year, AR4)	Lifetime (Years)	Average Charge Size (lbs.)	Average Annual Leak Rate (%)	Average End-of-Life Leak Rate (%)
Room AC – window/wall	R-410A; R-32	1,382	12	1.54	2.0%	98.5%
Room AC – portable	R-410A; R-32	1,382	10	1.54	1.0%	98.5%
Room AC – PTAC/PTHP	R-410A; R-32	1,382	12	1.0	2.0%	98.5%
Room AC – dehumidifiers	R-410A	2,088	5	1.0	1.0%	98.5%
Residential AC	R-410A	2,088	15	8.157	5.3%	80.0%
Residential HP	R-410A	2,088	15	7.5	5.0%	80.0%
Non-residential AC (≥ 65k to <135,000k BTUH)	R-410A	2,088	20	25	10.0%	56.0%
Non-residential AC (≥ 135,000k BTUH)	R-410A	2,088	20	60	7.0%	20.0%

[61] 11 C.F.R. § 431.92 2016.
[62] Ibid.
[63] California Air Resources Board, 2016, California's High Global Warming Potential Gases Emission Inventory: Emission Inventory Methodology and Technical Support Document, 2015 Edition (web link: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf, Last accessed February 2020).

II. Projected Populations of Regulated AC Equipment

CARB staff used the F-Gas Inventory to estimate the number of new ACs entering the California market to quantify baseline emission and costs related to this regulation. The number of AC units within California is growing, due to both continued construction of new buildings and because more and more buildings are installing ACs. CARB estimates AC equipment growth rates based on historical shipment data, housing and population projections growth, and AC saturation trends. The F-Gas Inventory uses data from the following sources for to estimate stationary AC equipment populations:

- National shipment data from the AHRI from 1999 to 2018.[64]
- California shipment data from Heating, Air-conditioning and Refrigeration Distributors International (HARDI).
- 2009 California Residential Appliance Saturation Surveys (RASS).[65]
- U.S. Energy Information Agency (EIA) Residential Energy Consumption Survey (RECS).[66]
- Population and housing demographic information from the California Department of Finance.[67]

The number of AC equipment using F-Gases correlate strongly with population.[68] DOF projects annual average population growth rates between 0.8 and 0.6 percent between 2020 and 2040 with an average of 0.7 percent. However, based on annual AC equipment shipments from 2000 through 2018 tracked by AHRI, we know that AC usage has historically grown faster than population growth in California, and if global warming continues, we expect this trend to continue into the future.[69] For residential ACs, staff estimates equipment growth at 1.5 times that population growth (1.1 percent annual equipment growth). For residential heat pumps, staff estimates equipment growth as double the annual population growth (1.5 percent annual equipment growth). For all other AC equipment categories staff estimates equipment growth as an equivalent one-to-one correlation with population growth. The figure below shows the number of projected new ACs based on these growth rates.

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[64] Air Conditioning, Heating, & Refrigeration Institute, 2019. Central Air Conditioners and Air-Source Heat Pumps" U.S. Manufacturers' Shipments of Central Air Conditioners and Air-Source Heat Pumps, 1999-2018. (web link: http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps, Last accessed February 2020).

[65] California Energy Commission, 2010. California 2009 Residential Appliance Saturation Study (RASS). *https://ww2.energy.ca.gov/appliances/rass/previous_rass.html*, Last accessed February 2020).

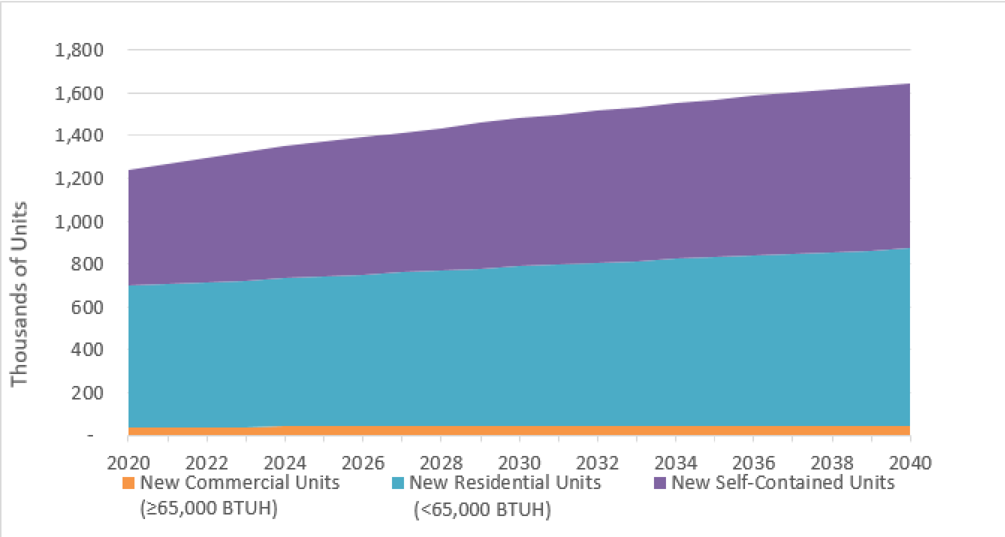
[66] California Energy Commission, 2010. California 2009 Residential Appliance Saturation Study (RASS). (web link: https://ww2.energy.ca.gov/appliances/rass/previous_rass.html, Last accessed February 2020). See also Energy Information Administration, Residential Energy Consumption Survey (RECS), 2003, 2009 and 2015 Survey Years. (web link: https://www.eia.gov/consumption/residential/data/2015/, Last accessed February 2020).

[67] California Department of Finance, 2019. Population Projections. http://www.dof.ca.gov/Forecasting/Demographics/Projections/, Last accessed February 2020).

[68] Barletta, et al., 2013. Emission estimates of HCFCs and HFCs in California from the 2010 CalNex study. (web link: https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1002/jgrd.50209, Last accessed February 2020).

[69] Air Conditioning, Heating, & Refrigeration Institute, 2019. Central Air Conditioners and Air-Source Heat Pumps" U.S. Manufacturers' Shipments of Central Air Conditioners and Air-Source Heat Pumps, 1999-2018. (web link: http://www.ahrinet.org/Resources/Statistics/Historical-Data/Central-Air-Conditioners-and-Air-Source-Heat-Pumps, Last accessed February 2020).

Figure 4. Projected New AC Shipments to California (2020 to 2040)



The projected populations of regulated AC equipment through 2040 is given below:

Table 7. Projected Shipments of Stationary AC Equipment

Year	New Air-Conditioning Units		
	Non-residential	Residential	Small Self-Contained AC
2020	37,797	659,713	539,390
2021	38,096	668,456	557,842
2022	38,393	677,215	577,154
2023	38,689	685,949	597,367
2024	38,982	694,689	618,526
2025	39,274	703,416	630,372
2026	39,566	712,192	642,486
2027	39,857	720,991	654,877
2028	40,145	729,737	667,549
2029	40,432	738,501	680,511
2030	40,718	747,262	693,769
2031	41,000	755,963	702,550
2032	41,277	764,565	711,450
2033	41,550	773,053	720,471
2034	41,820	781,495	729,616
2035	42,080	789,685	738,885
2036	42,337	797,801	745,705
2037	42,589	805,792	752,589
2038	42,836	813,657	759,538
2039	43,077	821,349	766,552
2040	43,311	828,870	773,632

6. Public Outreach and Input

The Proposed Amendments have been developed through an extensive process of engagement with the public and industry stakeholders. In 2017, 2018, 2019, and 2020, CARB conducted four public workshops, which were webcast and made available by teleconference, on the Proposed Amendments. Information regarding these workshops and any associated materials are posted on the CARB website and distributed through several public listserves that include over 30,000 recipients. The workshops and meetings allowed CARB staff to consider stakeholder feedback and to incorporate it into the Proposed Amendments, as appropriate. CARB staff will continue to consider stakeholder feedback throughout the regulatory adoption process, including up to the adoption of the final regulation.

CARB staff worked closely with many of the stationary refrigeration stakeholders over the last decade, many of whom are subject to *California's Refrigerant Management Program* that was approved by the Board in December 2009 as well as the "*Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration and Foam End-Uses*" (CA SNAP) adopted in March 2018. The public outreach process for RMP[70] and the CA SNAP[71] are described in the Initial Statement of Reasons (ISOR) for each of the rulemakings.

The low-GWP refrigerant requirements for both refrigeration and AC equipment were recommended by CARB and made publicly available as early as December 2008 in the first Climate Change Scoping Plan.[72] The low-GWP requirements proposed in this rulemaking were reiterated and described in three additional CARB documents: First Update to the Climate Change Scoping Plan (2014);[73] California's 2017 Climate Change Scoping Plan;[74] and the Short-Lived Climate Pollutant Reduction (SLCP) Strategy (2017).[75] The specific GWP limits were first proposed as 150 GWP for stationary refrigeration and 750 for stationary AC in the Draft SLCP

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[70] California Air Resources Board, Initial Statement of Reasons: Refrigerant Management Program, 2009. (web link: https://ww3.arb.ca.gov/regact/2009/gwprmp09/isorref.pdf, Last accessed February 2020).
[71] California Air Resources Board, Initial Statement of Reasons: Public Hearing to Consider the Proposed Regulation for Prohibitions on use of Certain Hydrofluorocarbons in Stationary Refrigeration and Foam End Uses, 2018. (web link: https://ww3.arb.ca.gov/regact/2018/casnap/isor.pdf?_ga=2.97926559.1258857852.1573774546-109732520.1501863071, Last accessed February 2020).
[72] California Air Resources Board, 2008. Climate Change Scoping Plan - a framework for change - pursuant to AB 32, The California Global Warming Solutions Act of 2006, and Climate Change Scoping Plan Appendices Volume 1: Supporting Documents and Measure Detail (web link: https://ww3.arb.ca.gov/cc/scopingplan/document/adopted_scoping_plan.pdf and https://ww3.arb.ca.gov/cc/scopingplan/document/appendices_volume1.pdf, Last accessed February 2020).
[73] California Air Resources Board, 2014. First Update to the Climate Change Scoping Plan - Building on the Framework - pursuant to AB 32, The California Global Warming Solutions Act of 2006 (web link: https://ww3.arb.ca.gov/cc/scopingplan/2013_update/first_update_climate_change_scoping_plan.pdf, Last accessed February 2020).
[74] California Air Resources Board, 2017. California's 2017 Climate Change Scoping Plan - The strategy for achieving California's 2030 greenhouse gas target (web link: https://ww3.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf, Last accessed February 2020).
[75] California Air Resources Board, 2017. Short-Lived Climate Pollutant Reduction Strategy (web link: https://ww3.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf, Last accessed February 2020).

Strategy,[76] which was released in September 2015 and included in the final draft approved by the Board in 2017. Since then, equipment manufacturers, trade organizations, nonprofits and others have been in close contact with CARB, providing information regarding the status of commercialization and market adoption of technologies that can meet these limits and input on the Proposed Amendments.

Recently, the outreach has focused on gathering stakeholder input on the technical feasibility, cost and enforceability of the proposal. Public outreach in support of developing the regulatory proposal includes but is not limited to the following activities:

CARB Public Workshops: Since 2017, CARB has held four public workshops regarding this regulatory proposal (October 2017; [77] October 2018; [78] March 2019; [79] and August 2019.[80]). Staff posted information regarding these workshops and associated materials on the HFC Reduction Measures website[81] and distributed notices through four public list serves maintained by CARB that include over 30,000 recipients who have identified the following as their topics of interest: "climate change"; "commercial refrigeration specifications"; "HFC reduction measures"; and" stationary equipment refrigerant management program." At the meetings, which were available by webinar and by teleconference, CARB solicited stakeholder feedback on the regulation. CARB staff worked closely with stakeholders, reviewing their comments from both the workshop along with several follow-up meetings to discuss their comments and recommendations.

External Public Presentations: In addition to public workshops and meetings hosted by CARB, staff presented details of the regulatory proposal and sought input through the following: presentation through Greenchill, a U.S. EPA web series supporting food retailers in reducing refrigerant emission and decreasing their impact on the ozone layer and climate in April 2019;[82] staff presentation at the UC Davis Energy Affiliates Forum in April 2019; conference presentation

[76] California Air Resources Board, 2015. California Air Resources Board (CARB) "Draft Short-Lived Climate Pollutant Reduction Strategy. "(web link: https://ww3.arb.ca.gov/cc/shortlived/2015draft.pdf, Last accessed February 2020).
[77] California Air Resources Board, 2017. Meeting Notice for Rulemaking Proposal: High-Global Warming Potential Refrigerant Emissions Reductions. (web link: https://ww3.arb.ca.gov/cc/shortlived/meetings/10242017/2017-10-5-workshop-notice-hfc-rulemaking.pdf?_ga=2.156768955.1258857852.1573774546-109732520.1501863071, Last accessed February 2020).
[78] California Air Resources Board, 2018. Workshop on Upcoming Hydrofluorocarbon Emission Reduction Measures. (web link: https://ww2.arb.ca.gov/resources/documents/hfc-reduction-measures-workshop-october-24-2018., Last accessed November 2019).
[79] California Air Resources Board, 2019. Technical Working Group Meeting on Upcoming Stationary Air Conditioning Regulation. (web link: https://ww2.arb.ca.gov/sites/default/files/2019-02/Email%20Invite%20-%20Technical%20Working%20Group_2019_03_06_1.pdf, Last accessed February 2020).
[80] California Air Resources Board, 2019. Technical Working Group Meeting on Upcoming HFC Regulations for Stationary Refrigeration and AC Equipment (web link: https://ww2.arb.ca.gov/sites/default/files/2019-07/Technical%20Working%20Group%20Notice%20-%20August%202019.pdf, Last accessed February 2020).
[81] California Air Resources Board, Stationary Hydrofluorocarbon Reduction Measures Website (web link: https://ww2.arb.ca.gov/our-work/programs/stationary-hydrofluorocarbon-reduction-measures, Last accessed February 2020).
[82] California Air Resources Board, 2019. California Cooling Act and Proposed High-Global Warming Potential Refrigerant Prohibitions. (web link: https://www.epa.gov/greenchill/events-and-webinars, Last accessed February 2020).

at ATMO America in June 2019;[83] staff presentation at a Western Heating Ventilation and Air Conditioning Performance Alliance (WHPA) meeting in May 2019 and a staff presentation at workshops organized by the North American Sustainable Refrigeration Council in July 2019 and January 2020.[84]

CARB Surveys: Staff circulated surveys to equipment manufacturers, refrigerant manufacturers, distributors/wholesalers, reclaimers, and trade groups from December 2018 to March 2019 to better understand cost impacts associated with the regulatory proposal.

Stakeholder Meetings: Staff held frequent in-person meetings and conference calls with multiple stakeholders interested in providing input to CARB throughout the period from October 2017 to January 2020. In addition to in-person meetings, CARB also held teleconferences to develop the proposed rule, exchange feedback, identify plausible solutions to any implementation challenges, and ultimately ensure the development of feasible compliance pathways for the end-users, one of which was suggested directly by them. CARB staff have worked closely with more than 150 separate stakeholders, in the development of the Proposed Amendments, who can be generally described as representing the following groups:

- Original equipment manufacturers (OEMs) of refrigeration and AC equipment.
- Components manufacturers of refrigeration and AC equipment.
- Groups of supermarket companies and the North American Sustainable Refrigeration Council (NASRC).
- Industry trade groups representing OEMs and end-users.
- End-users, including but not limited to: supermarket and grocery store owners and managers; wine, beer, and beverage makers; refrigerated warehouse, cold storage, and refrigerated distributing facilities.
- Design, engineering and consulting firms.
- Refrigerant manufacturers.
- Refrigerant distributors and distributor trade groups.
- Federal government agencies, including the U.S. EPA and the U.S. DOE.
- California state agencies, including local air districts, the CEC, California Public Utilities Commission (CPUC), and the Office of the State Fire Marshal.

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[83] California Air Resources Board, 2019. HFC Refrigerant Regulations in California –New and Proposed. (web link: https://www.slideshare.net/ATMO/glenn-gallagher-california-air-resources-board-carb, Last accessed February 2020).
[84] California Air Resources Board, 2019. NASRC Refrigerants Workshop Seeks to Align Climate and Energy Goals in California. (web link: http://nasrc.org/articles1/2019/5/29/nasrc-refrigerants-workshop-seeks-to-align-climate-and-energy-goals-in-california, Last accessed February 2020).

- Utility company representatives.
- Labor groups representing HVACR contractors and technicians.
- Non-profit environmental organizations.

CARB continues to consider public and stakeholder feedback and specifically requested data and input regarding alternatives from those who would be subject to or affected by the regulations (including other state agencies and local agencies, where appropriate) at the public workshops held in March and August 2018.

B. BENEFITS

The Proposed Amendments have been designed to support growth in technologies that lower HFC emissions. It is anticipated that the Proposed Amendments will reduce HFC emissions from the refrigeration sector by nearly 50 percent below baseline by 2040 and 56 percent below baseline by 2040 in the AC sector. Cumulatively, from 2022 through 2040, the Proposed Amendments are expected to yield 75 $MMTCO_2e$ in GHG reductions. Using 20-year GWP values, the Proposed Amendments are expected to yield cumulative GHG emissions reductions of nearly 150 $MMTCO_2e$ by 2040. The total benefits in avoided harms range between $1.69 billion to $7.32 billion through 2040, depending on the discount rate. \

CARB used its F-Gas Inventory to analyze the economic and emissions impacts and benefits for the baseline (or BAU) and alternative scenarios. We begin this section with a brief description of the F-Gas inventory methodology.

1. Inventory Methodology

CARB maintains a California specific F-Gas Inventory as a part of the statewide GHG Emission Inventory, which is used for establishing historical emission trends and tracking California's progress in reducing greenhouse gases. The F-Gas Inventory estimates annual emissions of F-gases, including HFCs, from sources including refrigeration, air conditioning, aerosol propellants, foams, solvents and fire protection end-uses. The F-Gas Inventory is based on the U.S. EPA's Vintaging Model that tracks the use and emissions of annual "vintages" of equipment that are produced each year.

To estimate emissions, CARB maintains emissions profiles for each distinct end-use category of equipment of product that emits an F-Gas. The emissions profile includes the number of units[85], amount of F-Gas required by each unit also called the "charge size," as well as annual and end-of-life leak rates. Since it was initially developed in 2007, CARB steadily refined initial F-Gas emission estimates by replacing scaled down national estimates from the U.S. EPA Vintaging Model with California state-specific estimates based on comprehensive research completed by CARB staff and studies completed by CARB contractors. The F-Gas Inventory is updated periodically as emissions profiles are further refined by incorporating the latest activity data, research and monitoring. The full methodology is available in the latest *Emission Inventory Methodology and Technical Support Document* for the Greenhouse Gas Inventory[86] and is also the subject of a peer-reviewed scientific paper by CARB staff Gallagher, et al., 2014, published in the journal Environmental Science and Technology.[87]

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[85] "Units" is generally interchangeable with the term "equipment" or "system" and for Inventory purposes refers to a single system connected through a refrigerant circuit.

[86] California Air Resources Board, 2016, California's High Global Warming Potential Gases Emission Inventory: Emission Inventory Methodology and Technical Support Document, *2015 Edition* (web link: https://ww3.arb.ca.gov/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf, Last accessed February 2020).

[87] Gallagher, G. et al., (2014), High-global Warming Potential F-Gas Emissions in California: Comparison of Ambient-based versus Inventory-based Emission Estimates, and Implications of Estimate Refinements (web link: https://pubs.acs.org/doi/pdf/10.1021/es403447v, Last accessed February 2020).

Staff assume that without regulatory drivers, the use of HFCs will continue to grow rapidly as ODS are phased out of new production. There are a few exceptions. The following non-refrigerant end-use sectors have voluntarily transitioned away from using HFCs:

- Foam expansion agents have replaced HFCs with less costly hydrocarbons for many foam end-use sectors.
- Aerosol propellants have replaced HFCs with hydrocarbons in many consumer products.
- HFC solvents have been replaced by non-fluorinated solvents, including water-based solvents.
- HFC fire suppressants have been replaced by non-fluorinated alternatives and low-GWP fluorocarbons.

The BAU does not include speculative future changes in equipment average charge sizes, annual leak rates, or end-of-life loss rates. Charge sizes, annual leak rates and equipment end-of-life loss rates remain the same as current years, unless acted upon by exterior forces such as regulations that have been adopted at the state or national level. New units are assumed to use the same amount and type of F-Gas as used in current and previous years, until adopted regulations prohibit the use of specific F-Gases for that end-use.

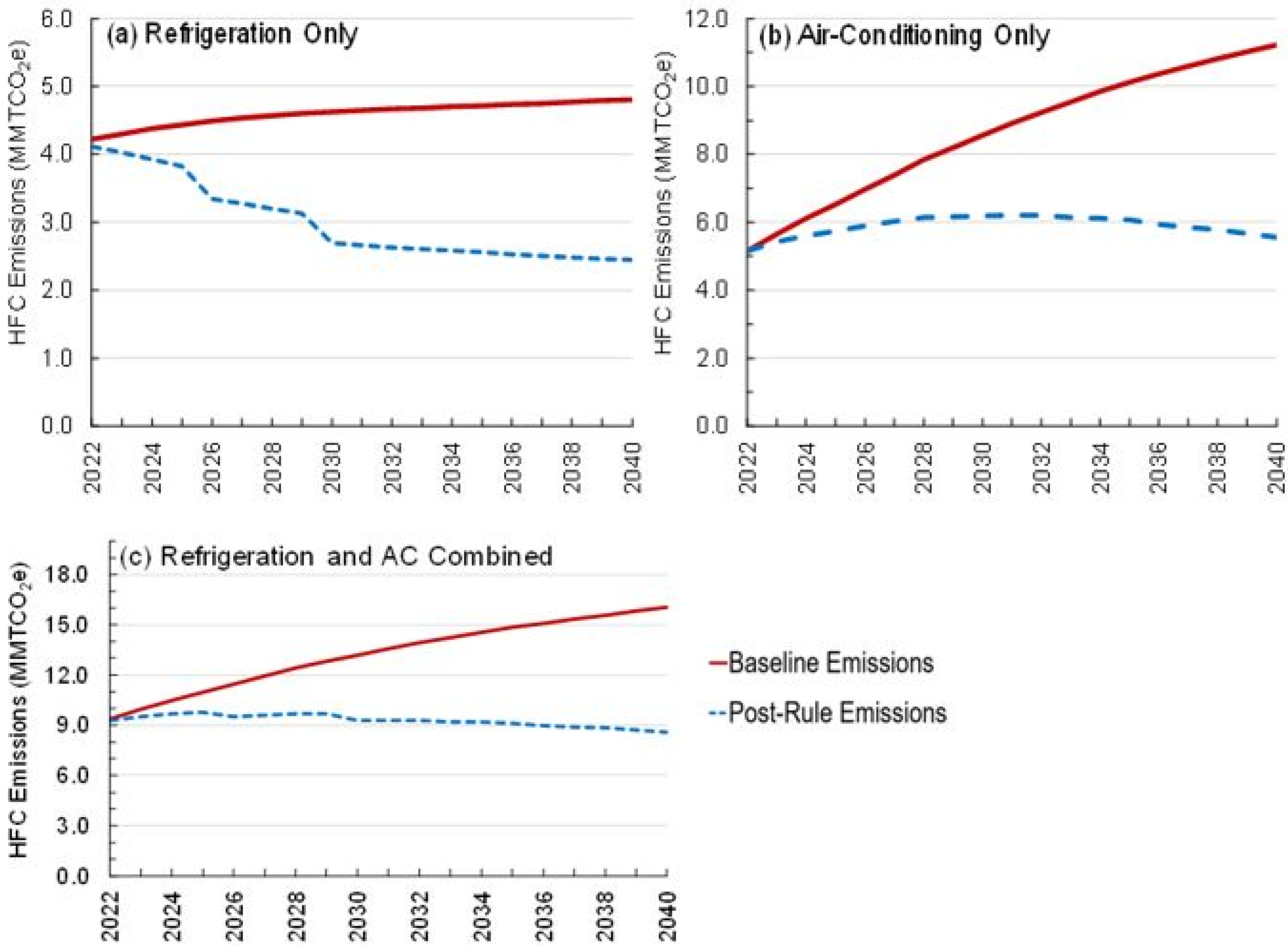
2. Emission Benefits

CARB's 2017 Short Lived Climate Pollutant Reduction Strategy identifies prohibitions of high-GWP refrigerants in new equipment as one of the key measures to reduce HFC emissions in the State, as mandated by the State legislature.[88] Figure 5 below identifies the projected annual baseline HFC emissions and expected reductions from the Proposed Amendments as they pertain to refrigeration equipment, AC equipment, and both sectors combined.

[88] California Air Resources Board, 2017. Short Lived Climate Pollutant Reduction Strategy. (web link: https://ww2.arb.ca.gov/sites/default/files/2018-12/final_slcp_report%20Final%202017.pdf, Last accessed February 2020).

[88] California Air Resources Board, 2017. Short Lived Climate Pollutant Reduction Strategy. (web link: https://ww2.arb.ca.gov/sites/default/files/2018-12/final_slcp_report%20Final%202017.pdf, Last accessed February 2020).

Figure 5. Projected Annual Baseline HFC Emissions and Expected Reductions from the Proposed Amendments as they pertain to (a) refrigeration equipment only, (b) air-conditioning equipment only, and (c) refrigeration and AC equipment combined



For refrigeration, existing SB 1013 requirements prevent a rapid increase in the projected baseline GHG emissions from those systems, but the high-GWP refrigerants currently contained in the existing systems continue to be the greatest source of emissions from the sector. Under the Proposed Amendments, most of the existing refrigerated facilities (i.e., retail food facilities) will be required to reduce their weighted-average GWP of their banked refrigerants to below 1,400 by 2030, with a progress step in 2026, which is reflected in Figure 5 (a) above. In addition, new systems that will be installed in newly constructed or remodeled facilities will be required to use refrigerants with GWP less than 150. From these measures combined, HFC emissions from the refrigeration sector are expected to decline by nearly 50 percent below baseline by 2040.

In contrast to the refrigeration equipment, HFC use and emissions from the air-conditioning sector are projected to grow rapidly. This is due to a combination of factors: use of HFCs in the sector is not currently regulated by SB 1013 and AC use is expected to grow in an increasingly warming climate. The primary factor driving the large increase of HFC use and emissions in the air-conditioning and refrigeration sectors is that new equipment using HFC refrigerants are replacing older equipment using ozone-depleting substance (ODS) refrigerants. Because ODS emissions are intentionally not included in California's GHG Inventory (by design of the Kyoto Protocol and AB 32), the growth of HFC emissions reflects not only simple growth in the number of new equipment used each year, but also the replacement of ODS equipment with HFC equipment. Reducing the GWP of new AC equipment to below 750 is expected to reduce emissions from this sector by 56 percent below baseline by 2040 (Figure 5. (b)).

Combined, the annual average reduction in HFC emissions from the refrigeration and AC sectors is estimated to 4.0 $MMTCO_2e$, from the stationary refrigeration and AC sectors combined between 2022 and 2040 (Figure 5. (c)). This is equivalent to removing GHG emissions from 850,000 passenger vehicles driven per year.[89] Cumulatively, from 2022 through 2040, the Proposed Amendments are expected to yield 75 $MMTCO_2e$ in GHG reductions from the two sectors. The annual and cumulative reductions are given in Table 8.

Table 8. Annual and Cumulative Emissions Reductions from the Proposed Amendments (using 100-year GWP values)

Year	Refrigeration + AC	
	Annual Reductions ($MMTCO_2e$)	Cumulative Reductions ($MMTCO_2e$)
2022	0.1	0.1
2023	0.4	0.5
2024	0.8	1.3
2025	1.2	2.5
2026	1.9	4.5
2027	2.3	6.8
2028	2.7	9.5
2029	3.1	12.6
2030	3.9	16.5
2031	4.3	20.8
2032	4.6	25.4
2033	5.0	30.4
2034	5.4	35.8
2035	5.7	41.5
2036	6.1	47.6
2037	6.5	54.1
2038	6.8	60.8
2039	7.1	67.9
2040	7.5	75.4

It is important to note that the emissions benefits discussed above are calculated using the 100-year GWP values of the HFC refrigerants. A 100–year GWP value is reflective of the warming

[89]United States Environmental Protection Agency, 2019. Greenhouse Gas Equivalencies Calculator. (web link: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator, Last accessed, January 2020).

impact of an HFC relative to CO_2 over that time period. In reality, most HFCs used as refrigerants or as part of refrigerant blends have atmospheric lifetimes shorter than 100 years and thus, their warming impact is even worse in the shorter term. To estimate more near term impacts, HFC emissions can be calculated using their 20-year GWP values. For the HFCs used in refrigeration and AC equipment, the average 20-year GWP is approximately double the 100-year average GWP. Thus, using 20-year GWP values, the Proposed Amendments are expected to yield cumulative GHG emissions reductions of more than 150 $MMTCO_2e$ by 2040. While we use 100-year GWP values throughout this document and for the purposes of the rulemaking, it is important to highlight the potential near-term impacts of these "super-pollutants" and the extent of damage HFCs can cause within just a few decades.

3. Benefits to Typical Businesses

a. Stationary Refrigeration

The economic analysis for refrigeration systems discusses all costs directly from an end-users perspective. End-users of regulated refrigeration systems include both typical and small businesses, such as independent owners / operators of grocery stores, cold storage warehouses and small industrial process refrigeration facilities. Benefits experienced by small businesses will be the same as those experienced by typical businesses discussed above.

Typical businesses (e.g., supermarkets, grocery stores, food production and other manufacturing facilities, and cold storage warehouses) are expected to benefit from early implementation of lower-GWP technologies. Equipment manufacturers providing compliant solutions will also benefit from increased market adoption of low-GWP technologies and will have the opportunity to establish themselves as market leaders in California. From an end-user standpoint, under the Proposed Amendments for refrigeration systems, facilities that replace their existing systems with low-GWP systems and start using non-synthetic or "natural" refrigerants (e.g., CO_2, ammonia or propane) will have much lower ongoing cost for replenishing leaked refrigerant. Additionally, any facility that only contains systems greater than 50 pounds using refrigerants with GWP values less than 150 will be exempt from the RMP regulation. This will reduce current costs associated with compliance. Furthermore, using low-GWP technologies will reduce the exposure of end-users to future regulations and the global HFC phase-down. Facilities that retrofit refrigeration equipment can also expect to realize electricity cost-savings due to two main factors: 1) energy efficiencies of compliant refrigerants like R-448A/R-449A are higher compared to current, commonly used refrigerants like R-404A and, 2) as part of the refrigerant retrofit, refrigeration systems will get a "tune up" that may not have otherwise occurred and generally results in greater energy efficiency. These cost-savings a fully quantified in the Direct Costs section.

b. Stationary AC

For AC, the typical business affected by the Proposed Amendments are AC manufacturers. There are no quantifiable benefits to AC manufacturers. However, AC manufacturers bringing new technologies to market will benefit economically in the long-term as other adoption of these technologies expands beyond California because of market pressures from the Kigali Amendment and other drivers to transition away from high-GWP refrigerants. There is no single typical business using commercial AC equipment. All businesses using commercial ACs that purchase a new AC after 2023 will be affected and there are no direct benefits to these businesses other than the avoided impacts of climate change.

c. Other California Businesses

The Proposed Amendments are estimated to result in increased expenditures for contractors who install and maintain the regulated equipment. This will benefit businesses who provide these services through increased sales. These indirect effects are accounted for in the Macroeconomic Analysis (Section E).

4. Benefits to Small Businesses

a. Stationary Refrigeration

The economic analysis for refrigeration systems discusses all costs directly from an end-users perspective. End-users of regulated refrigeration systems include both typical and small businesses, such as independent owners / operators of grocery stores, cold storage warehouses and small industrial process refrigeration facilities. Benefits experienced by small businesses will be the same as those experienced by typical businesses discussed above.

b. Stationary AC

There are no small business AC manufacturers that have been identified as affected by the Proposed Amendments. All small businesses in California that purchase a new AC system from 2023 onward are affected by the Proposed Amendments. There are no direct benefits to these businesses other than avoided impacts from climate change.

c. Other California Businesses

The Proposed Amendments for refrigeration equipment used in existing retail food outlets may result in benefits to both typical and small businesses – the proposed rule requires supermarkets and grocery stores in California to reduce their current average GWP and/or emissions potential by more than 50 percent by 2030. This can be accomplished through several options, all of which require technical skills and experiences likely to create a higher demand for refrigerant service and recovery contractors and technicians. The service industry jobs are local and located in California, and thus likely to benefit the local economy.

The Proposed Amendments are estimated to result in increased expenditures for contractors who install and maintain the regulated equipment. This will benefit small businesses who provide these services through increased sales. These indirect effects are accounted for in the Macroeconomic Analysis (Section E).

5. Benefits to Individuals

Other than the social cost of carbon discussed below, there are no direct health benefits to individuals as a result of the Proposed Amendments. Any indirect or induced impacts are discussed in the Macroeconomic Impact section.

a. Social Cost of Carbon

The benefit of these GHG reductions can be estimated using the Social Cost of Carbon (SC-CO_2), which provides a dollar valuation of the damages caused by one ton of carbon pollution and represents the monetary benefit today of reducing carbon emissions in the future.

In this analysis, CARB utilizes the current Interagency Working Group (IWG) supported SC-CO_2 values to consider the social costs of actions taken to reduce GHG emissions. This is consistent with the approach presented in the Revised 2017 Climate Change Scoping Plan [90] and is in line with Executive Orders including 12866 and the OMB Circular A-4 of September 17, 2003, and reflects the best available science in the estimation of the socio-economic impacts of carbon.[91]

The IWG describes SC-CO_2 as follows:

The social cost of carbon (SC-CO_2) for a given year is an estimate, in dollars, of the present discounted value of the future damage caused by a 1-metric ton increase in carbon dioxide (CO_2) emissions into the atmosphere in that year, or equivalently, the benefits of reducing CO_2 emissions by the same amount in that year. The SC-CO_2 is intended to provide a comprehensive measure of the net damages – that is, the monetized value of the net impacts – from global climate change that result from an additional ton of CO_2.

These damages include, but are not limited to, changes in net agricultural productivity, energy use, human health, property damage from increased flood risk, as well as nonmarket damages, such as the services that natural ecosystems provide to society. Many of these damages from CO_2 emissions today will affect economic outcomes throughout the next several centuries.[92]

Table 9 presents the range of IWG SC-CO_2 values used in regulatory assessments, including the 2017 Scoping Plan.

Table 9. Social Cost of Carbon, 2015 – 2040 (2007$ Per Metric Ton)

Year	5 Percent Discount Rate	3 Percent Discount Rate	2.5 Percent Discount Rate
2020	$12	$42	$62
2025	$14	$46	$68
2030	$16	$50	$73
2035	$18	$55	$78
2040	$21	$60	$84
2045	$23	$64	$89

[90] California Air Resources Board, California's 2017 Climate Change Scoping Plan, released in November 2017 (web link: https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf, Last accessed June 2019).
[91] Office of Management and Budgets, Circular A-4 (web link: https://www.transportation.gov/sites/dot.gov/files/docs/OMB%20Circular%20No.%20A-4.pdf, Last accessed February 2020).

[92] National Academies of Sciences, Engineering, Medicine, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017, (web link: www.nap.edu/24651, Last accessed February 2020).

The SC-CO_2 is year specific; that is, environmental damages are estimated for a given year in the future and the value of the damages is discounted back to the present. The SC-CO_2 increases over time as systems become stressed from the aggregate impacts of climate change and future emissions cause incrementally larger damages. The SC-CO_2 is highly sensitive to the discount rate. Higher discount rates decrease the value today of future environmental damages. The IWG estimates the SC-CO_2 across a range of discount rates that encompass a variety of assumptions regarding the correlation between climate damages and consumption of goods and is consistent with OMB's Circular A-4 guidance. CARB utilizes the IWG standardized range of discount rates, from 2.5 to 5 percent to represent varying valuation of future damages and adjusts them for inflation using California Consumer Price Index (CPI).[93] An inflation adjustment, using the California Consumer Product Index (CPI), is applied to the values to convert them 2018 dollars, consistent with the rest of this analysis.[94]

If all of the expected emissions reductions projected under the Proposed Amendment are achieved and assumed to be equivalent to CO_2 reductions, the avoided SC-CO_2 in a given year is the total emissions reductions (in $MTCO_2e$) multiplied by the SC-CO_2 (in $/$MTCO_2e$) for that year. The annual emissions reductions from the Proposed Amendments and the estimated benefits are shown in **Table 10** below. The total benefits range between $1.69 billion to $7.32 billion through 2040, depending on the discount rate.

Table 10. Avoided Social Cost of CO_2 (Million 2018$)

Year	GHG Emissions Reductions ($MMTCO_2e$)	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2022	0.1	$1.70	$5.60	$8.30
2023	0.4	$7.20	$24.4	$36.1
2024	0.8	$13.0	$45.1	$66.1
2025	1.2	$20.5	$67.4	$99.7
2026	1.9	$34.1	$115	$168
2027	2.3	$43.7	$140	$204
2028	2.7	$51.1	$167	$242
2029	3.1	$58.7	$192	$282
2030	3.9	$78.2	$244	$357
2031	4.3	$85.3	$272	$395
2032	4.6	$98.2	$301	$433
2033	5.0	$107	$334	$479
2034	5.4	$122	$364	$520

[93] National Academies of Sciences, Engineering, Medicine, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, 2017, (web link: www.nap.edu/24651, Last accessed February 2020). As noted in the 2017 Scoping Plan, CARB is aware that the current federal administration has recently withdrawn certain social cost of carbon reports as no longer representative of federal governmental policy. However, this determination does not call into question the validity and scientific integrity of federal social cost of carbon work, or the merit of independent scientific work. Indeed, the IWG's work remains relevant, valid, reliable, and appropriate for use for these purposes.

[94] California Department of Finance. California Consumer Product Index (CPI-U), (web link: http://dof.ca.gov/Forecasting/Economics/Indicators/Inflation/, Last accessed February 2020).

Year	GHG Emissions Reductions ($MMTCO_2e$)	5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2035	5.7	$129	$394	$558
2036	6.1	$146	$429	$605
2037	6.5	$154	$461	$655
2038	6.8	$169	$491	$694
2039	7.1	$178	$526	$740
2040	7.5	$196	$560	$784
Total	75	$1,690	$5,130	$7,320

There is an active discussion within government and academia about the role of SC-CO_2 in assessing regulations, quantifying avoided climate damages, and the values themselves. In January 2017, the National Academies of Sciences, Engineering, and Medicine (NAS) released a report examining potential approaches for a comprehensive update to the SC-CO_2 methodology to ensure resulting cost estimates reflect the best-available science. The NAS review did not modify the estimated values of the SC-CO_2, but evaluated the models, assumptions, handling of uncertainty, and discounting used in the estimating of the SC-CO_2. The report titled, "Valuating Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide," recommends near-term improvements to the existing IWG SC-CO_2 as well as a long-term comprehensive updates. The State will continue to follow updates to the IWG SC-CO2, outlined in the NAS report, and incorporate appropriate peer-reviewed modifications to estimates based on the latest available data and science.[95]

It is important to note that the SC-CO_2, while intended to be a comprehensive estimate of the damages caused by carbon globally, does not represent the cumulative cost of climate change and air pollution to society. There are additional costs to society outside of the SC-CO_2, including costs associated with changes in co-pollutants, the social cost of other GHGs including methane and nitrous oxide, and costs that cannot be included due to modeling and data limitations. The IPCC has stated that the IWG SC-CO_2 estimates are likely underestimated due to the omission of significant impacts that cannot be accurately monetized, including important physical, ecological, and economic impacts.[96] CARB will continue engaging with experts to evaluate the comprehensive California-specific impacts of climate change and air pollution.

It is also worth noting that the SC-CO_2 estimates discussed above were calculated using the social cost of atmospheric release of CO_2 and likely represent a lower bound for the damages caused by releasing HFCs. This is so because HFCs are hundreds to thousands of times more potent at trapping heat in the near term than the longer-lived climate pollutants like CO_2. Unlike CO_2, methane and nitrous oxide, there are no official government estimates for HFCs, though

[95] National Academy of Sciences, Valuing Climate Damages: Updating Estimation of the Social Cost of Carbon Dioxide, web link: http://www.nap.edu/24651, Last accessed February 2020)
[96] Intergovernmental Panel on Climate Change, Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate change, web link: https://www.ipcc.ch/site/assets/uploads/2018/03/ar4_wg3_full_report-1.pdf, Last accessed February 2020.

one study estimates of social cost of atmospheric release of HFC-134a to be at least thousand-fold higher than CO_2.[97]

b. Health Benefits

While there are no direct health benefits that can be quantified using present methodologies, there are co-benefits of controlling global warming by removing GHG emissions. There is mounting scientific evidence that an increase in average temperatures is linked to the increase in number and intensity of wildfires, exacerbation of drought conditions in the State and prolonged, more intense heat waves, which have a disproportionate impact on the sensitive age groups as well as disadvantaged communities.[98] The Social Cost of Carbon discussion in the preceding section provides monetary estimates of the damages that would be avoided by reducing GHG emissions under this Proposed Amendments.

c. Other Benefits

The Proposed Amendments pertaining to refrigeration equipment are expected to result in improved energy efficiency for existing supermarket systems that reduce the weighted average GWP to below 1,400. The most common strategy for achieving the necessary emissions reductions will be to do a "refrigerant retrofit." This means replacing the high-GWP refrigerant in an existing system with a lower-GWP refrigerant. Retrofits are commonly accompanied by changes in seals, valves and lubricants. Systems retrofitted from R-404A to R-448A/R-449A have shown improved energy efficiency.[99] This is likely due to a combination of two factors – the replacement refrigerants are more efficient (see Section C, Direct Costs for more details) and as part of the retrofit, the systems receive a "tune-up" (new seals, valves etc.) which improves the overall energy efficiency of systems that otherwise would not have received these upgrades.

Many of the alternative refrigerants which may be used to comply with the Proposed Amendments pertaining to AC equipment have better energy efficiency or refrigerant performance characteristics. Manufacturers may elect to use more efficient refrigerants to comply with the Proposed Amendments. It is speculative to predict the market share of these refrigerants and refrigerant choice is only one factor for how manufacturer's choose to meet minimum efficiency requirements set by the U.S. DOE.

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[97] Shindell, D. T. (2015). The social cost of atmospheric release. (web link: https://link.springer.com/article/10.1007/s10584-015-1343-0, Last accessed February 2020).

[98] State of California (2018) *California's Fourth Climate Change Assessment*, http://climateassessment.ca.gov/, Last accessed February 2020); See also U.S. EPA (2018) *Climate Change in the United States: Benefits of Global Action*, https://www.epa.gov/cira/downloads-cira-report, Last accessed February 2020).

[99] U.S. Department of Energy (DOE). Working Fluids: Low Global Warming Potential Refrigerants - 2014 Building Technologies Office Peer Review. Omar Abdelaziz, Oak Ridge National Laboratory (web link: https://www.energy.gov/sites/prod/files/2014/10/f18/emt13_abdelaziz_042414.pdf, Last accessed February 2020).

C. DIRECT COSTS

The Proposed Amendments cover the following categories of businesses that use AC and refrigeration systems and have a total cost as outlined in table below.

Table 11. Regulated Businesses and Overview of Costs

General End Use	Specific End Use	Entities Affected	Average Annual Direct Costs, 2022-2040 (million 2018$ / year)
Air Conditioning	Air conditioning equipment (new) residential and commercial	*A*ir conditioning equipment manufacturers	*$210*
Refrigeration	Systems containing more than 50 pounds of refrigerant (typically used in commercial refrigeration, cold storage and industrial process refrigeration)	Supermarkets and grocery stores (i.e., retail food facilities); cold storage warehouses; industrial processes including, but not limited to, food production and manufacturing, wineries, breweries, chemical manufacturing etc. for full six-digit codes and description , see ***Table*** 69 in the Appendix	*$29.6*

The average annual direct costs between 2022 and 2040 are $29.6 million for the refrigeration end-use sectors and $210 million for the AC end-use sectors. The direct costs comprise costs related to equipment, installation, maintenance, refrigerant replenishment, electricity, retrofit of manufacturing facilities, and in case of refrigeration, the costs associated with compliance with the weighted-average GWP reduction requirements for retail food facilities.

Refrigeration and AC costs are discussed separately below.

1. Direct Cost Inputs

a. Direct Cost Inputs – Refrigeration

For regulated refrigeration systems, two distinct rules will apply, depending on whether the systems are used in new or existing facilities:

- **In Newly Constructed and Remodeled Facilities:** New systems will be required to have refrigerants with a GWP less than 150, starting January 1, 2022.
- **In Existing Facilities:** Systems in existing retail food facilities will be required to reduce their weighted-average GWP to below 1,400 by 2030 (with a progress step in 2026 for large businesses). New systems in other facilities (for example, cold storage and industrial process refrigeration) will be required to use refrigerants with GWP below 1,500.

Below is a brief overview of the compliance options available to end-users of regulated refrigeration systems and the methodology used to assess costs to end-users for compliance with the Proposed Amendments.

To comply with the GWP limit of 150 in new facilities, the currently available refrigerant options include carbon dioxide (CO_2), ammonia (NH_3), which have GWP values of 1 and 0, respectively, and hydrocarbons e.g., propane, which typically have GWP values below 10. All three are historical refrigerants and were in use in the late 19th and early 20th century, before the first generation of synthetic fluorinated refrigerants, i.e., chlorofluorocarbons or CFCs were invented. They are commonly dubbed "natural refrigerants" because unlike HFCs, these are naturally occurring gases. Their thermodynamic properties make them ideal refrigerants. However, they do present some risks and occupational safety challenges due to their toxicity (for NH_3), flammability (for NH_3 and hydrocarbons) and high operating pressures (for CO_2). Over the last few decades, extreme health- and climate-damaging impacts of fluorinated refrigerants have come to light, due to which the so-called "natural refrigerants" are now re-gaining popularity. Unlike the current fluorinated refrigerants, natural refrigerants are deemed environmentally benign, given that they are not ozone depleting substances and have very low to zero global warming potentials. Additionally, over the last few decades, advances in technology coupled with rigorous safety regulations have made it possible to manage the risks associated with NH_3, CO_2 and hydrocarbons, and use them safely in refrigeration systems.

Apart from these options, refrigerant manufacturers are already actively working towards developing and optimizing the next generation of synthetic fluorinated refrigerants with GWP values below 150. Field trials of low-GWP hydrofluoroolefin (HFO) systems are already underway in Europe.[100] For the purposes of this regulation, CARB remains technology neutral, and will allow the use of all refrigerants with GWP values below 150.

Table 12 summarizes the refrigerant / system options with GWP values less than 150.

[100] Cooling Post, Co-op store trials A2L refrigerant R-454C (web link: https://www.coolingpost.com/uk-news/co-op-store-trials-a2l-refrigerant-r454c/, Last accessed February 2020).

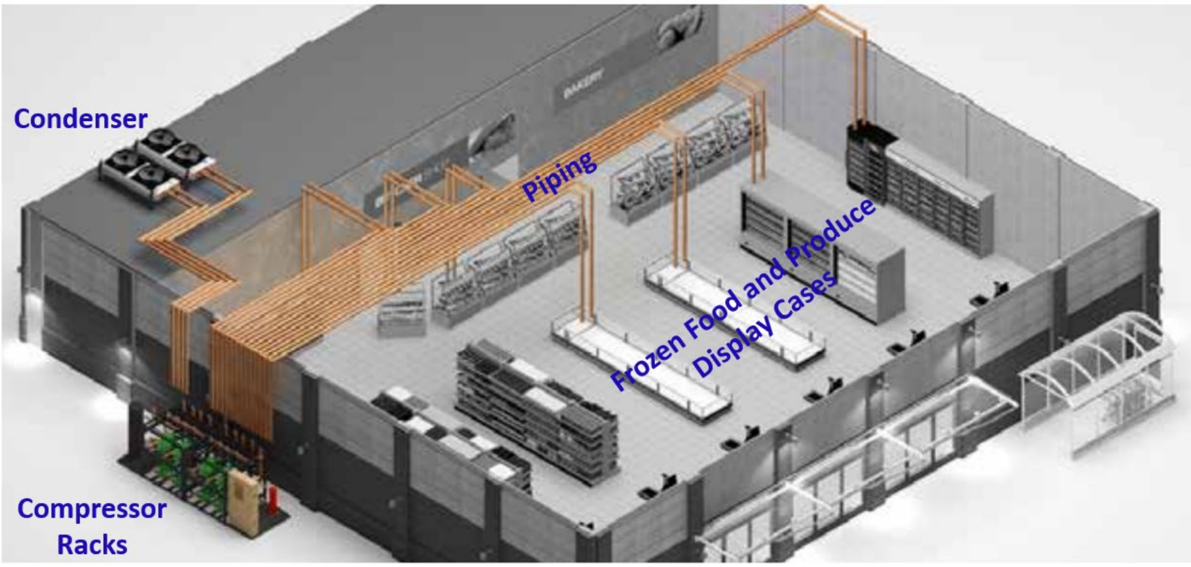
Table 12. Currently Available Refrigerants / Refrigeration System Types with GWP values less than 150

Refrigeration End-Use Sector	Compliant Options
Commercial refrigeration	Transcritical CO_2 Ammonia/CO_2 cascade Propane/CO_2 cascade Micro-distributed propane systems HFOs-based systems (under development)
Industrial process refrigeration; Cold storage	Low-charge ammonia Transcritical CO_2 Ammonia/CO_2 cascade HFO-based systems (under development)

CARB's original proposal included a GWP limit of 150 even for new systems in existing facilities. For cost and logistical reasons, it is difficult for existing facilities to switch from systems currently using HFC refrigerants to new ones using refrigerants with GWP less than 150.

The schematic below shows the typical layout of the refrigeration equipment in a supermarket – broadly, it consists of the following (1) compressors (often located in a machine room, mezzanine level or at the back of the facility , (2) condenser often located on the rooftop, (3) fixtures like display cases for storing and showcasing produce and frozen foods inside the supermarket, (4) expansion valves or metering devices (not labeled), and (5) refrigerant piping or lines connecting the display cases to the compressors and condensers. The refrigerant piping carries cold, mostly liquid refrigerant to the display cases for chilling the products. Inside the display cases, the cold refrigerant absorbs heat and vaporizes, cooling the products. After this, refrigerant piping carries the hot, vaporized refrigerant from the cases back to the compressor and eventually the condenser, to reject heat.

Figure 6. Example of a Centralized Refrigeration System[101]



The differences in thermodynamic properties and safety-related requirements for the currently available low-GWP refrigerants make them incompatible with equipment designed for HFC refrigerants. For example, CO_2 has higher operating pressures and a higher volumetric capacity than HFCs – this results in CO_2 systems having smaller compressors, and CO_2 systems require thicker refrigerant piping with a smaller diameter. Thus, the existing equipment in a supermarket that uses HFC refrigerants today cannot function with the currently available low-GWP refrigerants. However, systems installed in existing facilities account for a majority of the emissions from this sector, and reducing those emission is vitally important to meeting California's HFC reduction mandates.

Thus, to get meaningful emissions reductions and promote a transition to lower-GWP technologies in the existing facilities, the Proposed Amendments will require all retail food facilities to reduce the weighted-average GWP of all the refrigerants used across each company to below 1,400. Additionally, new systems being installed in all remaining refrigeration facilities, including industrial process refrigeration and cold storage will be required to have a GWP value less than 1,500. These GWP limits can be met by several HFC/HFO refrigerants available in the market today, some of which are given in Table 13.

[101] Adapted from original image in Kysor Warren, Parallel Compression Refrigeration, Installation and Operation Manual, web link: http://www.kysorwarren.com/files/literature/merchandisers/service/i/KW-IOM-HFC.pdf, Last acessed February 2020.

Table 13. Currently available refrigerants with GWP values less than 1,400

Refrigeration End-Use Sector	Currently Available Compliant Options
Commercial refrigeration; Industrial process refrigeration; Cold storage	R-448A R-449A R-513A R-450A

I. Cost Methodology and Baseline Upfront Costs for New Refrigeration Systems

Compliance with the Proposed Amendments are expected to result in costs higher than the baseline scenario, due to higher upfront costs for equipment and installation. In some cases, savings are expected on an ongoing basis from reductions in costs for refrigerant replenishment and electricity. Changes in regulatory costs associated with both, CARB's RMP regulation and the Proposed Amendments are also discussed.

Table 14 shows the types of costs and entities that will incur the costs associated with the Proposed Amendments as they pertain to refrigeration equipment. All costs are expected to be passed on to the end-users and thus, for this analysis, all costs are estimated from an end-user's standpoint for refrigeration systems.

Table 14. Industries Incurring Compliance Costs for Refrigeration Systems

<table>
<tr><th>Type of Cost</th><th>Industries incurring costs (assumed to be passed-on)</th><th>Industries or entities with passed-on costs</th></tr>
<tr><td>Equipment (initial)</td><td>OEMs</td><td rowspan="5">Refrigeration end-users (e.g., supermarkets, grocery stores, cold storage warehouses, process refrigeration facilities)</td></tr>
<tr><td>Installation (initial) Maintenance (ongoing)</td><td>Technicians (costs of training for low-GWP)</td></tr>
<tr><td>Refrigerant (ongoing)</td><td>Distributors/ Wholesalers</td></tr>
<tr><td>Electricity (related to Energy Efficiency) (ongoing)</td><td>End-user</td></tr>
<tr><td>Regulatory Cost (ongoing)</td><td>End-user</td></tr>
</table>

To quantify costs resulting from the Proposed Amendments above the baseline scenario, we first estimate baseline costs and then the incremental costs above the baseline.

Baseline Costs: In almost all cases, regulated refrigeration systems are designed to serve large cooling needs and are built and installed per the needs and specifications of the facility. Unlike smaller systems like residential refrigerators and ACs, estimates of baseline system costs are not available directly online. End-users like supermarkets use the services of design / engineering firms and equipment manufacturers to receive competitive bids for purchase and installation of all equipment needed for the facility, which may not necessarily be on a per-system basis. Since the F-Gas inventory tracks emissions on a per-system basis, we estimated costs per system for this analysis. To estimate upfront costs per system, CARB staff first estimated the baseline equipment costs on a per-facility basis using past stakeholder input and a few publicly available estimates.[102] The baseline cost estimates were shared and discussed with stakeholders during a public technical working group meeting[103] and through individual phone meetings.[104] Baseline facility-level costs were apportioned to systems based on the average amount of refrigerants they contain (i.e., average system full charge). The conversion of baseline facility equipment and installation costs to system costs are given in Table 62 in the Appendix. Baseline costs per refrigeration system size (large, medium, and small) and type (commercial, industrial process, and cold storage) are given below in Table 16.

Table 15. Baseline Upfront Costs for New Refrigeration Systems (2018$)

End-Use Sector	System Size	Baseline Upfront Costs (HFC DX system)	
		Equipment	Installation
Retail Food Refrigeration	Large	$958,000	$431,000
	Medium	$219,000	$98,500
	Small	$76,500	$34,400
Other Commercial Refrigeration	Large	$670,000	$144,000
	Medium	$153,000	$32,800
	Small	$53,600	$11,500
Industrial Process Cooling	Large	$912,000	$411,000
	Medium	$293,000	$132,000
	Small	$99,000	$44,600
Cold Storage	Large	$1,130,000	$507,000
	Medium	$245,000	$110,000
	Small	$108,000	$48,400

Incremental Costs: To assess the incremental costs resulting from the proposed rules, incremental costs as a percentage above baseline were estimated by seeking direct input from stakeholders during the public technical working group meetings and phone meetings referenced above, and are discussed in detail below. To obtain incremental costs per system in dollars, the incremental cost percentages were multiplied with the baseline costs for each type of

[102] HillPhoenix, DeCO$_2$ded: Understanding ROI on CO2 Refrigeration Systems (web link: http://www.r744.com/files/Hillphoenix_CO2_ROI_WhitePaper_v10_Oct24_2014.pdf, Last accessed February 2020); See also CTA Architects Engineers, 2014. Energy & Store Development Conference Presentation (web link: https://www.fmi.org/docs/default-source/energy/supermarket-refrigeration-system-design-process---a-consultant's-view.pdf?sfvrsn=2).
[103] CARB, 2019. Agenda for CARB Technical Working Group, Refrigeration Session (web link: https://ww2.arb.ca.gov/sites/default/files/2019-08/Refrigeration%20Hand-Out%20%28Final%2008-01-19%29.pdf)
[104] Direct communications with stakeholders between August 2019 and December 2019.

refrigeration system, i.e. *Incremental Cost per System (in 2018$) = Baseline Cost per System (in 2018$) x Incremental Cost as a Percentage above Baseline.*

II. Incremental Costs for New Refrigeration Systems in Newly Constructed / Remodeled Facilities

Because there are several options available to end-users for compliance, the baseline and incremental costs in this analysis are meant to be representative averages for the available options. The assumptions for direct costs are detailed in the following sections.

Equipment Cost: Currently, equipment using low-GWP refrigerants is more expensive than the baseline HFC systems and is the main source of added costs for compliance with the Proposed Amendments. Since these are custom-built systems, information about incremental costs are not easily available. Based on direct input from stakeholders and a few publicly available estimates,[105] for low-GWP equipment in newly constructed or fully remodeled facilities, staff assumes the incremental cost to be between 15 and 25 percent, and on average, 20 percent above baseline. Factors contributing to the higher equipment costs for compliant systems are primarily the differences in the design of the low-GWP systems compared to the baseline HFC systems. Since it is speculative to quantitatively parse out incremental costs due to the different design factors, here we describe them qualitatively: Different compliant refrigerants have differing thermodynamic, physical or chemical properties that may require specialized system architecture. For example, for CO_2, the systems are built to withstand higher pressures than baseline systems and may require some additional features like adiabatic condensers to achieve energy efficiencies in hot ambient climates; in micro-distributed propane systems, very small quantities of propane (< 150 grams per system) are used to cool/freeze products in display cases directly and the heat is rejected through a water loop running through the facility; in low-charge ammonia systems used primarily in IPR and cold storage, small completely sealed units containing ammonia may be placed on rooftops – this helps mitigate the costs associated with managing very large quantities of ammonia and the associated safety risks. In addition, the refrigerant lines or piping, which can be very extensive and runs all through the facility is different for each of the low-GWP refrigerants and different from the current baseline system piping.

Installation Cost: For commercial refrigeration systems, CARB staff assumes that the cost of installation, mainly tied to labor, could be higher on average by 10 percent, due to the fact that service technicians familiar with the low-GWP systems are not as easily available as those for traditional systems. The currently available technicians familiar with the low-GWP systems may have to work extra hours to meet the initial demand or may charge higher rates. It is important to note that availability of technicians is directly linked to market adoption of the technologies. As low-GWP systems become more common, the technician base servicing those systems will grow bringing parity in installations costs. Additionally, the added installation cost is offset to some extent by a few factors. Based on stakeholder input, costs of electrical installation of the low-

[105] HillPhoenix, DeCO_2ded: Understanding ROI on CO2 Refrigeration Systems (web link: http://www.r744.com/files/Hillphoenix_CO2_ROI_WhitePaper_v10_Oct24_2014.pdf, Last accessed February 2020); See also CTA Architects Engineers, 2014. Energy & Store Development Conference Presentation (web link: https://www.fmi.org/docs/default-source/energy/supermarket-refrigeration-system-design-process---a-consultant's-view.pdf?sfvrsn=2, Last accessed February 2020).

GWP systems, e.g., transcritical CO_2 can be lower since it requires less after-market electrical installation because the wiring for the case controllers and electronic expansion valves come factory installed.[106] In contrast, baseline HFC refrigerant cases need to have additional after-market electrical installation of temperature sensors.

Ammonia is already widely used in the industrial refrigeration and cold storage sectors, and there is no shortage of a trained and experienced technician base servicing ammonia systems. However, there is a lack of technicians familiar with the system architecture of the newer types of ammonia systems. Based on stakeholder input, some electrical upgrades may be needed in IPR and cold storage facilities for the low-GWP systems and that can contribute to higher installation costs. Thus, for IPR and cold storage, CARB assumes a 20 percent incremental cost for installation, mainly to incorporate the potentially higher electrical costs associated with the installation of low-charge NH_3 and NH_3/CO_2 cascade systems. Tables below show the baseline and incremental costs per system. Incremental costs were calculated by multiplying the baseline costs with the incremental cost percentages discussed above. All values are rounded up to three significant figures.

Table 16. Incremental Upfront Costs for New, GWP < 150 Refrigeration Systems (2018$)

End-Use Sector	System Size	Incremental Upfront Costs (%)[a]		Incremental Upfront Costs[b] (2018$)	
		Equipment	Installation	Equipment	Installation
Retail Food Refrigeration	Large	20%	10%	+$192,000	+$43,100
	Medium			+$43,800	+$9,800
	Small			+$15,300	+$3,400
Other Commercial Refrigeration	Large			+$134,000	+$14,400
	Medium			+$30,600	+$3,280
	Small			+$10,700	+$1,150
Industrial Process Cooling	Large		20%	+$182,000	+$82,100
	Medium			+$58,700	+$26,400
	Small			+$19,800	+$8,910
Cold Storage	Large			+$225,000	+$101,000
	Medium			+$49,100	+$22,100
	Small			+$21,500	+$9,690

[a] Incremental costs above baseline for compliant systems in percentages.
[b] Incremental costs are calculated by multiplying baseline upfront costs (given in ***Table 15***) with incremental costs in percentages.

[106] HillPhoenix, DeCO₂ded: Understanding ROI on CO2 Refrigeration Systems (web link: http://www.r744.com/files/Hillphoenix_CO2_ROI_WhitePaper_v10_Oct24_2014.pdf, Last accessed February 2020).

In contrast to the upfront costs discussed above, some savings are expected on an ongoing basis for new refrigeration systems. These savings are associated with replenishment of leaked refrigerant, electricity costs and compliance costs associated with CARB's RMP regulation. Each of these are discussed below.

Refrigerant Replenishment: Annually, regulated refrigeration systems leak on average, between 4 to 24 percent of the total refrigerant amount they contain (see Table 4 for baseline leak rates). For example, a large retail food system containing 3,352 pounds of refrigerant, with an annual average leak rate of 24.2% leaks an average of 810 pounds of refrigerant per year. Multiplied by an average annual refrigerant cost of $7 per pound gives an annual cost of replenishing leak refrigerant of approximately $5,700 per year. Across different system sizes and types, annual baseline costs for refrigerant replenishment per system can range widely, and depending on the full charge and leak rate, are estimated to between $29 and $7,500 per year per system (see Appendix ***Table 73*** for details). The current, market-ready low-GWP refrigerants like CO_2 and NH_3 are naturally-occurring gases which are cheaper than synthetic on- and off-patent HFC refrigerants. On average, CO_2 and NH_3 cost between $2 and $4 per pound, at least 50 percent lower than the baseline HFC refrigerant costs, which can range between $5 and $10 per pound (average: $7 per pound).

Table 17. Incremental Refrigerant Costs for New Refrigeration Systems with GWP < 150

Description	In new construction/full remodels, new systems with GWP < 150
Average Incremental Cost Percentage	–50%
Incremental Annual Cost Per Commercial Refrigeration System ($ / year)	- $56 to -$2,800 [a]
Incremental Annual Cost Per Industrial Process Refrigeration System ($ / year)	- $33 to -$2,500 [a]
Incremental Annual Cost Per Cold Storage System ($ / year)	- $15 to -$3,800 [a]

[a] The range of values represent the average savings for the different system sizes (large, medium and small) for each type of refrigeration system (i.e., commercial refrigeration, industrial process refrigeration and cold storage). See Appendix Table 66 for full calculations.

Electricity: Energy usage and thus, electricity costs vary widely by facility type. For example, the electricity costs for a cold storage warehouse can be very different from that of a supermarket. In addition, for some low-GWP refrigerants like CO_2, energy usage by the refrigeration system is heavily influenced by the climate zone. Despite the evidence that currently available low-GWP refrigeration systems can be at energy parity or in some cases, be more energy efficient than baseline HFC systems, the performance of commercial systems e.g., those in supermarkets can still vary due to a number of factors, like operation and maintenance. Due to lack of overarching U.S. DOE energy efficiency requirements on the systems themselves and lack of adequate benchmarking of baseline energy performance of commercial refrigeration systems in the field, CARB staff did not include energy-related costs or savings for the new low-GWP systems in newly constructed / fully remodeled commercial refrigeration facilities.

On the other hand, for industrial process refrigeration and cold storage, because the industry is already well-acquainted with the use of low-GWP refrigerants like ammonia, there are studies and real-world examples of energy cost-savings associated with their use. There are several accounts of end-users installing low-charge ammonia systems and experiencing significant energy savings over HFC systems in cold storage and IPR facilities, reportedly up to 30 percent savings in some cases.[107] In addition to ammonia, CO_2 is emerging as an industrial refrigerant, whether used alone or in combination with NH_3. Ammonia and CO_2 used together in cascade systems minimizes the amount of NH_3 thus lowering the associated risks, and removes any energy penalty issues that can arise from purely CO_2 systems in hot climates, while maximizing the use of environmentally benign, low-cost refrigerants. Using a NH_3/CO_2 cascade system, energy savings of 10 to 25 percent have been measured relative to an HFC baseline system by a California utility company.[108]

As a conservative estimate and based on the data discussed above, CARB staff assumes a10 percent savings in energy for large IPR and cold storage systems being installed in new or remodeled facilities. For the small and medium systems, due to lack of studies comparing the use of low-GWP refrigerants with high-GWP HFC systems. Thus, no savings are assumed for this analysis for the small and medium IPR and cold storage systems (although energy parity with baseline systems and even savings in some cases are likely). On the whole, for IPR and cold storage, a 10 percent energy savings estimate for large systems only is likely an underestimate. Based on available reports, on average, the baseline annual cost of electricity for a large cold storage or IPR system used to serve the needs of a whole facility is estimated to be $350,000 per year (see Appendix ***Table 74*** for details). Thus, a 10 percent annual savings equates to savings of $35,000 per year per large IPR and cold storage system.

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[107] Process Cooling, Electrification: Providing Efficiencies Through the Cold Chain (web link: https://www.process-cooling.com/articles/89403-electrification-providing-efficiencies-throughout-the-cold-chain, Last accessed February, 2020); Accelerate America, 2016. Baker Cold Storage. (web link: https://issuu.com/shecco/docs/aa1609/46, Last accessed February 2020); Accelerate America, 2016. Lineage Logistics (web link: https://issuu.com/shecco/docs/aa1609/46, Last accessed February 2020); Accelerate America, 2018. KPAC Cold Storage, (web link: https://issuu.com/shecco/docs/aa1803/36, Last accessed February 2020).

[108] Southern California Edison Company, 2017. *Ammonia/CO_2 Refrigeration System Evaluation at a Food Processing Facility*. (web link: https://www.etcc-ca.com/reports/ammoniaco2-refrigeration-system-evaluation-food-processing-facility, Last accessed February 2020).

Table 18. Incremental Electricity Costs for New Refrigeration Systems with GWP < 150

Description	In new construction/full remodels, new systems with GWP < 150
Average Incremental Cost Percentage	–10% for large IPR and cold storage systems; no change for others
Average Annual Incremental Costs for Large IPR and Cold Storage Systems ($ / year)	- $35,000

Regulatory Cost: Currently, CARB's RMP regulation affects all facilities using refrigeration systems containing more than 50 pounds of a high-GWP refrigerant, where "high-GWP" means a GWP value of 150 or greater. Cost of compliance with the RMP rule includes paying an annual implementation fee (based on facility size) and costs associated with record-keeping and reporting. Baseline annual costs for RMP compliance per system are estimated to be $151, $645 and $3,100 for small, medium and large systems, respectively (see Appendix *Table 75* for details). These baseline costs do not include savings expected under the RMP due to avoided leaks.

The Proposed Amendments will require systems with more than 50 pounds of refrigerant in all newly constructed and fully remodeled facilities to use refrigerants with GWP less than 150, and thus will be exempt from RMP's annual implementation fee, recordkeeping and reporting requirements. This will result in cost-savings for those facilities and the implementation costs borne by the State.

Under the Proposed Amendments, newly constructed or remodeled facilities will have to complete a one-time free registration in CARB's online refrigerant management database, R3. Since most companies that own these facilities already register their existing facilities in R3 under the RMP regulation, this requirement is not expected to add any costs. In addition, equipment manufacturers will be required to add labels and keep records of sales. The current California SNAP regulation requires recordkeeping and a disclosure statement. Here, a labeling requirement is being proposed in lieu of the disclosure. Some labels are required under the current product standards for various components of built-up refrigeration systems and, if sufficient, those existing labels may be used to comply with the proposed rules. Thus, the Proposed Amendments are not expected to add any regulatory costs on any entities.

Table 19 summarizes the change in regulatory costs relative to the baseline scenario.

Table 19. Incremental Regulatory Costs for New Refrigeration Systems with GWP < 150

Cost Categories	In new construction/full remodels, new systems with GWP < 150
Incremental Cost Percentage For RMP Compliance	-100%
Incremental Annual Costs for RMP Compliance Per System ($ / year)	-$151 to -$3,100 per system [a]
For Labeling, Recordkeeping and One-time Facility Registration Requirements under the Proposed Amendments	No change from baseline

[a] The range of values represent the average savings for the different system sizes (large, medium and small). For full calculation, see Appendix Table 68.

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III. Total Incremental Costs per New Refrigeration System with GWP < 150

To illustrate total incremental costs from this proposed rule, we will discuss costs for large systems under each refrigeration sub-sector.

All upfront costs i.e., equipment and installation, were amortized over 15 to 20 years, depending on the average lifetime for different types of systems, using a 5 percent annual real interest rate to reflect end-user financing.

Total incremental costs range between 5 and 18 percent above the baseline scenario for most refrigeration systems, while net savings are expected for a few. The annual total incremental costs per large system ranges up to $17,000 per year and are given in Table 20 through 22 below. Net savings are expected for large IPR and cold storage systems due to expected reduction in all ongoing costs. For medium systems, incremental annual costs range between $2,000 and $6,000 per year.

Table 20. Total Incremental Costs per New, Large Refrigeration System with GWP < 150 (2018$)

Cost Categories	Commercial – Retail Food	Commercial – Other	Industrial Process	Cold Storage
Upfront Costs (Equipment and Installation)				
Equipment ($)	+$192,000	+$134,000	+$182,000	+$225,000
Installation ($)	+$43,100	+$14,400	+$82,100	+$101,000
Total Upfront ($)	+$235,000	+$148,000	+$264,000	+327,000
Amortized Annual Upfront ($ / year)	+ $22,600	+$14,300	+ $21,200	+$26,200
Ongoing Costs				
Refrigerant Replenishment ($ / year)	– $2,800	– $2,800	– $2,500	-$3,800
Electricity ($ / year)	$0	$0	– $35,000	– $35,000
RMP Compliance ($ / year)	– $3,100	– $3,100	– $3,100	– $3,100
Total Incremental Costs				
Total Annual ($ / year)	+$16,600	+$8,320	-$19,400	-$15,700
Total Lifetime ($)	+$249,000	+$125,000	-$389,000	-$314,000

Table 21. Total Incremental Costs per New, Medium Refrigeration System with GWP < 150 (2018$)

Cost Categories	Commercial – Retail Food	Commercial – Other	Industrial Process	Cold Storage
Upfront Costs (Equipment and Installation)				
Equipment ($)	+$43,800	+$30,600	+$58,700	+$49,100
Installation ($)	+$9,850	+$3,280	+$26,400	+$22,100
Total Upfront ($)	+$53,600	+$33,900	+$85,100	+$71,100
Amortized Annual Upfront ($ / year)	+$5,170	+$3,270	+$6,830	+$5,710

Cost Categories	Commercial – Retail Food	Commercial – Other	Industrial Process	Cold Storage
Ongoing Costs				
Refrigerant Replenishment ($ / year)	-$548	-$548	-$289	-$199
Electricity ($ / year)	$0	$0	$0	$0
RMP Compliance ($ / year)	-$645	-$645	-$645	-$645
Total Incremental Costs				
Total Annual ($ / year)	+$3,970	+$2,100	+$5,890	+$4,860
Total Lifetime ($)	+$59,600	+$31,100	+$118,00	+$97,300

Table 22. Total Incremental Costs per New, Small Refrigeration System with GWP < 150 (2018$)

Cost Categories	Commercial – Retail Food	Commercial – Other	Industrial Process	Cold Storage
Upfront Costs (Equipment and Installation)				
Equipment ($)	+$15,300	+$10,700	+$19,800	+$21,500
Installation ($)	+$3,440	+$1,150	+$8,910	+$9,690
Total Upfront ($)	+$18,700	+$11,900	+$28,700	+$31,200
Amortized Annual Upfront ($ / year)	+$1,504	+$952	+$2,300	+$2,500
Ongoing Costs				
Refrigerant Replenishment ($ / year)	-$56	-$56	-$33	-$15
Electricity ($ / year)	$0	$0	$0	$0
RMP Compliance ($ / year)	-$151	-$151	-$151	-$151
Total Incremental Costs				
Total Annual ($ / year)	+$1,300	+$745	+$2,120	+$2,340
Total Lifetime ($)	+$25,900	+$14,900	+$42,400	+$46,800

IV. Incremental Costs for Refrigeration Systems in Existing Facilities

i. Retail Food Facilities

The Proposed Amendments require retail food companies, i.e., supermarkets and grocery stores, to reduce their current banks of high-GWP HFC refrigerants. Instead of implementing this on a per-store basis, CARB staff proposes taking a wider approach, where each retail food company will be required to reduce their company-wide average GWP (weighted by the pounds of refrigerant, across all their stores) to below 1,400 by 2030. Hereafter, this is referred to as the "Weighted-average GWP Reduction Program." In effect, this will be a performance standard for the retail food industry and is akin to CARB's vehicular fleet standards whereby retail food companies will be required to reduce HFC emissions from their current "fleet" of supermarkets and grocery stores, while being encouraged to transition to low-GWP technologies.

This approach provides flexibility to companies to (1) reduce their GWP using strategies most suitable for them; and (2) to plan and distribute costs over an 8-year period, between 2022 and 2030. Retail food companies will also have an alternative compliance option, under which they can reduce both, the total amount of refrigerant used and GWP of those refrigerants across their stores. This is called the "Greenhouse Gas Potential" or "GHGp" and represents the potential HFC emissions that can result from all the systems a company owns. End-users will have the option to opt-into this compliance pathway by January 1, 2022, and will be required to reduce their company-wide GHGp by 55 percent below their 2018 baseline.

The following are some options for meeting the weighted-average GWP or the GHGp reduction targets:

- Reduce GWP by
    - Retrofits to refrigerants with GWP below 1,400.
    - Partial system conversions to low-GWP (GWP < 150) refrigerants in the store.
- Reduce refrigerant amount (or charge) and GWP by
    - Replace a current system with distributed and micro-distributed HFC systems using refrigerants with GWP < 1,400. These systems use smaller amounts of refrigerants than the current systems.
    - Replace a current system with an indirect system, i.e., systems which use smaller quantities of HFC refrigerants as the primary refrigerants and a secondary heat transfer fluid or low-GWP refrigerant to cool products e.g., cascades.
    - Replace a current system with stand-alone systems (much smaller quantities of refrigerants and lower GWPs).

Since there are several ways to comply with the Proposed Amendments, CARB staff estimated the incremental costs for this rule based on the most common-place practice in the industry today, i.e., retrofits to refrigerants with GWP below 1,400. Based on stakeholder input, this will also likely be the most economical option to achieve compliance. Other options listed above may cost more but will have the added benefit of being more future-proof in terms of future national and global HFC regulations and could allow companies to leave some stores un-altered (if extra reductions are obtained from some stores, others may be left untouched).

To estimate the incremental costs of refrigerant retrofits, CARB staff sought direct input from supermarket end-users[109] and those are discussed below and summarized in Table 23. Each cost category is discussed in detail below.

Table 23. Average Incremental Costs for Existing Retail Food Systems (i.e., in Supermarkets and Grocery Stores)

Cost Categories	Average Incremental Costs
Equipment and Installation	+$45 per pound of refrigerant
Refrigerant Replenishment	+50% per pound of refrigerant
Operation and Maintenance	No change from baseline
RMP Compliance	No change from baseline
Electricity	–5% per system

While the F-Gas Inventory tracks emissions on a per-system basis, end-users may plan to carry out retrofits for the entire store or facility at once, instead of one system at a time. To provide a holistic look, an example of incremental costs for retrofitting a typical supermarket is given below in Table 24. For this example, an average supermarket is assumed to use 2,500 pounds of refrigerant across all systems containing more than 50 pounds of refrigerant, and having a facility-wide annual refrigerant leak rate of 23 percent.

Table 24. Supermarket Refrigeration Cost Example for Retrofit (2018$)

Cost Category	Baseline System using R-404A	System retrofitted to R-448A / R-449A	Difference
Upfront Costs (amortized over 10 years with a 5% interest rate)	$0	$14,569	+$14,569
Refrigerant Replenishment	$4,025	$6,038	+$2,013
Electricity	$205,292	$195,027	- $10,265
Total Annual Costs per Supermarket ($ / year)	$209,317	$215,634	+$6,320

Upfront Equipment and Installation Costs: For the existing retail food systems, a typical refrigerant retrofit includes the following: recovery/removal of old refrigerant, replacing necessary seals and valves on the display cases and receivers, replacement of lubricant oil and filters, filling in the new refrigerant, re-labeling all equipment, leak and pressure checks before

[109] Direct communications with stakeholders between August 2019 and December 2019.

and after changing the refrigerant, and recordkeeping related to the changes. Altogether, along with associated labor costs, the upfront costs of retrofit are on average, $45 per pound of refrigerant in the system. For an average supermarket that uses a total of 2,500 pounds of R-404A type refrigerant, the upfront cost for retrofitting the entire store is estimated to be 2,500 lb. × $45 per lb. = $112,500. For the purposes of this analysis, this upfront cost is amortized over a period of 10 years, roughly half the average lifetime of a new system. The assumption here being that a retrofitted system will at least be used for another 10 years. A full 20-year amortization is not used because systems being retrofitted are going to be of varying ages and may not all last as long. The amortization also includes a 5 percent annual real interest rate to reflect end-user financing. For an average supermarket, the annualized incremental upfront cost is approximately $14,600 per store.

Refrigerant Replenishment: The ongoing costs may be higher for refrigerant replenishment; based on stakeholder input, it is estimated that costs for refrigerants with GWP less than 1,400, for example, R-448A / R-499A are on average 50 percent higher than R-404A-type refrigerant per pound. For an average supermarket that has a total charge of 2,500 lb. and an annual average refrigerant leak rate of 23 percent, the baseline cost for replenishing leaked refrigerant annually is 2,500 lb. × 23% per year × $7 per lb. = $4,025 per year. After the retrofit, assuming no change in annual leak rates occurs, the annual cost for refrigerant will be = 2,500 lb. × 23% per year × $10.50 per lb. = $6,038 per year. Thus, the incremental cost per year is expected to be $6,038 – $4,025 = $2,013 per year. While it is expected that the cost of the refrigerants like R-448A and R-449A will soon achieve parity with the current commonly used refrigerants, we do not factor in a declining cost curve to be conservative and not understate the costs.

Operation and Maintenance: No incremental costs are expected for maintenance because systems using refrigerants with GWP less than 1,400 are already in use today and do not require any additional maintenance than the baseline high-GWP HFC systems.

RMP Compliance: These systems will continue to be regulated under the RMP unless the GWP of the system falls below 150, so no change in RMP compliance costs is assumed. There are some recordkeeping and reporting requirements associated with compliance with the weighted-average GWP / GHGp reduction requirements. However, those align with the current requirements under the RMP and thus, are not expected to increase the costs to end-users for compliance.

Electricity: Retrofits are expected to yield energy savings. Laboratory studies of retrofits have demonstrated that R-448A/R-449A have higher coefficients of performance and use less compressor power compared to high-GWP refrigerants like R-404A, which results in lower energy consumption when existing systems are retrofitted to use the former.[110] Additionally, as part of

[110] Mota-Babiloni, et al., (2015). Experimental evaluation of R448A as R404A lower-GWP alternative in refrigeration systems. (web link: https://www.tib.eu/en/search/id/tema%3ATEMA20150916080/Experimental-evaluation-of-R448A-as-R404A-lower/, Last accessed February 2020); Sethi, et al., (2016). Experimental evaluation and field trial of low global warming potential R404A replacements for commercial refrigeration. (web link: https://www.tandfonline.com/doi/abs/10.1080/23744731.2016.1209032, Last accessed February 2020); Fricke, B. A., Sharma, V., & Abdelaziz, O. (2017). Low Global Warming Potential Refrigerants for Commercial Refrigeration Systems. (web link: https://info.ornl.gov/sites/publications/Files/Pub75272.pdf, Last accessed February 2020).

the retrofit process, refrigeration systems receive an overhaul and "tune-up" – this tune-up, though not related to the refrigerants' properties, improves the energy efficiency of the system, which results in savings that may not have otherwise occurred. Laboratory studies of retrofits report energy savings of up to 20 percent[111] and supermarket end-users experienced with retrofits have reported a reduction in energy consumption of up to 9 percent after retrofitting from R-404A to R-448A / R-449A.[112] Since, apart from the R-404A / R-507 systems, retrofits will likely be carried out for systems using other refrigerants as well (for example, R-22 and R-407A), as a conservative estimate, CARB staff assume at least an average of 5 percent reduction in electricity costs can be expected from all retrofitted systems.

To calculate the savings in dollars, an U.S. EPA estimate of average baseline electricity costs for a typical supermarket was used,[113] and 5 percent savings were calculated assuming at least 50 percent of the annual cost of electricity borne by a supermarket is due to its refrigeration systems. On average, a supermarket is expected to save at least $10,000 per year due to improved energy efficiency if all systems greater than 50 pounds were retrofitted.

For the cost analysis to be consistent with the F-Gas Inventory which tracks emissions per system and not per facility, we multiplied the number of systems that would need to be retrofitted (Table 25) with the incremental annual costs per system (Table 26) to estimate total annual costs for retrofits on a statewide level. To comply with the progress step in 2026, some of the existing retail food systems are modeled to retrofit in 2026 while the remaining in 2030 to comply with the overall requirement for the statewide weighted-average GWP to be below 1,400 by 2030. The number of systems affected by this rule decreases from 2026 to 2030 as some of those existing systems reach their end of life and turn over into new equipment which are then required to use refrigerants compliant with the GWP limits for new systems (discussed in the preceding section).

Table 25. Number of Refrigeration Systems Affected by the Weighted-Average GWP Requirement

Year	Existing Systems Affected by Weighted-Average GWP Reduction Program (e.g., Retrofits)		
	Large	Medium	Small
2026	70	3,197	8,365
2030	26	1,958	6,730

[111] *Ibid.*
[112] Direct communications with stakeholders between August 2019 and December 2019.
[113] U.S.EPA. Supermarkets: An Overview of Energy Use and Energy Efficiency Opportunities (web link: https://www.energystar.gov/sites/default/files/buildings/tools/SPP%20Sales%20Flyer%20for%20Supermarkets%20and%20Grocery%20Stores.pdf), Last Accessed: February 2020.

Table 26. Total Incremental Costs per Retail Food System for Retrofitting to GWP < 1,400 (2018$)

Cost Categories	Large	Medium	Small
Upfront Costs (Equipment and Installation)			
Total Upfront ($)	+$151,000	+$30,800	+$4,640
Amortized Annual Upfront ($ / year)	+$19,500	+$3,990	+ $600
Ongoing Costs			
Refrigerant Replenishment ($ / year)	+$2,840	+$548	+ $56
Electricity ($ / year)	- $13,800	- $$2,800	- $600
Regulatory Compliance ($ / year)	$0	$0	$0
Total Incremental Costs			
Total Annual ($ / year)	+$8,620	+$1,730	+$56

ii. Other Refrigerated Facilities

Under the Proposed Amendments, new systems being installed in all existing facilities have to use refrigerants with a GWP below 1,500. This requirement applies to all facilities except retail food facilities, which are addressed separately above.

To comply with this rule, HFCs like R-448A, R-449A and R-134a can be used. The costs associated with this proposed rule are relatively minor compared to the rules discussed before, since refrigerants compliant with this GWP limit are already required under the current regulations for cold storage and are already used in commercial refrigeration. Thus, of the three refrigeration end-use sectors, this proposed rule mainly affects only industrial process refrigeration (IPR). Additionally, the rule will apply only to those IPR refrigeration systems that are not chillers.[114]

After discussion with stakeholders, CARB staff estimated a 10 percent incremental equipment cost for the IPR non-chiller systems. Across system sizes (small to large), the lifetime incremental equipment costs per IPR system range between $9,900 and $91,000 (see Table 65). No incremental installation costs are assumed because there are no fundamental differences between installation of systems using currently used HFCs like R-404A or R-407A and HFCs with a GWP less than 1,500. Refrigerant costs on an ongoing basis are expected to be higher than baseline, because costs for R-448A/R-499A are on average 50 percent higher than R-404A-type refrigerant per pound. Across system sizes (small to large) and types (commercial, industrial, cold storage), the incremental annual costs ranges between $33 and $2,800 per year (see

[114] Chillers have a separate GWP limit of 750, which is discussed in Section A.

Table ***66***). Since the refrigerants with GWP values just under 1,500 and systems using them do not differ in any significant way from the baseline refrigerants, no other changes are expected relative to the baseline since costs associated with operation and maintenance, electricity, and compliance with RMP and the Proposed Amendments are expected to remain the same as the baseline scenario. For full costs and details, the incremental costs per system type for this rule are given in the Appendix tables.

V. Total Costs – Refrigeration

To calculate total costs for the Proposed Amendments for regulated refrigeration systems, the incremental costs per system are multiplied by the number of new or existing systems that are affected by the rule, i.e., *Annual Total Costs for Refrigeration = (Incremental cost per new system using refrigerant with GWP < 150 or 1,500 x Number of new systems affected by rule per year) + (Incremental cost per existing retail food system x Number of affected retail food systems).* In addition, an 8.5 percent sales tax was added to the equipment costs.[115] System populations affected by the Proposed Amendments for refrigeration are discussed in Section A, Baseline Information.

Table 27 shows the total direct costs and savings associated with all the proposed rules for regulated refrigeration equipment. Between 2022 and 2040, the total annual costs range between $2.18 million and $41.7 million, with an average annual cost of $27.4 million. Across new and existing refrigeration facilities, added compliance costs for refrigeration systems arise mainly due to the higher upfront equipment and installation costs. Some savings are expected due to reduced RMP compliance costs and lower refrigerant costs for new facilities with GWP less than 150. Some energy savings are also expected for new industrial process facilities and for retail food facilities as they make system upgrades to comply with the weighted GWP reduction requirement. The total costs for refrigeration increase sharply in 2026 and 2030 as existing retail food facilities comply (by retrofits) and reduce their weighted-average GWP to below 1,400. The costs for retrofits are amortized over 10 years and thus, starting 2036, total costs start to decline and plateau. All values are rounded up to three significant figures. For the emissions analysis, systems being retrofitted continue to survive and yield emissions reductions based on the equipment survival curves built into the inventory. At their end of life, retiring systems get replaced by new systems which are governed by GWP limits discussed above.

Table 27. Total Costs for the Proposed Amendments for Refrigeration Systems (Millions 2018$)

Year	Equipment and Installation Cost[a]	Refrigerant Cost[b]	Regulatory Cost[c]	Electricity Cost[d]	Total Cost[e]
2022	$2.07	$0.57	-$0.19	-$0.15	$2.30
2023	$4.15	$1.15	-$0.39	-$0.30	$4.61
2024	$6.25	$1.73	-$0.58	-$0.46	$6.95
2025	$8.37	$2.32	-$0.78	-$0.61	$9.30

[115] The sales tax varies across the state from a minimum of 7.25% up to 10.25% in some municipalities; a value of 8.5% was used for staff's analysis based on a statewide population weighted average.[115]

Year	Equipment and Installation Cost[a]	Refrigerant Cost[b]	Regulatory Cost[c]	Electricity Cost[d]	Total Cost[e]
2026	$30.8	$5.33	-$0.98	-$16.0	$19.2
2027	$33.0	$5.93	-$1.18	-$16.1	$21.6
2028	$35.1	$6.53	-$1.38	-$16.3	$23.9
2029	$37.3	$7.13	-$1.58	-$16.6	$26.2
2030	$52.6	$9.27	-$1.78	-$27.1	$33.0
2031	$54.8	$9.88	-$1.99	-$27.3	$35.4
2032	$57.1	$10.5	-$2.20	-$27.5	$37.9
2033	$59.3	$11.1	-$2.41	-$27.6	$40.4
2034	$61.6	$11.7	-$2.62	-$27.8	$42.9
2035	$63.8	$12.4	-$2.83	-$28.0	$45.4
2036	$45.8	$10.6	-$3.04	-$12.7	$40.7
2037	$47.4	$10.7	-$3.16	-$12.8	$42.2
2038	$49.0	$10.9	-$3.27	-$13.0	$43.7
2039	$50.7	$11.1	-$3.39	-$13.2	$45.1
2040	$39.2	$9.7	-$3.51	-$3.1	$42.2

[a] Total annual added equipment and installation cost above the baseline, for new systems complying with the GWP limits of 150 and 1,500 in new and existing facilities, and the weighted-average GWP requirement for retail food facilities. Equipment costs contain an 8.5 percent sales tax.
[b] Total annual cost for replenishing leaked refrigerant across all affected systems (added costs from retail food systems complying with weighted-average GWP requirement and new systems complying with a GWP limit of 1,500 minus savings for new systems complying with a GWP limit of 150).
[c] Total annual cost savings due to lower regulatory (RMP) costs for new systems in newly constructed facilities complying with a GWP limit for 150.
[d] Total annual electricity savings for new, large IPR systems complying with the GWP limit of 150 and savings from retrofitted retail food systems.
[e] Total annual costs are the sum of all annual costs and savings per year.

b. Direct Cost Inputs – Air Conditioning

For regulated air conditioners, the following GWP limit would apply under the Proposed Amendments:

- **New AC Equipment:** New equipment will be required to have refrigerants with GWP less than 750.

Manufacturers have two main refrigerant options to meet the 750 GWP limit. One option is to use an A2L (lower flammability) refrigerant and the other option is to use an A1 (non-flammable) refrigerant.[116] The refrigerant replacement options identified for R-410A are all Class A (nontoxic). AC equipment using A2L refrigerants are widely available in other countries (Japan, China, Europe and Australia). The costs associated with A2L equipment includes mitigation for its lower flammability properties, which includes preventing refrigerant leaks from occurring and

[116] These refrigerant designations are set by the nationally accredited standard setting body, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

appropriate mitigation if leaks do occur. Depending on the A2L refrigerant selected, there may be higher refrigerant costs or cost savings. The other option is to use an A1 (non-flammable) refrigerant. Equipment and component manufacturers are currently conducting product testing to use an A1 refrigerant with a GWP less than 750. The costs associated with this option include product redesign and higher refrigerant costs. The incremental costs in this analysis are meant to be representative averages for the available refrigerant options which could be used to comply with the Proposed Amendments. The assumptions for direct costs are detailed in the following sections.

I. Cost Methodology for Air Conditioning Costs

The Proposed Amendments will require manufacturers to produce and sell AC equipment that has higher upfront and ongoing costs for maintenance and repair than in the baseline. These costs included higher equipment and installation costs (upfront costs) and higher repair and maintenance costs (ongoing costs). Staff first estimate baseline costs and then estimate the costs to comply with the Proposed Amendments, which are expressed as incremental costs above the baseline. Table 28 shows the types of costs and industries incurring costs to comply with the limits for new AC equipment under the Proposed Amendments. While equipment pricing is complex, and different manufacturers could use different strategies to pass on these costs, staff make a conservative assumption that all costs from deploying compliant equipment for the California market are fully passed on to end-users. Further details on the upfront and ongoing costs are provided in the sections below.

Table 28. Industries Incurring Direct Costs under the Proposal for Stationary AC

<table>
<tr><th>Type of Cost</th><th>Industries incurring costs
and NAICS costs</th><th>Industries or entities
with passed-on costs</th></tr>
<tr><td>Equipment
(upfront cost)</td><td>Equipment Manufacturers</td><td rowspan="4">AC end-users
(e.g., owners of AC equipment
in: single
and multi-family homes,
commercial buildings,
and non-residential buildings
such as schools and
hospitals)</td></tr>
<tr><td>Transport and
Storage
(ongoing)</td><td>Distributors/ Wholesalers</td></tr>
<tr><td>Installation
(upfront)
and Maintenance
(ongoing)</td><td>Technicians</td></tr>
<tr><td>Refrigerant
(ongoing)</td><td>Refrigerant and Equipment
Manufacturers,
and Distributors/ Wholesalers</td></tr>
</table>

Baseline Costs: The baseline costs for new residential and commercial AC equipment are based on U.S. DOE Technical Support Documents for their energy conservation standards.[117] Staff

[117] Energy Conservation Program: Energy Conservation Standards for Residential Central Air Conditioners and Heat Pumps, 82 Fed. Reg. 1786 (Jan. 6, 2017); See Technical Support Documents submitted as part of rulemaking available here: https://www.regulations.gov/document?D=EERE-2014-BT-STD-0048-0102; Energy Conservation

obtained the baseline costs including manufacture production cost (MPC) and retail cost for equipment, as well as installation, maintenance and repair costs from U.S. DOE shipment-weighted product distribution projected by U.S. DOE for 2020 to 2040 and average cost per product. Staff obtained this information for the "hot-dry" southwest region (California, Arizona, New Mexico and Nevada). Therefore the average baseline costs used in this analysis take into account the range of product prices, which vary by energy efficiency rating, type of product and size, and are weighted by the distribution of products shipped to the southwest market (see Table 29). California represents nearly 80 percent of the population in this region, therefore, the product distribution for the southwest region from the U.S. DOE is expected to be a good characterization of the California market, even with some variation in AC usage between states. Staff corroborated product distributions from U.S. DOE analysis[118] by comparing shipment data submitted to CARB by the Heating, Air-conditioning and Refrigeration Distributors International (HARDI). HARDI provided annual shipments of residential ACs in California for the years 2013 through 2018 by product type and efficiency rating. Both the U.S. DOE and HARDI data show that the majority (80 percent or more) of AC shipments are in the base efficiency ranges. From 2023 onward, the product distribution shifts into higher base efficiency ranges according to U.S. DOE standard compliance dates taking effect. This is taken into account in the costs staff used to characterize the baseline. The baseline upfront costs (equipment retail + installation costs) are amortized using a 5 percent real interest rate, a 15-year life for residential equipment and 20-year life for commercial equipment to reflect end-user financing.

Table 29. Baseline Costs for AC Equipment in 2023 ($2018)

Cost Categories	Residential Central AC	Residential Central HP	Commercial AC/HP (Small – Medium)	Commercial AC/HP (Large)
Equipment Retail Costs ($)	$3,300	$4,655	$8,875	$21,120
Installation Cost ($)	$1,790	$2,020	$4,290	$6,600
Amortized Upfront Costs (Equipment Retail + Installation)	$7,356	$9,646	$21,128	$44,486
Annual Maintenance/Repair Cost ($)	$70	$105	$945	$810
Lifetime Maintenance/Repair Costs ($)	$1,050	$1,575	$18,900	$16,200
Lifetime Unit Costs ($) (Amortized Upfront + Lifetime Maintenance and Repair)	$8,406	$11,221	$40,028	$60,686

Standards for Small, Large, and Very Large Commercial Package Air Conditioning and Heating Equipment, 81 Fed. Reg. 2420 (Jan. 15, 2016); See Technical Support Documents submitted s part of rulemaking available here: https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0007 (Hereinafter collectively "U.S. DOE Technical Support Documents").
[118] *Ibid.*

The cost of ACs have generally decreased over the last several decades, even with product redesigns and the introduction of new energy conservation standards. Economic literature and historical data[119] suggest that the costs of AC products trend downward over time according to "learning" or "experience" curves.[120] CARB incorporates an experience curve[121] to estimate future baseline costs of products as follows:

$$P = P_0(\frac{X}{X_0})^{-b} = P_0\left(\frac{{X_0}^{at}}{X_0}\right)^{-b} = P_0e^{-\alpha t}$$

where,

P = price of the unit

P_0 = price of the first unit of production

X = cumulative production

X_0 = initial cumulative production

b = experience rate parameter

t = time variable, equal to the difference between the base year and any given year

α = exponential parameter of the time variable

Staff uses a learning rate of 11 percent,[122] which represents the percentage reduction in cost that occurs with each doubling of cumulative production consistent with the U.S. DOE.[123]

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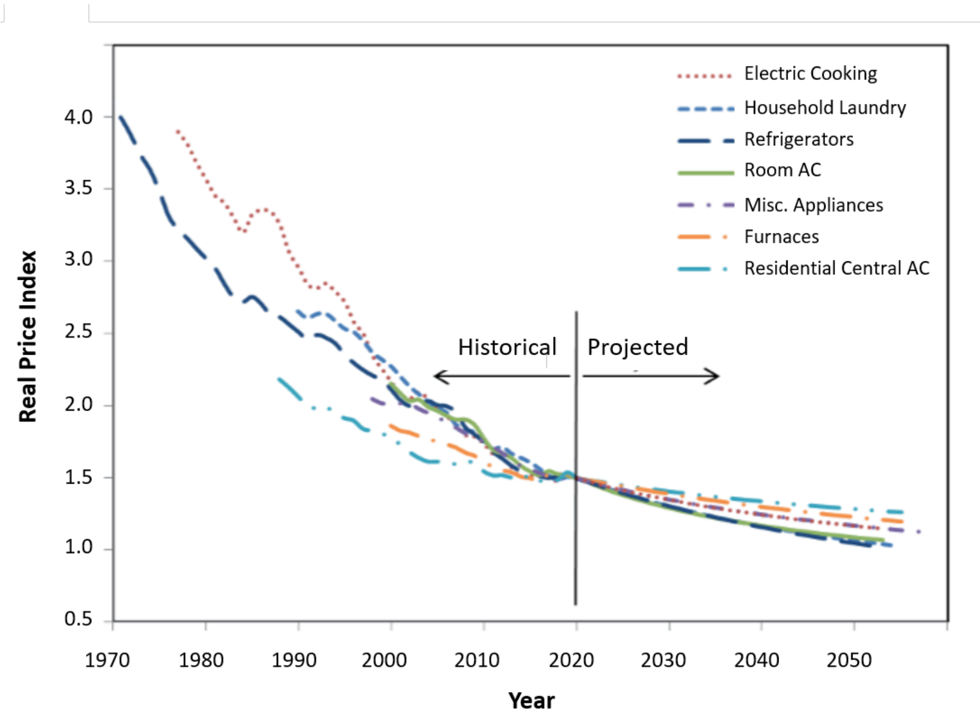
[119] Descroches, L., et al., (2013). Incorporating experience curves in appliance standards analysis. (web link: https://www.sciencedirect.com/science/article/pii/S0301421512008488, Last accessed February 2020); See also U.S. DOE Technical Support Documents.

[120] Staff estimates the initial cumulative production at 200 million units sold to California from 1978 to 2015 based on CARB's F-Gas Inventory. Staff use 0.163 as the experience rate parameter consistent with the U.S. DOE.

[122] The learning rate (LR) is found from the formula $LR = 1 - 2^{-b}$, where b is the experience rate parameter of 0.163.

[123] *Ibid.*

Figure 7. Long-Term Decrease in Residential AC Costs[124]



Incremental Costs: Staff estimate the incremental cost to comply with the Proposed Amendments as a percentage above baseline. Incremental costs were estimated by seeking input from stakeholders during public working group meetings, stakeholder meetings and surveys as described in Section A.6., Public Outreach and Input. The incremental cost to comply with the Proposed Amendments vary depending on the specific alternative refrigerant selected. Cost impacts for room ACs are not included in this analysis as products are available today at the same or lower cost as equipment using R-410A and a full transition to a refrigerant with a GWP less than 750 is not expected to increase costs.[125] Staff estimated average incremental costs for stationary AC residential and commercial equipment, which takes into account a range of refrigerant options and the associated costs. To obtain incremental costs per system in dollars, the incremental cost percentages were multiplied with the baseline costs for each type of air conditioning system, i.e. *Incremental Cost per System (in 2018$) = Baseline Cost per System (in 2018$) x Incremental Cost as a Percentage above Baseline.*

All upfront costs were amortized over 15 to 20 years, depending on the average lifetime for different types of equipment, and using a 5 percent annual interest rate, to reflect end-user financing. Staff applies the learning rate described in the previous section to incremental costs

[124] Figure adapted from Desroches et al., 2013.
[125] UNEP, *Fact Sheet 7: Small Self Contained Air-Conditioning*, Last visited February 2020); See also JMS Consulting, *Consumer Cost Impacts of U.S. Ratification of the Kigali Amendment*. (web link: http://www.ahrinet.org/App_Content/ahri/files/RESOURCES/Consumer_Costs_Inforum.pdf, Last accessed February 2020).

under the Proposed Amendments from 2023 to 2040 and estimates the cumulative sales consistent with the number of new ACs described in Section A.5., Baseline Information.

Energy Efficiency: Alternative refrigerants either match or have better performance in terms of energy efficiency compared to baseline.[126] However, it is uncertain what the market penetration of the various alternative refrigerants will be and whether manufacturers will use this efficiency to meet U.S. DOE energy efficiency standards in place of other features for California equipment. Due to these uncertainties, staff did not model energy efficiency savings for end-users.

II. Upfront Equipment and Installation Costs

Equipment Costs: The majority of AC and refrigeration equipment manufacturers selling equipment to California are international corporations which are transitioning product lines away from high-GWP refrigerants and have invested billions to bring next generation refrigerants and equipment to market. [127] Equipment manufacturers can select an A2L or A1 refrigerant to comply with the 750 GWP limit. Regardless of which refrigerant option manufacturers elect to use to comply, changing refrigerants requires system design changes. Even refrigerants that are "near drop-in" replacements require design changes to optimize system performance.
AC manufacturers incorporate design changes through design cycles to ensure that new equipment meeting all regulatory requirements are available as needed for commercial introduction. The 2023 compliance date was selected by CARB to allow industry to incorporate a refrigerant change into their ongoing design cycle to meet new U.S. DOE energy conservation standards. CARB had initially proposed a compliance date of 2021. CARB shifted this date to 2023 in order to minimize cost impacts by aligning with the ongoing design cycle, as requested by industry.[128] Aligning design cycles significantly reduces the anticipated cost impacts associated with major design cycles, enabling industry to move quickly and efficiently to new equipment designs.[129]

The cost of a design cycle for equipment manufacturers to redesign product lines traditionally costs $20 to $50 million depending on the timing and complexity of redesign.[130] According to AHRI, equipment manufacturers anticipate spending an average of $21 million per manufacturer to bring AC products to market for California that comply with the Proposed Amendments.[131] Manufacturers will balance refrigerant cost against other properties of the refrigerant, which can

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[126] https://aceee.org/files/proceedings/2010/data/papers/1933.pdf
[127] AHRI & ARAP, Letter to United States Senate and House of Representatives (Oct. 8, 2019). (web link: https://images.magnetmail.net/images/clients/AHRI/attach/FINALCEOLetterwithSignaturesFinal.pdf, Last accessed February 2020).
[128] AHRI, NRDC, Carrier Corporation, Daikin Applied Americas, Inc., Goodman Manufacturing Company, L.P., Lennox International, Nortek Global HVAC LLC, Trane Inc., The Chemours Company, Honeywell International Inc., Letter to Chair Nichols. 14 September AHRI et al., Joint Voluntary Commitment Letter to CARB (Sept. 14, 2018). (web link: http://www.ahrinet.org/Portals/_Appleseed/documents/news/AHRI_NRDC_CARB_Letter_regarding_SLCP_HFC_measures.pdf., Last accessed February 2020).
[129] JMS Consulting, Consumer Cost Impacts of U.S. Ratification of the Kigali Amendment (web link: http://www.ahrinet.org/App_Content/ahri/files/RESOURCES/Consumer_Costs_Inforum.pdf, Last accessed February 2020)
[130] *Ibid.*
[131] The basis of these costs estimates includes a survey of AC equipment manufacture conducted by CARB and cost analysis provided during stakeholder meetings as described in Section A. 6. Public Outreach.

add to design costs. For example, a low-cost refrigerant might require more extensive component redesign while a more expensive refrigerant might offer cost savings or efficiencies elsewhere, or other benefits that are not related to cost. Manufacturers will select a refrigerant that presents a balance of tradeoffs that minimizes product costs and aligns with their strategic priorities to transition refrigerants across different market segments and AC applications.

The AC industry has a history of continually innovating to deliver products with higher efficiency and performance at lower costs while phasing out environmentally harmful refrigerants under the Montreal Protocol. As with past refrigerant transitions and redesigns, added costs are expected, at least initially. Depending on the choice of refrigerant, there may be added costs for design changes to components such as compressors, increases in commodity metal costs, or additional safety features for A2L refrigerants. These costs can be offset by reduced charge sizes, increased efficiency and other benefits of next generation refrigerants. In addition, the cost to transition refrigerants can be minimized through advances in manufacturing and efficiency improvements, which reduce lifecycle costs.

Based on cost analysis provided by equipment manufacturers to CARB, the incremental costs of compliant equipment is estimated to range 5 to 10 percent higher compared to baseline retail costs (see ***Table 30***). The incremental costs of compliant AC equipment is expected to decrease as production increases. CARB incorporates a learning curve as described in Section B, under Subsection I, Cost Methodology for Air Conditioning, which takes into account diminishing incremental costs relative to baseline as cumulative production increases. Staff take a conservative approach that compliant equipment are developed and sold exclusively for the California market. However, as other states commit to taking action on high-GWP HFCs, demand for these products is expected to expand into other market segments.

Table 30. Incremental Equipment Costs for New AC Systems

Cost Categories	Residential Central AC	Residential Central HP	Commercial AC/HP (Small – Medium)	Commercial AC/HP (Large)
Total Incremental Equipment Costs (compared to baseline retail) (%)	+5%	+5%	+10%	+6%
Baseline Retail ($)	$3,300	$4,655	$8,875	$21,120
Total Incremental Equipment Costs ($)	+$165	+$213	+$908	+$1,196

Installation Cost: The installation process will remain largely the same as for baseline R-410A equipment. However, for A2L products, installers would need to be trained to ensure that they are fully equipped to install A2L systems. Training for A2L equipment is expected to be incorporated into existing training programs. Many of the tools used for current R-410A can be used for A2L refrigerants. Technicians will largely be able to replace older tools with ones that are also rated for A2Ls as their older tools are retired at the end of their useful life. The pipework installation is exactly the same as R-410A. While most systems come factory charged, installers transporting refrigerant cylinders will need store them vertically, vehicles must have a flammable gas placard, ($5 to $40) and class B fire extinguishers ($30 to $60). If manufacturers comply with the Proposed Amendments using an A1 refrigerant, there will be no change in installation costs. The cost range for installing AC systems with a refrigerant less than 750 GWP ranges from zero to 6 percent higher. To represent an average scenario, staff estimate installation costs at 3 percent higher for AC systems with the Proposed Amendments in effect (see ***Table 31***).

Table 31. Incremental Installation Costs for New AC Systems

Cost Categories	Residential Central AC	Residential Central HP	Commercial AC/HP (Small – Medium)	Commercial AC/HP (Large)
Total Incremental Installation Costs (%)	+3%	+3%	+3%	+3%
Baseline Installation Cost ($)	$1,790	$2,020	$4,290	$6,600
Total Incremental Installation Costs ($)	+$54	+$61	+$129	+$198

III. Ongoing Maintenance and Repair Costs

CARB anticipates that much of the routine servicing and repairs will be the same as for a baseline system. Many repairs do not involve adding refrigerant, so many of the routine repair items like replacing electronics, motors, etc., are expected to be the same for baseline R-410A systems. In most cases, the cost of labor is the majority of the repair cost. In the event a system requires a refrigerant recharge, there may be a change in refrigerant cost. Refrigerant costs may not increase for alternative refrigerants currently in mass production. In fact, there is an opportunity for cost savings for refrigerant that require less charge size for the same capacity system and as systems become more leak tight. However, new, more complex molecules, such as HFO blends and blends with trifluoroiodide (CF_3I) are expected to be more expensive. Industry has indicated to CARB that new refrigerant blends that would comply with the Proposed Amendments may be two to five times the cost of R-410A at the point of sale to the equipment manufacturer. The average price of R-410A to the equipment manufacturer today is about $3.00 per pound. It is typical for new refrigerant blends to be more expensive initially and for prices to come down as production increases. While the refrigerants used to comply with the Proposed Amendments are also being deployed around the globe, it is speculative to predict how refrigerant prices may come down in the future. As with current R-410A equipment, refrigerant costs are expected to account for a small portion, less than one percent of the total cost of ownership over the lifetime of the equipment.

Maintenance and repair costs reflect annualized labor and material costs for maintaining and operating of AC equipment and for replacing components that have failed. There is no change in labor time for an A1 alternative. However, for an A2L alternative, there may be an increase in labor time because of additional safe handling processes that will be required with the introduction of A2Ls. For example, in the event that a refrigerant leaks, the technician will have to evacuate and purge the system with dry nitrogen before they can repair the leak. This is a best practice already but will be required for an A2L system. As with the installation, technicians will need to be trained to work on A2L systems and will need to verify that their tools (gauge manifolds, recovery pumps, leak detectors and recovery cylinders etc.) are suitable for use with A2Ls. CARB estimates the incremental cost for servicing and maintenance to be 5 percent. This reflects an extra thirty minutes to an hour of labor time and more expensive replacement parts or the use of a refrigerant that may be more expensive.

Table 32. Incremental Maintenance and Repair Costs for New AC Systems

Cost Categories	Residential Central AC	Residential Central HP	Commercial AC/HP (Small – Medium)	Commercial AC/HP (Large)
Total Incremental Maintenance and Repair Costs (%)	+5%	+5%	+5%	+5%
Baseline Lifetime Maintenance and Repair Costs ($)	$1,050	$1,575	$18,900	$16,200
Total Lifetime Incremental Maintenance and Repair Costs ($)	+$53	+$79	+$945	+$810

IV. Total Costs – Air-Conditioning

The primary reason for cost increases for AC systems associated with the Proposed Amendments is costs incurred at the manufacturing level. Staff assume all costs are passed on to end-users as higher upfront costs for equipment and a summary of per unit costs are provided in Table 33. The total incremental upfront costs is the equipment and installation cost added together and amortized to reflect end user financing at a 5 percent real interest rate across the lifetime of the equipment—15 year average for residential; 20 year average for commercial. The total incremental ongoing costs per unit come from the added cost of maintenance and repair.

To calculate total costs (Table 34) for the Proposed Amendments for regulated AC equipment, the annual incremental costs per system are multiplied by the number of new or existing systems that are affected by the rule, i.e., *Annual Total Costs for AC = (Incremental cost per new system* *using refrigerant with GWP < 750 (in 2018$) x Number of new units affected by rule per year) + (Incremental cost per unit (in 2018$)*. System populations affected by the Proposed Amendments for refrigeration are discussed in Section A, Baseline Information. Sales tax is included in the baseline costs.

Table 33. Total Incremental Costs for Per Unit for New AC Equipment ($2018)

Cost Categories	Residential Central AC	Residential Central HP	Commercial AC/HP (Small – Medium)	Commercial AC/HP (Large)
Upfront Costs (Equipment + Installation)				
Equipment Retail ($)	+$165	+$213	+$908	+$1,196
Installation ($)	+$54	+$61	+$129	+$198
Total Upfront ($)	+$219	+$274	+$1,037	+$1,394
Amortized Annual Upfront ($/year)	+$21	+$26	+$83	+$112
Ongoing Costs (Maintenance/Repair)				
Lifetime ($)	+$53	+$79	+$945	+$810
Annual ($/year)	+$4	+$5	+$47	+$41
Total Incremental Costs				
Total Lifetime ($)	+$369	+$474	$2,192	$2,488
Total Annual ($)	+$25	+$32	+$110	+$124

Table 34. Annual Incremental Costs for the Proposed Amendments for New AC Systems (Millions 2018$)

Year	Equipment and Installation Costs	Service and Maintenance Costs	Total Costs
2023	$18.4	$4.60	$23.0
2024	$37.0	$9.20	$46.2
2025	$55.7	$13.8	$69.5
2026	$74.4	$18.5	$93.0
2027	$93.3	$23.3	$117
2028	$112	$28.1	$140
2029	$132	$33.0	$164
2030	$151	$37.9	$189
2031	$170	$42.8	$213
2032	$190	$47.8	$237
2033	$209	$52.9	$262
2034	$229	$58.0	$287
2035	$249	$63.1	$312
2036	$269	$68.3	$337

Year	Equipment and Installation Costs	Service and Maintenance Costs	Total Costs
2037	$289	$73.6	$362
2038	$294	$76.0	$370
2039	$299	$78.5	$378
2040	$304	$81.0	$385

c. Total Costs for the Proposed Amendments

The total net direct costs inputs of the Proposed Amendments are summarized in Table 35. These include all upfront and ongoing costs incurred. All values are rounded up to three significant figures.

Table 35. Total Annual Costs for the Proposed Amendments (millions of 2018$)

Year	Refrigeration		Air-Conditioning		Total Costs for Refrigeration and AC Equipment ($ / Year)
	Upfront[a]	Ongoing[b]	Upfront[c]	Ongoing[d]	
2022	$2.07	$0.23	$0	$0	$2.30
2023	$4.15	$0.46	$18.4	$4.60	$27.6
2024	$6.25	$0.70	$37.0	$9.20	$53.1
2025	$8.37	$0.93	$55.7	$13.8	$79
2026	$30.8	-$11.63	$74.4	$18.5	$112
2027	$33.0	-$11.38	$93.3	$23.3	$138
2028	$35.1	-$11.19	$112	$28.1	$164
2029	$37.3	-$11.08	$132	$33.0	$191
2030	$52.6	-$19.66	$151	$37.9	$222
2031	$54.8	-$19.42	$170	$42.8	$248
2032	$57.1	-$19.17	$190	$47.8	$276
2033	$59.3	-$18.93	$209	$52.9	$302
2034	$61.6	-$18.68	$229	$58.0	$330
2035	$63.8	-$18.43	$249	$63.1	$357
2036	$45.8	-$5.11	$269	$68.3	$378
2037	$47.4	-$5.24	$289	$73.6	$405
2038	$49.0	-$5.37	$294	$76.0	$414
2039	$50.7	-$5.50	$299	$78.5	$423
2040	$39.2	$3.07	$304	$81.0	$427

[a] Refrigeration upfront costs include equipment and installation cost increments above the baseline, for new systems complying with GWP limits of 150 and 1,500 in new and existing facilities, respectively, and for compliance with the weighted-average GWP requirement for retail food facilities.
[b] Refrigeration ongoing costs include cost increments and savings for refrigerant replenishment, electricity and RMP compliance above the baseline, for new systems complying with GWP limits of 150 and 1,500 in new and existing facilities, respectively, and for compliance with the weighted-average GWP requirement for retail food facilities.
[c] AC upfront costs include equipment and installation cost increments above the baseline for new equipment.
[d] AC ongoing costs include repair and maintenance cost increments about the baseline for new equipment.

2. Direct Costs on Typical Businesses

a. Stationary Refrigeration

Based on user-reported data in CARB's RMP database in 2018, regulated refrigeration systems are most commonly used in retail food facilities such as supermarkets, grocery stores, warehouse clubs, supercenters and discount department stores (NAICS code 445110, 452910, 452112) and followed distantly by merchant wholesalers (NAICS codes starting with 424), food production and manufacturing facilities including wineries and breweries (NAICS codes starting with 311 and 312), refrigerated warehouses and storage facilities (NAICS code 493) and a small number of various types of industrial process facilities. To illustrate the typical costs for companies owning these facilities, the average estimated costs for (1) a supermarket company and (2) a cold storage / food processing company are discussed below.

I. Retail Food Facilities (Supermarkets and Grocery Stores)

As discussed earlier, under the Proposed Amendments, retail food companies will have to comply with two sets of rules (1) use refrigerants with GWP lower than 150 in newly constructed/fully remodeled facilities starting 2022, and (2) on a company-wide basis, reduce the weighted-average GWP to 1,400 or emissions potential by 55 percent by 2030 across all their stores (with a progress step in 2026).

To illustrate the costs to a typical business, we will consider an average large supermarket company with 120 stores in California.[132] All cost assumptions are the same as discussed in previous sub-sections, for a large commercial retail food system. For newly constructed facilities, equipment and installation will result in incremental costs while savings are expected from the avoided costs of complying with the RMP regulation and for replenishing leaked refrigerant.

It is worth noting that costs of equipment and installation are expected to decline as market adoption of low-GWP systems and relatedly, contractor experience with those systems, to increase. As an example, the European Union also has a similar rule for large refrigeration systems and low-GWP systems are expected to achieve cost parity with the baseline HFC systems by 2022 when the rule goes into effect.[133] While CARB staff expect similar trends in California, to be conservative, we did not factor any experience curves into the analysis. Since the estimated growth rate for supermarkets is 1 percent per year, the incremental annual cost for a company with 120 supermarkets, for opening 1 new supermarket per year. The annual incremental costs for a newly constructed supermarket are given in Table 20. Overall, the added annual costs are expected to be $16,600 per year,[134] which is on average, 10 percent higher than the baseline scenario.

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[132] Based on CARB's RMP database. The average number of supermarkets owned by companies with 20 or more stores is 120.

[133] The European Commission, 2017. Report from the Commission Assessing the 2022 Requirement to Avoid Highly Global Warming Hydrofluorocarbons in Some Commercial Refrigeration Systems.

[134] Using the incremental annual cost for one, large system containing 3,300 pounds of refrigerant as a proxy for a single centralized system serving the entire supermarket.

Under the Proposed Amendments, supermarkets (and grocery stores) are also required to reduce their company-wide weighted-average GWP to below 1,400. End-users will also have an alternative compliance pathway under which they will be required to reduce their company-wide GHGp by 55 percent below their 2018 levels, by 2030. Table 24 shows the expected incremental costs associated with refrigerant retrofits in an average supermarket, the most common and economical option to comply. The annual average incremental cost per store is estimated to be $6,320 per year. For an average large company that owns 120 supermarket stores in California, retrofits or other conversions to refrigerants with GWP values less than 1,400 have to occur by 2030. The proposed rules, become effective in 2022, which gives each company 8 years to plan and carry out the changes in all their stores. On average, this means a typical company with a 120 stores would retrofit 15 stores per year. Thus, the average annual incremental cost for this company is expected to be 15 × $6,320 = $94,800, for compliance with the weighted-average GWP reduction requirement.

Here, it is important to note that retail food companies are not required to retrofit every system and store under the weighted-average GWP reduction requirement, even though retrofits are expected to be the most economical option on a per-store basis. Additional costs savings can be achieved if companies choose to invest more upfront capital (to simultaneously reduce GWP along with refrigerant charge) in some stores while leaving some other stores unaltered. The requirements under the weighted-average GWP / GHGp reduction programs are designed to provide this type of flexibility to regulated companies. However, since there can be several ways in which GWP and charge reduction can be accomplished, each with different costs, for this analysis, CARB staff are estimating the costs for the most straightforward, economically conservative approach of retrofits. This is to avoid speculation on both, costs and on the likelihood of companies choosing from the different options.

Including one newly constructed store per year, the annual average incremental costs for a supermarket company with 120 stores in California to comply with the proposed rules is expected to be $111,000 per year. Between 2022 and 2030, for retrofitting all 120 stores[135] and for opening 1 new / remodeled store per year, the cumulative annual costs to the company by 2030 are $111,000 x 8 = $888,000. Past 2030, incremental costs will only be borne for opening new / remodeled stores since all existing stores would have already made the changes necessary to the comply with the requirements.

II. Industrial Process Refrigeration and Cold Storage Warehouses

For industrial process and cold storage facilities, the Proposed Amendments will require refrigerants with GWP values less than 150 for new systems in newly constructed/fully remodeled facilities. For large systems containing more than 5,000 pounds of refrigerant – systems like these typically serve very large warehouses and processing facilities, net annual savings of up to $19,000 are expected, due to reduced ongoing costs related to refrigerant replenishment, electricity and RMP compliance. For medium and small systems, incremental costs range between $2,000 and $6,000 per system per year. Total costs or savings will depend on how many systems are used by a facility.

[135] Only if a company chooses to retrofit all their stores.

Some incremental costs for replacing new systems in existing facilities are only expected for industrial process refrigeration facilities, since cold storage warehouses are required to use refrigerants with GWP less than 1,500 in the baseline scenario, under SB 1013. The main source of incremental costs for new systems in existing IPR facilities is the 10 percent premium on equipment. Total annual incremental cost with amortization of 20 years and 5 real percent interest is expected to be between $800 and $9,000 for small, medium and large systems, respectively (see Appendix tables).

b. Stationary AC

Manufacturers are responsible for selling ACs meant to use a refrigerant with less than 750 GWP in California. The Proposed Amendments requires manufacturers to build and sell compliant AC systems and keep records of their sales to California as part of their regulatory requirements. Stationary AC manufacturing is concentrated in relatively few multinational corporations. Seven large manufacturers supplying over 95 percent of the U.S. central ACs and heat pumps market, including California.[136] These businesses have manufacturing facilities in the U.S., but there are no AC manufacturers building systems in California. The majority of room ACs are produced overseas in Asia and imported into the United States. While there are no AC manufacturers building systems in California, this analysis is included to provide further information to stakeholders.

Most room ACs are manufactured in Asia and a transition to products that would be compliant with the Proposed Amendments is already underway. Residential and commercial central AC/HP manufacturers will comply with the Proposed Amendments by developing new product lines for California. AC manufacturers are producing products for the international market to use refrigerants with a GWP less than 750. Developing products for California does require additional investment to adapt lower-GWP refrigerant technology to the types of systems used most commonly in the U.S. and California, which are ducted systems.

It is typical for companies to invest additional research and development to adapt new technologies to expand into another region with different building designs and regulatory frameworks, such as different codes and standards. The cost to transition products includes research and development, facility retrofits, testing and certifying new products and training employees as well as technicians and contractors. CARB estimates the cost to a typical manufacturer to be approximately $20 million per year assuming the seven major manufacturers have equal market share for residential and commercial AC products. Depending on market share, manufacturers may have higher or lower costs.

These costs include a premium for California-specific products. However, California is the most populous State in the United States and therefore constitutes a significant fraction of the U.S. appliance market. While manufacturers have indicated that sales of less than 750 GWP ACs will be exclusively for California, the State represents approximately 12 percent of U.S. population and as such, represents a significant portion of the U.S. market. As other states commit to action on HFCs, it is possible that economies of scale may lower the incremental costs provided in this

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[136] See U.S. DOE Technical Support Documents.

analysis as the market expands.[137] For example, the Washington State Building Council has adopted ASHRAE 15-2019 and the third edition of UL 60335-2-40, which allows the use of A2L refrigerants in direct systems such as residential and other commercial ACs.

The cost impact to manufacturers in this analysis is conservative. Cost estimates for refrigerant transitions and equipment redesigns are typically higher than what is actually experienced.[138] Part of the reason for this is that manufacturers have become increasingly efficient at redesigning their products and are constantly working on developments to minimize their own costs by counterbalance expensive improvements with savings elsewhere.[139] In addition, manufacturers build ongoing research and development and redesign costs into product prices. For these reasons, it is possible that the cost impacts may be lower. While equipment pricing is complex and different manufacturers could use different strategies to pass on these costs, staff assume all costs from deploying compliant equipment for the California market are passed on to end-users.

Table 36. Direct Costs on a Typical Business – AC Manufacturer

Costs to Typical AC Manufacturer	
Year	Costs ($Million)
2023	$22.0
2024	$22.1
2025	$22.2
2026	$22.3
2027	$22.4
2028	$22.5
2029	$22.6
2030	$22.7
2031	$22.8
2032	$22.9
2033	$23.0
2034	$23.1
2035	$23.2

[137] United States Climate Alliance, 2019 Annual Report: Strength in Numbers: American Leadership on Climate, available at http://www.usclimatealliance.org/annual-report; See also United States Climate Alliance, Short-Lived Climate Pollutant Challenge. (web link: http://www.usclimatealliance.org/slcpchallenge, Last accessed February 2020).
[138] Descroches, L., et al., (2013). Low Global Warming Potential Refrigerants for Commercial Refrigeration Systems. (web link: https://www.eceee.org/library/conference_proceedings/eceee_Summer_Studies/2013/6-appliances-product-policy-and-ict/trends-in-the-cost-of-efficiency-for-appliances-and-consumer-electronics/, Last accessed February 2020); See also U.S. DOE Technical Support Documents.
[139] United States Department of Energy, The Future of Air Conditioning for Buildings (web link: https://www.energy.gov/sites/prod/files/2016/07/f33/The%20Future%20of%20AC%20Report%20-%20Full%20Report_0.pdf, Last accessed February 2020); See also JMS Consulting, Consumer Cost Impacts of U.S. Ratification of the Kigali Amendment (web link: http://www.ahrinet.org/App_Content/ahri/files/RESOURCES/Consumer_Costs_Inforum.pdf, Last accessed February 2020); Deutsche Gesellschaft für Internationale Zusammenarbeit, Green Cooling Initiative (web link: https://www.green-cooling-initiative.org/data/user_upload/Downloads/Publications/EN_Green_Cooling_Technologies_-_Market_trends_in_selected_refrigeration_and_air_conditioning_subsectors.pdf, Last accessed February 2020).

Costs to Typical AC Manufacturer	
Year	Costs ($Million)
2036	$23.3
2037	$23.4
2038	$23.4
2039	$23.5

The direct costs to typical businesses who purchase a new commercial AC systems compliant with the Proposed Amendments are shown in Table 37 below. On average, compliant equipment is expected to cost owners and operators of commercial systems an average of 5 to 7 percent above the baseline cost over the lifetime of the equipment based on cost analysis provided to CARB by manufacturers. Since AC is used across all types of businesses, there is no average typical business that is reflective of commercial AC end-users. All businesses and non-residential facilities either installing an AC in new construction or replacing an AC will experience higher costs as shown below, beginning 2023.

Table 37. Commercial AC/HP Cost ($2018)

End-Use	Baseline Costs[a] (Annual)	Baseline Lifetime Costs (Total)	Incremental Costs (Annual Amortized)	Lifetime Incremental Costs (Total)
Commercial AC/HP (Small – Medium)	$2,001	$40,028	+$130 (+7%)	+$2,608 (+7%)
Commercial AC/HP (Large)	$3,034	$60,686	+$152 (+5%)	+$3,048 (+5%)

[a] Baseline costs are for year 2023.

3. Direct Costs on Small Businesses

a. Stationary Refrigeration

Like AC, manufacturing of commercial and industrial refrigeration systems is concentrated under a few companies, and none of these are small businesses. Compliant, low-GWP systems for newly constructed facilities and remodeled facilities are already in production today, and used widely around the world. Any costs associated with increasing production is assumed to be passed onto the end-users.

For end-users who will use new systems in newly constructed or remodeled facilities, the costs to small businesses are not expected to be different from the costs experienced by typical businesses. The proposed rules requires new refrigeration systems in these facilities to have a GWP below 150, whenever they are constructed or remodeled. Businesses are expected to take the added costs into account when planning to open a new facility or fully remodel an existing one. The 50 pound system threshold for the proposed rules automatically exempts most small businesses like convenience and corner stores which generally use smaller refrigeration systems.

For existing retail food outlets such as supermarkets and grocery stores, the additional requirement to reduce the weighted GWP to below 1,400 or achieve a 55 percent reduction in their GHGp by 2030 will place some cost burden on small businesses. Overall, the incremental costs per store are the same as those to a typical business, i.e., an annual incremental cost of $6,320 per supermarket or grocery store (Table 24).

Approximately 4,000 supermarkets and grocery stores are registered with CARB under RMP, and less than 20 percent of those are likely owned by small businesses. Based on employment[140] and RMP data, companies with less than a 100 employees own fewer than 20 stores in California and are considered to be small businesses for this analysis. These companies own an average of 2 stores. Thus, an average small company will incur an incremental cost of $6,320 x 2 = $12,600 per year for compliance with the Proposed Amendments. However, to minimize the impact on small businesses, companies with fewer than 20 stores in California that are not a national chain will only be required to comply by 2030, without a progress step at 2026. This will provide small businesses a full 8 years from the regulation's effective date to plan and spread out the costs. Additionally, since the large companies will be complying with a progress step, contractor familiarity with retrofits and other compliant technology solutions will increase, which will likely bring down the installation costs as well as ongoing costs associated with replenishing the refrigerant.

In the future, California and all of the United States may be affected by the global HFC phase-down resulting from the Kigali Amendment to the Montreal Protocol.[141] The European Union has already started experiencing the impact of the phase-down, where end-users of HFCs have reportedly experienced drastic refrigerant price volatility and refrigerant shortages.[142] One reason to have all commercial refrigeration businesses, large and small, reduce their weighted-average GWP is to prepare them for a future domestic HFC phasedown and to reduce their exposure to similar market upheavals if and when the phasedown is implemented domestically.

b. Stationary AC

None of the AC manufacturers qualify as small businesses. For end-users who will use new systems, the costs to small businesses are not expected to be different from the costs experienced by typical businesses (see Section C.2.b).

4. Direct Costs on Individuals

a. Stationary Refrigeration

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[140] Dun and Bradstreet Database, 2018. Employment data for RMP companies.

[141] United Nations Industrial Development Organization. (web link: https://www.unido.org/our-focus/safeguarding-environment/implementation-multilateral-environmental-agreements/montreal-protocol/montreal-protocol-evolves-fight-climate-change, Last accessed February 2020).

[142] Cooling Post, R404A price rises 62% in a month, (web link: https://www.coolingpost.com/world-news/r404a-price-rises-62-in-a-month/, Last accessed February 2020); See also Cooling Post, 2017 ends with a 60% price rise. (web link: https://www.coolingpost.com/uk-news/2017-ends-60-price-rise/, Last accessed February 2020); R744, EU's HFC price skyrocketing since start of F-Gas Regulation, (web link: http://r744.com/articles/8339/eu_s_hfc_prices_skyrocketing_since_start_of_f_gas_regulation, Last accessed February 2020).

There are no direct costs to individuals as a result of the Proposed Amendments as they pertain to refrigeration. As the prevalence of low-GWP refrigeration systems increase, some individuals in the service contractor industry may see benefits through increased sales; those are discussed in the macroeconomic section.

b. Stationary AC

Individuals who purchase new AC systems will incur incremental costs beginning in 2023. This includes homeowners, multi-family housing, commercial and other non-residential facility owners who purchase and operate AC systems. The cost of the most affordable type of AC equipment, room ACs, will not change. For residential central AC/HP, the total incremental cost, including equipment, installation and maintenance/repair, is estimated to increase by $360 to $474 which is equivalent to a 4 percent higher cost for the end-user over the lifetime of the equipment (see

Table **38** below).

Table 38. Residential AC/HP Cost ($2018)

End-Use	Baseline Cost[a] (Annual)	Baseline Lifetime Cost (Total)	Incremental Cost (Annual Amortized)	Lifetime Incremental Costs (Total)
Residential AC	$560	$8,406	+$25 (+4%)	+$369 (+4%)
Residential HP	$748	$11,221	+$32 (+4%)	+$474 (+4%)

[a]Baseline costs are for year 2023.

In 2018, the median value of a home in California in 2018 was $546,800.[143] The incremental costs relative to home values represents a change in housing costs of less than 0.1 percent. The cost of energy will continue to be the larger portion of AC ownership after the initial equipment and install cost. The average household electricity use for an AC system is about 2,177 kWh/house per year in the mixed-dry/hot-dry region, which includes California.[144] At a $0.19 per kWh, which is the average cost in California for 2018, a homeowner can expect to spend approximately $6,205 on average on energy over the lifetime of their system.[145] The new U.S. DOE standards taking effect are expected to reduce the energy use associated with residential systems by about 4 percent. While energy use is not expected to change as a result of this regulation, the net effect of the Proposed Amendments and new U.S. DOE regulations will be higher upfront cost for equipment and lower energy costs than the units sold today.[146]

[143] United States Census, Selected Housing Characteristics (web link: https://data.census.gov/cedsci/table?q=housing%20value&hidePreview=true&table=DP04&tid=ACSDP1Y2018.DP04&t=Housing%20Value%20and%20Purchase%20Price&lastDisplayedRow=25&moe=false&g=0400000US06, Last accessed February 2020).

[144] U.S. Energy Information Administration, Residential Energy Consumption Survey (RECS) (web link: (https://www.eia.gov/consumption/residential/data/2015/index.php?view=consumption#undefined Last accessed February 2020).

[145] U.S. Energy Information Administration, Electric Power Monthly (web link: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a, Last accessed: February, 2020).

[146] The higher upfront equipment costs due to new U.S. DOE requirements are included in the baseline.

While not included in this analysis, there are a variety of incentives offered by utilities for the purchase of new more efficient units. These incentives will continue to assist home and building owners to offset upfront costs of new systems which are more energy efficient than older equipment. The cost impacts to end-users who own and operate commercial systems is discussed under section "C. Direct Costs" under "Direct Cost on Typical Businesses."

D. FISCAL IMPACTS

1. Local Government

a. Incremental Cost

Local governments that utilize AC and refrigeration systems may incur incremental costs when they purchase and install new low GWP equipment. Some facilities owned by local school districts are registered in the RMP database as users of the regulated refrigeration systems. Together, they make up less than 1 percent of all registered refrigerated facilities and therefore affected by proposed amendments. In this analysis, we assume the same portion of the overall incremental costs are passed on the local governments. AC systems are generally used in state and local government buildings throughout California. Staff assumes the incremental cost of these systems for state and local government is proportional to the share of state and local government demand in California, being 2.0 percent and 6.7 percent, respectively.[147]

b. Sales Tax Revenue

Sales taxes are levied in California to fund a variety of programs at the state and local level. These Proposed Amendments will result in the sale of more expensive AC and refrigeration systems in California, which will result in higher sales tax collected by local governments. Overall, state sales tax revenue may increase less than the direct increase from equipment sales if overall business and consumer spending does not increase.

c. Utility User Fee

Many cities and counties in California levy a Utility User Fee on electricity usage. This fee varies from city to city and ranges from no tax to 11 percent. A value of 3.53 percent was used in this analysis representing a population-weighted average.[148] By decreasing the amount of electricity used, there will be a decrease in the amount of the utility user fee revenue collected by cities and counties.

d. Fiscal Impacts on Local Governments

Over the regulatory lifetime, Local Governments are estimated to incur incremental costs of about $66 million resulting from AC and refrigeration systems used by local government facilities. Local Governments are also estimated to see a direct increase in sales tax revenue of $166 million and a decrease in revenue from the Utility User Fee of $8.5 million. On net, the total fiscal impact (revenues – costs) is estimated to be $17 million over the first three years and $91 million through 2040 (Table 39).

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[147] Based on REMI Policy Insight Plus (v 2.3), state and local governments' share of demand in California is 8.7 percent, which is then disaggregated to state government and local government based on employment share.

[148] California State Controller's Office, User Utility Tax Revenue and Rates (web link: https://sco.ca.gov/Files-ARD-Local/LocRep/2016-17 Cities UUT.pdf, Last accessed February 2020).

Table 39. Fiscal Impacts on Local Governments (Million 2018$)

Year	Incremental Costs	Sales Tax Revenue	Utility User Fee Revenue	Total Fiscal Impact*
2022	$0.0	$1.1	$0.0	$1.1
2023	$0.4	$8.3	$0.0	$7.9
2024	$0.8	$8.3	$0.0	$7.5
2025	$1.1	$8.3	$0.0	$7.2
2026	$1.5	$15.3	-$0.5	$13.2
2027	$1.9	$8.4	-$0.5	$6.0
2028	$2.3	$8.5	-$0.6	$5.6
2029	$2.7	$8.5	-$0.6	$5.3
2030	$3.1	$11.4	-$0.8	$7.5
2031	$3.5	$8.6	-$0.8	$4.3
2032	$3.9	$8.6	-$0.8	$4.0
2033	$4.2	$8.7	-$0.8	$3.6
2034	$4.6	$8.7	-$0.8	$3.2
2035	$5.0	$8.8	-$0.8	$2.9
2036	$5.4	$8.8	-$0.3	$3.1
2037	$5.8	$8.8	-$0.3	$2.7
2038	$6.2	$8.9	-$0.3	$2.3
2039	$6.6	$8.9	-$0.3	$2.0
2040	$7.0	$8.9	-$0.1	$1.8
Total	$66.1	$165.8	-$8.5	$91.1

*The Total Fiscal Impact is calculated as the change in revenue minus costs.

2. State Government

a. Incremental Cost

Some California state government facilities use regulated refrigeration systems and may incur incremental costs when they purchase new equipment. These facilities include but are not limited to state prisons, correctional and rehabilitation facilities, and the state universities. Based on the RMP database, in 2018, 1 percent of all registered refrigerated facilities were owned by the state government. For this analysis, we assume the same percentage of costs are passed on to state government. AC systems are generally used in state and local government buildings throughout California. Staff assumes the incremental cost of these systems for state and local government is proportional to the share of state and local government demand in California, being 2.0 percent and 6.7 percent, respectively.[149]

[149] Based on REMI Policy Insight Plus (v 2.3), state and local governments' share of demand in California is 8.7 percent, which is then disaggregated to state government and local government based on employment share.

b. Sales Tax Revenue

Sales taxes are levied in California to fund a variety of programs at the state and local level. The Proposed Amendments will result in the sale of more expensive AC and refrigeration systems in California, which will result in higher sales tax collected by the state government. Overall, state sales tax revenue may increase less than the direct increase from equipment sales if overall business spending does not increase.

c. CARB Staffing

The Proposed Amendments will have an impact on CARB's staffing requirements. Existing staff will support implementation of the requirements in the Proposed Amendments. However, existing staff cannot be fully devoted to tasks related to implementation because of the need for further rulemakings to implement additional strategies to reduce HFC emissions. CARB will require four additional Air Pollution Specialist (APS) positions for implementing and enforcing the requirements for existing supermarkets and grocery stores. The additional personnel would be responsible for data analysis, annual review of company's emissions reductions, assisting stakeholders with inquiries, supporting enforcement by going on site visits and carrying out audits of stakeholder reports, and other general implementation duties. Any additional work related to implementation of rules for new equipment will be distributed among the existing resources. Each position will place an annual cost burden of $180,000 per year on CARB, starting fiscal year 2022-23.

d. Energy Resource Fee Revenue

The Energy Resource Fee is a $0.0003/kWh surcharge levied on consumers of electricity purchased from electrical utilities. The revenue collected is deposited into the Energy Resources Programs Account of the General Fund which is used for ongoing energy programs and projects deemed appropriate by the Legislature, including but not limited to, activities of the California Energy Commission.

e. Fiscal Impacts on State Government

Over the regulatory lifetime, the State government is estimated to incur incremental costs of about $25 million resulting from AC and refrigeration systems used by State government facilities and $20 million for CARB staffing and resources. The State government is also estimated to see a direct increase in sales tax revenue of $140 million and a decrease in revenue from the Energy Resource Fee of $1 million. On net, the total fiscal impact (revenues – costs) is estimated to be $12 million over the first three years and $94 million through 2040 (Table 39).

Table 40. Fiscal Impacts on State Government (Million 2018$)

Year	Incremental Costs	CARB Staffing & Resources Costs	Sales Tax Revenue	Energy Resource Fee Revenue	Total Fiscal Impact*
2022	$0.0	$0.4	$0.9	$0.0	$0.5
2023	$0.2	$1.1	$7.0	$0.0	$5.7
2024	$0.3	$1.1	$7.0	$0.0	$5.6
2025	$0.4	$1.1	$7.0	$0.0	$5.5
2026	$0.6	$1.1	$12.9	$0.0	$11.1
2027	$0.8	$1.1	$7.1	$0.0	$5.2
2028	$0.9	$1.1	$7.1	$0.0	$5.1
2029	$1.1	$1.1	$7.2	$0.0	$5.0
2030	$1.2	$1.1	$9.6	-$0.1	$7.2
2031	$1.4	$1.1	$7.2	-$0.1	$4.7
2032	$1.5	$1.1	$7.3	-$0.1	$4.6
2033	$1.6	$1.1	$7.3	-$0.1	$4.5
2034	$1.8	$1.1	$7.4	-$0.1	$4.4
2035	$1.9	$1.1	$7.4	-$0.1	$4.3
2036	$2.0	$1.1	$7.4	$0.0	$4.3
2037	$2.1	$1.1	$7.4	$0.0	$4.2
2038	$2.3	$1.1	$7.5	$0.0	$4.1
2039	$2.4	$1.1	$7.5	$0.0	$4.0
2040	$2.5	$1.1	$7.5	$0.0	$3.9
Total	$25.1	$20.4	$139.8	-$0.6	$93.8

*The Total Fiscal Impact is calculated as the change in revenue minus costs.

E. MACROECONOMIC IMPACTS

1. Methods for Determining Economic Impacts

This section describes the estimated total impact of the Proposed Amendments on the California economy. The Proposed Amendments will result in incremental cost and cost-savings for businesses to comply with the regulation. These costs result in direct changes in expenditures in the economy as these cost are passed on to business and individual end-users. These changes in expenditures by end-users will indirectly affect employment, output, and investment in sectors that supply goods and provide services to affected businesses.

These direct and indirect effects lead to induced effects, such as changes in personal income that affect consumer expenditures across other spending categories. The total economic impact is the sum of these effects and are presented in this section. The total economic impacts of the Proposed Amendments are simulated relative to the baseline scenario using the cost estimates described in Section C. The analysis focuses on the changes in major macroeconomic indicators from 2020 to 2040 including employment, output, personal income, and gross state product (GSP). The years of the analysis are used to simulate the Proposed Amendments through more than 12 months post full implementation.

Regional Economic Models, Inc. (REMI) Policy Insight Plus Version 2.3 is used to estimate the macroeconomic impacts of the Proposed Amendments on the California economy. REMI is a structural economic forecasting and policy analysis model that integrates input-output, computable general equilibrium, econometric and economic geography methodologies.[150] REMI Policy Insight Plus provides year-by-year estimates of the total economic impacts of the Proposed Amendments, pursuant to the requirements of SB 617 and the California Department of Finance.[151] CARB uses the REMI single-region, 160-sector model with the model reference case adjusted to reflect the Department of Finance conforming forecasts. These forecasts include California population figures dated May 2019, U.S. real GDP forecast, and civilian employment growth numbers dated April 2019.

2. Inputs of the Assessment

The estimated economic impact of the Proposed Amendments are sensitive to modeling assumptions. This section provides a summary of the assumptions and inputs used to determine the suite of policy variables that best reflect the macroeconomic impacts of the Proposed Amendments. The direct costs and savings estimated in Section C are translated into REMI policy variables and used as inputs for the macroeconomic analysis.[152]

The requirements for low GWP refrigerants in AC systems are estimated to add an incremental cost to the AC equipment, installation, and maintenance for both residential and commercial

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[150] For further information and model documentation see: https://www.remi.com/model/pi/.

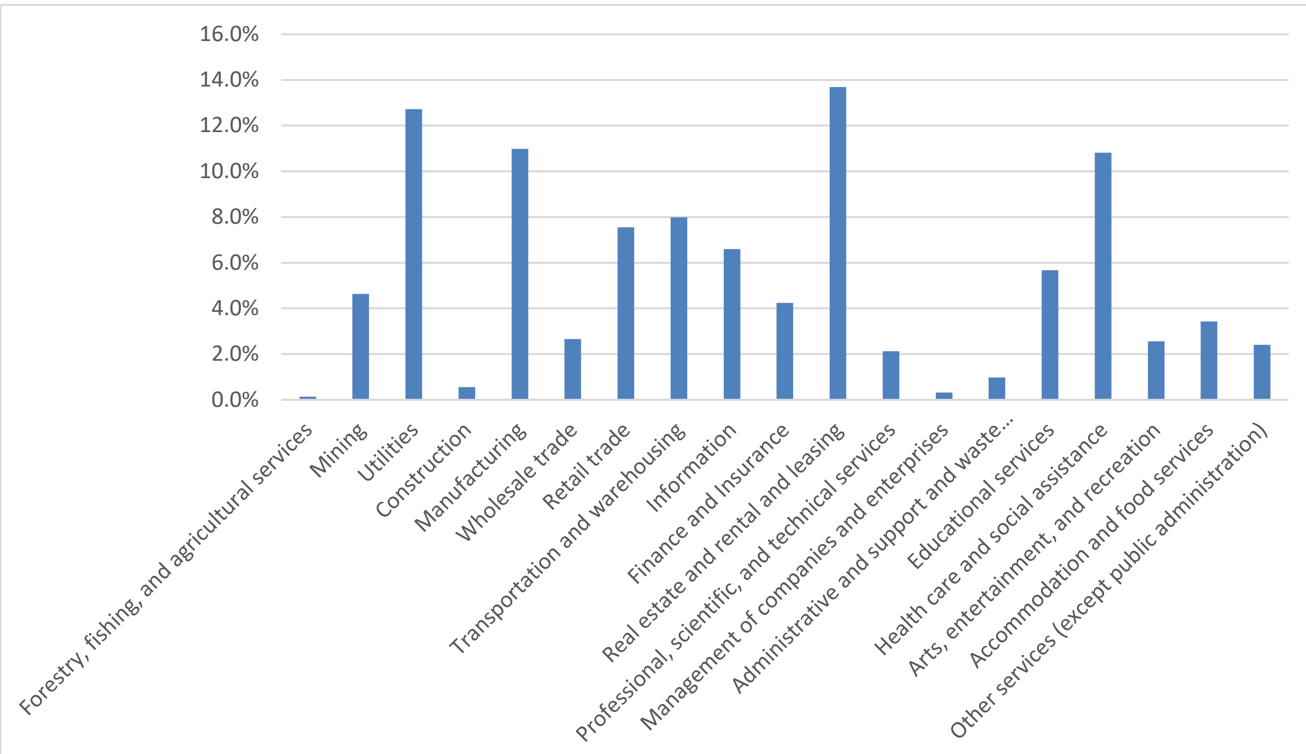
[151] Senate Bill 617 (Calderon, Stats. of 2011, Ch. 496; amending Gov. Code §§ 11346.2, 11346.3, 11346.5, 11346.9, 11347.3, 1139.1, 13401, 13402, 13403, 13404, 13405, 13406, 13407 and adding Gov. Code §§ 11342.548, 11346.36, 11349.1.5); Department of Finance Standardized Regulatory Impact Assessment For Major Regulations, Cal. Code Regs., tit. 1, §§ 2000 et seq.

[152] Refer to Section G: Macroeconomic Appendix for a full list of REMI inputs for this analysis.

equipment, as described in Section C. These costs are expected to be passed through to end-users of these systems (i.e. businesses and households).

The costs incurred by businesses that use AC are input into the model as an increase in production costs for the affected industry. The share of costs incurred across different sectors are assumed to be distributed according to their share of capital expenditures on structures as shown in Figure 8.[153]

Figure 8. Share of Capital Expenditures on Structures by Sector



The costs incurred by residential AC end-users are separated into those for replacement systems in existing structures and those for systems in new structures, as described in Section C. The cost incurred for replacement systems are input into the model as an increase in the consumer price for Household Appliances.[154] The consumer price policy variable affects the economy through changes in expenditures on goods and services based on consumers' response to a price increase for this consumption category. The model assumes that the consumer demand for the good is inelastic,[155] which implies that a price increase, increases total expenditures on this

[153] Annual Capital Expenditures Survey 2017. U.S. Census Bureau. (web link: https://www.census.gov/library/publications/2019/econ/2017-aces-summary.html). Expenditures on mining structures are excluded here.
[154] Household appliances are a component Personal Consumption Expenditures as described by BEA https://www.bea.gov/media/5711. This PCE category within REMI best represents the types of equipment affected under this proposed regulation.
[155] This refers to the technical definition of inelastic in economics, where a percent change in quantity demanded is less than the percent change in price, for a given good. This implies that a price increase, increases total expenditures on this good.

category, corresponding with an equivalent reduction in expenditures on all other goods and services. This input reflects the logic of a behavioral response to an increase in the price of AC systems, as illustrated in Section C.4. The cost incurred for AC systems for new housing are input into the model as an increase in consumer spending on Household Appliances, with an equivalent reduction in consumer spending on all other consumption categories and savings.

These costs incurred by AC and heat pump end-users results in corresponding changes in final demand for industries supplying those particular goods or services as shown in Table 41. As the direct costs on AC equipment manufacturers are incurred out of state, it is assumed here that the changes in demand for the HVAC supply chain also occur out state. This increase in demand is therefore omitted from evaluation in the economic model. All other changes in demand related to AC equipment are included in this analysis. The increased installation costs corresponds to an increase in demand for the general contractors (NAICS 23) that provide this service. The increased maintenance costs corresponds to an increase in demand for the mechanical contractors (NAICS 23) that provide this service.

Table 41: Sources of Changes in Production Costs or Prices and Final Demand by Industry

Source of Cost or Savings	Industries or Individuals with Change in Production Cost or Prices (NAICS)	Industries with Changes in Final Demand (NAICS)
AC - Equipment cost	All Industries and Individuals that use stationary AC equipment	None (out of state)
AC - Installation cost	All Industries and Individuals that use stationary AC equipment	General contractors (23)
AC - Maintenance cost	All Industries and Individuals that use stationary AC equipment	Mechanical contractors (23)
Refrigeration – Equipment cost	All Industries that use commercial stationary refrigeration. Primarily: Retail trade (44-45), Wholesale trade (42), Food mfg. (311), Beverage mfg. (3121), Pharmaceutical and medicine mfg. (3254).*	None (out of state)
Refrigeration – Installation cost	All Industries that use commercial stationary refrigeration. Primarily: Retail trade (44-45), Wholesale trade (42), Food mfg. (311), Beverage mfg. (3121), Pharmaceutical and medicine mfg. (3254).*	Contractors (23)
Refrigeration – Electricity cost-savings	All Industries that use commercial stationary refrigeration. Primarily: Retail trade (44-45), Wholesale trade (42), Food mfg. (311), Beverage mfg. (3121), Pharmaceutical and medicine mfg. (3254).*	Electric power generation, transmission, and distribution (2211)
Refrigeration – Refrigerant cost	All Industries that use commercial stationary refrigeration. Primarily: Retail trade (44-45), Wholesale trade (42), Food mfg. (311), Beverage mfg. (3121), Pharmaceutical and medicine mfg. (3254).*	Basic chemical mfg. (3251)
Refrigeration – RMP reporting cost-savings	All Industries that use commercial stationary refrigeration. Primarily: Retail trade (44-45), Wholesale trade (42), Food mfg. (311), Beverage mfg. (3121), Pharmaceutical and medicine mfg. (3254).*	None (changes firms' labor productivity)

The direct costs of the requirements of low GWP systems for commercial refrigeration and chillers are also expected to be passed on to end-users of the equipment, as described in Section C. The end-users of the equipment will incur an incremental cost related to changes in the equipment and installation cost and the cost of refrigerants. The energy-efficiency gains from the retrofit requirement results in cost-savings to end-users. The net change in the costs is input into the model as a change in production costs for the affected industries. Additionally, facilities that move to low GWP systems will no longer be required to report as part of CARB's RMP, resulting cost-savings, which is input in the model as increase in firms' labor productivity. The share of cost borne by each industry is assumed to be distributed proportionally to the number of systems by industry as reported to the CARB's RMP. This is primarily retail trade (44-45), wholesale trade (42), food manufacturing (311), beverage manufacturing (3121), and pharmaceutical and medicine manufacturing (3254).

These costs incurred by refrigeration and chiller end-users correspond with changes in final demand for industries supplying those particular goods or services as shown in Table 41. As the direct costs on refrigeration and chiller system equipment manufacturers are incurred out of state, it is assumed here that the changes in demand for the supply chain also occur out state. This change in demand is therefore omitted from evaluation in the economic model. All other changes in demand related to refrigeration and chillers equipment is included in this analysis. The increased installation costs corresponds to an increase in demand for contractors (NAICS 23) that provide this service. The increased refrigerant costs corresponds to an increase in demand for the basic chemical manufacturing industry (NAICS 3251), which produces these refrigerants. The cost-savings from energy efficiency gains, correspond with a decrease in demand for Electric power generation, transmission, and distribution (2211) industry.

In addition to these changes in production costs or prices and final demand, there will also be economic impacts as a result of the fiscal effects, primarily from passed-through compliance costs on AC and refrigeration equipment and changes in sales tax revenue. These changes in costs along with changes in government revenue are modeled as a change in state and local government spending, assuming these revenue increases are not offset elsewhere. Additional CARB staff and resources in support of this regulation are modeled as changes in state government employment and spending.

3. Results of the Assessment

The results from the REMI model provide estimates of the impact of the Proposed Amendments on the California economy. These results represent the annual incremental change from the implementation of the Proposed Amendments relative to the baseline scenario. The California economy is forecasted to grow through 2040, therefore, negative impacts reported here should be interpreted as a slowing of growth and positive impacts as an acceleration of growth resulting from the Proposed Amendments. The results are reported here in five year intervals from 2020 through 2040.

a. California Employment Impacts

Table 42 presents the impact of the Proposed Amendments on total employment in California across all private industries and the public sector. Employment comprises estimates of the number of jobs, full-time plus part-time, by place of work for all industries. Full-time and part-time jobs are counted at equal weight. Employees, sole proprietors, and active partners are included, but unpaid family workers and volunteers are not included. The employment impacts represent the net change in employment across the economy, which is composed of positive impacts for some industries and negative impacts for others. The Proposed Amendments are estimated to result in an initial slight increase in employment growth through 2025, followed by a decrease in employment growth through 2040. These changes in employment represent 0.01 percent of baseline California employment.

Table 42: California Employment Impacts

Impact	2020	2025	2030	2035	2040
California Employment	24,321,773	24,825,743	25,207,076	25,874,320	26,713,095
% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
Change in Total Jobs	0	92	-1,198	-1,934	-1,966

The total employment impacts presented above are net of changes at the industry level. The overall trend in employment changes by major sector are illustrated in ***Figure 9***. ***Table 43*** shows the changes in employment by industries that are directly impacted by the Proposed Amendments. As the requirements of the Proposed Amendments go into effect there is initially a slight acceleration of job growth due to expenditures on installation and maintenance activities direct at the contractor industries. Over time the increased production costs for business end-users of commercial refrigeration and chillers and AC equipment and the increase in consumer prices for AC equipment result in a slight decrease in job growth, primarily in the major sectors of Retail and Wholesale and Services.

Figure 9: Job Impacts by Major Sector

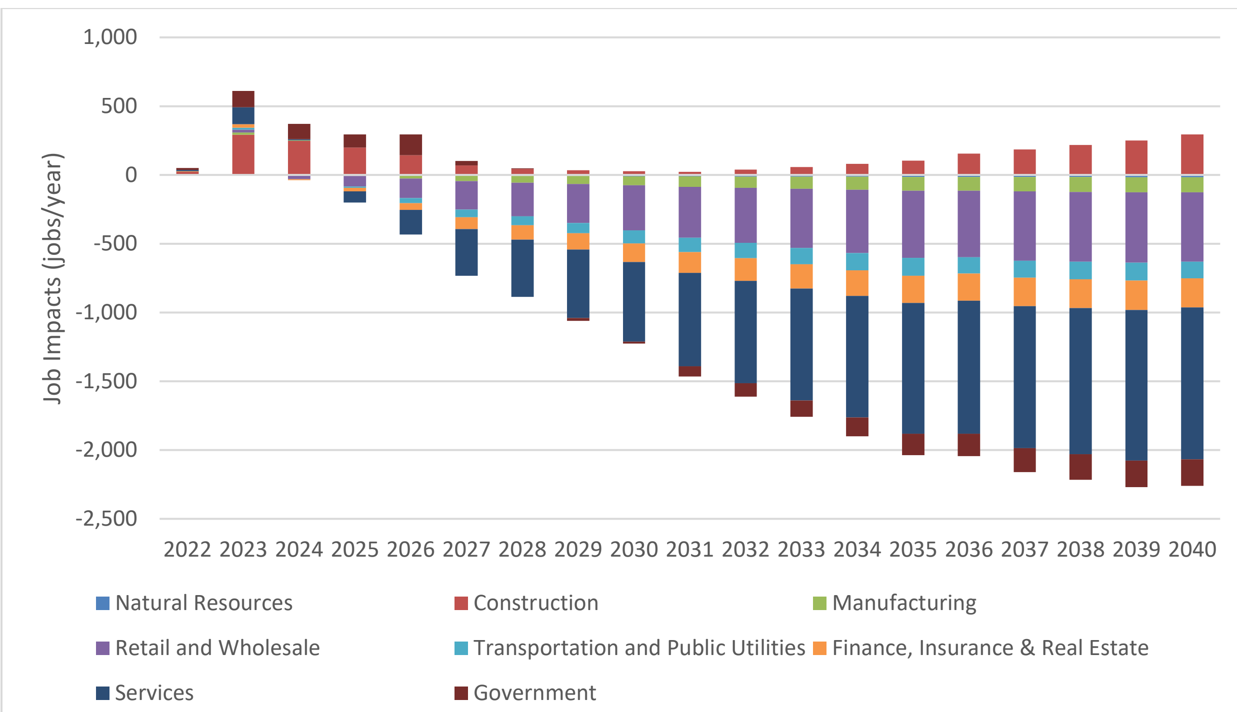


Table 43: Job Impacts by Primary and Secondary Industries

Industry	Impact	2020	2025	2030	2035	2040
Electric power generation, transmission and distribution (2211)	% Change	0.00%	0.00%	-0.06%	-0.07%	-0.02%
	Change in Jobs	0	-1	-30	-31	-10
Construction (23)	% Change	0.00%	0.02%	0.00%	0.01%	0.02%
	Change in Jobs	0	200	27	103	295
Other food manufacturing (3119)	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
	Change in Jobs	0	-1	-5	-8	-10
Beverage manufacturing (3121)	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change in Jobs	0	-1	-3	-5	-6
Basic chemical manufacturing (3251)	% Change	0.00%	0.00%	0.02%	0.02%	0.01%
	Change in Jobs	0	0	1	1	1
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing (3334)	% Change	0.00%	-0.01%	-0.03%	-0.04%	-0.04%
	Change in Jobs	0	0	-1	-2	-2
Household appliance manufacturing (3352)	% Change	0.00%	-0.03%	-0.07%	-0.10%	-0.10%
	Change in Jobs	0	-1	-2	-2	-2
Wholesale trade (42)	% Change	0.00%	0.00%	-0.01%	-0.01%	-0.01%
	Change in Jobs	0	-6	-49	-73	-74
Retail trade (44-45)	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
	Change in Jobs	0	-69	-279	-415	-429
Warehousing and storage (493)	% Change	0.00%	0.00%	-0.01%	-0.01%	-0.01%
	Change in Jobs	0	-3	-15	-24	-27
State & Local Government	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change in Jobs	0	94	-14	-156	-195

b. *California Business Impacts*

Gross output is used as a measure for business impacts because as it represents an industry's sales or receipts and tracks the quantity of goods or services produced in a given time period. Output is the sum of the amount of production, including all intermediate goods purchased as well as value added (compensation and profit), across all private industries and the public sector, and is affected by production cost and demand changes. As production cost increases or demand decreases, output is expected to contract, but as production costs decline or demand increases, industry will likely experience output growth.

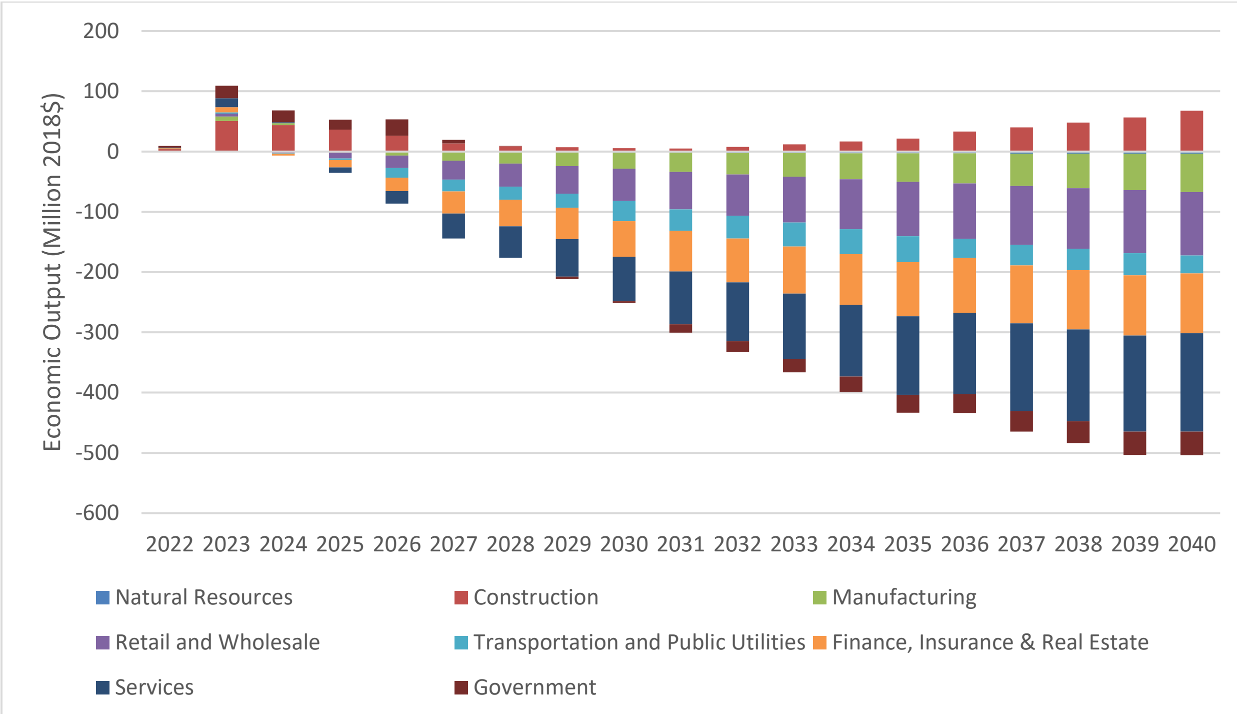
The results of the Proposed Amendments show a decrease in output of $245 million in 2030 and a decrease of $436 million in 2040 as shown in ***Table*** 44, representing a change of about 0.01 percent of baseline output. The trend in output changes is illustrated by major sector in ***Figure 10***. Similar to the employment impacts, there is an initial positive impact, primarily comprised of the construction sector, followed by a decrease primarily comprised of the Retail and Wholesale and Services major sectors.

Table 44: Change in California Output Growth by Industry

Industry	Impact	2020	2025	2030	2035	2040
California economy	Output (2018M$)	4,485,291	4,888,434	5,293,094	5,854,565	6,585,520
	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change (2018M$)	0	18	-245	-412	-436
State & local government	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change (2018M$)	0	17	-3	-30	-39
Electric power generation, transmission and distribution (2211)	% Change	0.00%	0.00%	-0.07%	-0.07%	-0.02%
	Change (2018M$)	0	-1	-23	-26	-9
Construction (23)	% Change	0.00%	0.02%	0.00%	0.01%	0.03%
	Change (2018M$)	0	36	6	22	68
Other food manufacturing (3119)	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
	Change (2018M$)	0	0	-2	-3	-4
Beverage manufacturing	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%

Industry	Impact	2020	2025	2030	2035	2040
(3121)	Change (2018M$)	0	0	-1	-2	-3
Basic chemical manufacturing (3251)	% Change	0.00%	0.00%	0.02%	0.02%	0.01%
	Change (2018M$)	0	2	6	7	5
Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing (3334)	% Change	0.00%	-0.01%	-0.03%	-0.04%	-0.04%
	Change (2018M$)	0	0	-1	-1	-1
Household appliance manufacturing (3352)	% Change	0.00%	-0.03%	-0.07%	-0.10%	-0.10%
	Change (2018M$)	0	0	-1	-1	-1
Wholesale trade (42)	% Change	0.00%	0.00%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0	-2	-17	-28	-32
Retail trade (44-45)	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
	Change (2018M$)	0	-8	-37	-62	-73
Warehousing and storage (493)	% Change	0.00%	0.00%	-0.01%	-0.01%	-0.01%
	Change (2018M$)	0	0	-1	-2	-2

Figure 10: Change in Output in California by Major Sector



c. *Impacts on Investments in California*

Private domestic investment consists of purchases of residential and nonresidential structures and of equipment and software by private businesses and nonprofit institutions. It is used as a proxy for impacts on investments in California because it provides an indicator of the future productive capacity of the economy.

The relative changes to growth in private investment for the Proposed Amendments are shown in Table 45 and show a decrease of private investment of about $120 million in 2030 and $102 million in 2040, or less than 0.01 percent of baseline investment.

Table 45: Change in Gross Domestic Private Investment Growth

Gross Domestic	2020	2025	2030	2035	2040
Private Investment (2018M$)	401,332	436,725	471,989	531,538	600,769
% Change	0.00%	0.00%	0.00%	0.00%	0.00%
Change (2018M$)	0	-31	-120	-141	-102

d. *Impacts on Individuals in California*

The Proposed Amendments result in impacts to individuals as the incremental costs of AC equipment is passed on to residential end-users. Additionally, the costs incurred by affected businesses and the public sector will cascade through the economy and impact individuals. One measure of this impact is the change in real personal income, which includes worker compensation and government and business transfer payments, adjusted for inflation.

Table 46 shows the annual change in real personal income across all individuals in California. Total personal income growth decreases by about $426 million in 2030 and $823 million in 2040 as a result of the Proposed Amendments, or less than 0.03 percent of the baseline. The change in personal income estimated here can also be divided by the California population to show the average or per capita impact on personal income. The decrease in personal income growth is estimated to be about $6 per person in 2030 and $7 per person in 2040.

Table 46: Change in Personal Income Growth

Description	2020	2025	2030	2035	2040
Personal Income (2018M$)	2,473,892	2,764,513	3,074,439	3,411,855	3,810,321
% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
Change (2018M$)	0	-115	-426	-706	-823
Personal Income per capita (2018$)	61,133	65,717	70,464	75,603	81,969
% Change	0.00%	0.00%	-0.01%	-0.01%	-0.01%
Change (2018$)	0	-3	-6	-8	-7

e. Impacts on Gross State Product (GSP)

Gross State Product (GSP) is the market value of all goods and services produced in California and is one of the primary indicators used to gauge the health of an economy. Under the Proposed Amendments, GSP growth is anticipated to decrease by about $209 million in 2030 and decrease by $326 million in 2040 as shown in Table 47. These changes represent less than 0.01 percent of baseline GSP.

Table 47: Changes in Gross State Product (GSP) Growth

Description	2020	2025	2030	2035	2040
GSP (2018M$)	2,775,611	3,026,419	3,282,868	3,602,543	3,984,281
% Change	0.00%	0.00%	0.00%	0.00%	0.00%
Change (2018M$)	0	-40	-209	-312	-326

f. Creation or Elimination of Businesses

The REMI model cannot directly estimate the creation or elimination of businesses. Changes in jobs and output for the California economy described above can be used to understand some potential impacts. The overall jobs and output impacts of the Proposed Amendments are very small relative to the total California economy, representing changes of less than 0.01 percent.

Impacts to directly affected industries are also very small relative to the baseline, with only one industry exceeding 0.04 percent. Reductions in output could indicate elimination of businesses.

Conversely, increased output within an industry could signal the potential for additional business creation if existing businesses cannot accommodate all future demand. There is no threshold that identifies the creation or elimination of a business. The industry with largest absolute decrease in employment and output is retail trade, this is a large and varied sector consisting of many different types of businesses; it is unlikely that a slowing of growth of 0.02 percent in the high cost scenario indicates the elimination of any particular existing business. The industry with largest absolute increase in employment and output is construction sector, with an acceleration of growth of about 0.04 percent in the high cost scenario, this could lead to an expansion or creation of businesses over time.

g. Incentives for Innovation

The Proposed Amendments sets performance standards for achieving the requirements across both AC and refrigeration sectors. This standard provides an incentive for manufacturers to find innovative methods to achieve these standard in a low cost manner in order to mitigate compliance costs. Staff anticipates that these requirements will result in a growing market for new low-GWP refrigerants and technologies such as CO_2 transcritical and cascade systems, micro-distributed hydrocarbon systems as well low-GWP HFO systems. Manufacturers who invest and gain experience in these technologies will benefit as the market expands. Not only is the demand for air conditioning and refrigeration increasing, but the demand for climate friendly technologies is also increasing. Other U.S. states have committed to taking action on lowering emissions of high-GWP HFCs. In addition, both chemical manufacturers who produce refrigerants and manufacturers of refrigeration and AC equipment are global corporations. The manufacturers producing compliant refrigerants and equipment for California also participate in global markets which include markets where existing policies are already driving adoption of next generation technologies, markets where new measures are driving near-term transformation, as well the worldwide transition that is occurring over a longer-term because of the Kigali Agreement. There is an incentive to commercially deploy and gain experience with these technologies which is bolstered by the Proposed Amendments.

h. Competitive Advantage or Disadvantage

The AC equipment manufacturers that must comply with requirements of the Proposed Amendments are based outside of California and therefore do not present any competiveness impacts for this industry inside California. The incremental costs are anticipated to be incurred generally across business end-users and are not anticipated to result in any competitive advantages or disadvantages within industries.

The refrigeration equipment manufacturers that must comply with requirements of the Proposed Amendments are based outside of California and therefore do not present any competiveness impacts for this industry inside California. The incremental costs of compliance with the AC requirements are assumed to be passed on to end-users in California, primarily in the sectors of retail and wholesale trade. The incremental costs are anticipated to be incurred generally across business end-users and are not anticipated to result in any competitive advantages or disadvantages within industries.

4. Summary and Agency Interpretation of the Assessment Results

The results of the macroeconomic analysis of the Proposed Amendments are summarized in Table 48. As analyzed here, CARB estimates the Proposed Amendments is unlikely to have a significant impact on the California economy. Overall, Proposed Amendments are estimated to result in a change in the growth of jobs, State GDP, and output that is projected to not exceed 0.01 percent of the baseline, while achieving a significant cumulative reduction in GHG emissions. This change is small compared the average annual growth rate of 1.8 percent projected for this time horizon. The Proposed Amendments will result in a small decrease in growth in the Retail and Wholesale trade sectors due to incremental cost incurred by businesses and increased consumer prices for household appliances. The Proposed Amendments will also result in a small increase in growth in the construction sector resulting from increased expenditures on contractors who install and maintain equipment AC and refrigeration equipment.

Table 48: Summary of the Macroeconomic Impacts of the Proposed Amendments

Description	Impact	2020	2025	2030	2035	2040
GSP	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-40	-209	-312	-326
Personal Income	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.02%
	Change (2019M$)	0	-115	-426	-706	-823
Employment	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change in Jobs	0	92	-1,198	-1,934	-1,966
Output	% Change	0.00%	0.00%	0.00%	-0.01%	-0.01%
	Change (2019M$)	0	18	-245	-412	-436
Private Investment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-31	-120	-141	-102

F. ALTERNATIVES

1. Alternative 1

Alternative 1 is a more stringent requirement for both stationary refrigeration systems containing more than 50 pounds of refrigerant and stationary AC systems. Under this alternative, every new refrigeration system would be required to have a refrigerant with a GWP value below 10. Only natural refrigerants (CO_2, NH_3 and hydrocarbons) would currently be able to comply with this limit; HFO/HFC blends such as R-454C with GWP values between 11 and 150 would be prohibited under this scenario. For AC equipment, room ACs would be required to have a refrigerant with a GWP value less than 10 and residential and commercial AC equipment would be required to use a refrigerant with a GWP value less than 500. Currently, there is only one A1 refrigerant that industry has identified as a refrigerant alternative to R-410A with a GWP under 750. A GWP limit of 500 would exclude this option. A GWP limit of 500 would also exclude multiple A2L options which manufacturers are either selling in the market today or are in the process of commercializing. Options for room ACs would include propane and HFOs. There compliance options for stationary AC systems would be more limited, and would have some degree of flammability properties. These GWP limits align with proposals from stakeholders advocating for the most stringent GWP limits technologically feasible today.

Table 49 summarizes the requirements of Alternative 1.

Table 49. Alternative 1 GWP Limits for Stationary Refrigeration and AC

Stationary Refrigeration or AC Sector	Refrigerant GWPs Prohibited (100-year GWP Value)	Prohibition Date
Stationary Refrigeration (new systems with over 50 lb. refrigerant in new, remodeled and existing facilities)	10 or greater	January 1, 2022
Stationary Room AC (new)	10 or greater	January 1, 2023
Stationary AC (new) (Commercial)	500 or greater	January 1, 2023
Stationary AC (new) (residential)	500 or greater	January 1, 2023

a. Costs

Based on CARB's F-Gas inventory, refrigeration systems used in supermarkets, grocery stores, cold storage and industrial process cooling have an average lifetime of 15 – 20 years. At that time, one or more motor-bearing parts (e.g., compressors, condensers, evaporators) typically need to be replaced. In existing facilities, a system would be considered "new" if the repair/replacement costs of the components being replaced exceed 50 percent of the cost of replacing the whole system. In that case, the facility owners/operators would then be required to swap out all of the remaining equipment to make the whole facility run using a refrigerant with a

GWP value less than 10. Because the current refrigerants with GWP less than 10 are not compatible with any of the HFC equipment currently in use, the upfront costs related to equipment and installation would be high. Table 50 shows the direct cost inputs for the refrigeration equipment for Alternative 1.

Table 50. Alternative 1 Incremental Costs for New Refrigeration Systems

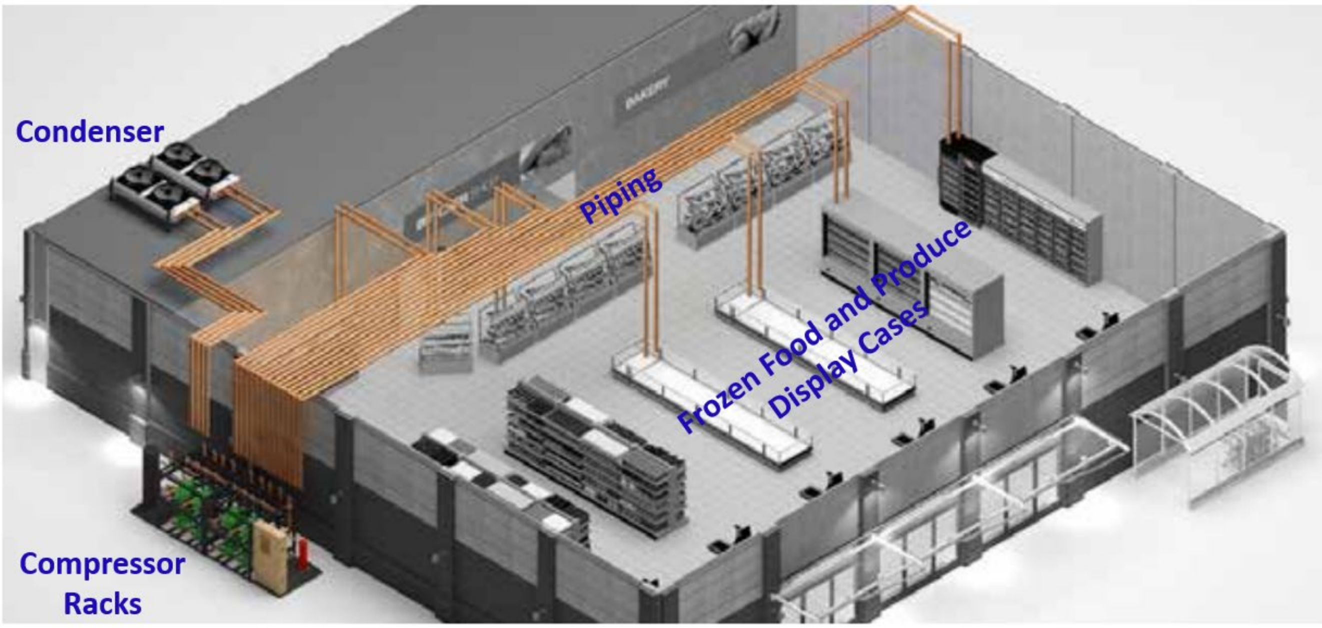
Cost Categories	New systems in existing facilities, GWP < 10	Incremental Annual Costs for New Systems Existing Facilities ($ / year)[a]
Equipment and Installation (Upfront)	Equipment: + 80%; Installation: +20% for commercial refrigeration, +40% for IPR and cold storage	+$3,620 to +$82,100 [b]
Refrigerant Replenishment (ongoing)	– 50%	+$15 to +$2,840
Maintenance (ongoing)	No change from baseline	+$0
Electricity (ongoing)	–10% for large IPR and cold storage systems; no change for others	-$35,000 to +$0
RMP Compliance (ongoing)	– 100%	-$151 to -$3,100
Total Annual Costs ($ / year)		+$3,410 to +$75,900

[a] The range of values represents the different incremental costs based on system sizes (i.e., small, medium, large) and system types (i.e., commercial, industrial process and cold storage).
[b] Amortized annual incremental upfront costs, including a 5 percent rate to reflect end-user financing.

The key difference between the main proposal and Alternative 1 are the higher incremental costs for placing new systems in existing facilities. As discussed earlier, if in an existing facility, a refrigeration system undergoes partial component replacement but that replacement exceeds a capital cost threshold, then the systems is deemed "new." In this case, the facility would be required to use a refrigerant with a GWP value below 10. All the equipment from that facility previously in use for HFC refrigerants would need to be replaced to make it compatible for a refrigerant with GWP less than 10 (none of the HFC equipment is compatible for use with refrigerants with GWP < 10 that are currently available).

The schematic below shows the typical layout of the refrigeration equipment in a supermarket – broadly, it consists of the following (1) compressors (often located in a machine room, mezzanine level or at the back of the facility , (2) condenser often located on the rooftop, (3) fixtures like display cases for storing and showcasing produce and frozen foods inside the supermarket, (4) expansion valves or metering devices (not labeled), and (5) refrigerant piping or lines connecting the display cases to the compressors and condensers. The refrigerant piping carries cold, mostly liquid refrigerant to the display cases for chilling the products. Inside the display cases, the cold refrigerant absorbs heat and vaporizes, cooling the products. After this, refrigerant piping carries the hot, vaporized refrigerant from the cases back to the compressor and eventually the condenser, to reject heat.

Figure 11. Example of a Centralized Refrigeration System[156]



The differences in thermodynamic properties and safety-related requirements for the currently available low-GWP refrigerants make them incompatible with equipment designed for HFC refrigerants. For example, CO_2 has higher operating pressures and a higher volumetric capacity than HFCs – this results in CO_2 systems having smaller compressors, and CO_2 systems require thicker refrigerant piping with a smaller diameter. Thus, any existing equipment in a supermarket that uses HFC refrigerants today cannot simply be "retrofitted" with the currently available low-GWP refrigerants. To use low-GWP refrigerants, all existing equipment will need to be completely replaced. For this analysis, based on stakeholder input, CARB staff assume an 80 percent average incremental cost for compliant new equipment in existing facilities. Even though a full replacement will occur, the incremental costs are not assumed to be 100 percent because some components would have to be replaced as part of the baseline, for example, some display cases and other components would be replaced upon which the capital cost threshold of 50 percent is triggered and, as a result of which, a full replacement is triggered. In addition, the installation costs would double relative to the main proposal, because labor would be required to uninstall the existing HFC-compatible equipment and then install the compliant new equipment. Because the currently available compliant refrigerant options for the main proposal will be the same if the GWP limit is 10 instead of 150 (i.e., CO_2, ammonia and propane), ongoing costs such

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[156] Adapted from original image in Kysor Warren, Parallel Compression Refrigeration, Installation and Operation Manual. (web link: http://www.kysorwarren.com/files/literature/merchandisers/service/i/KW-IOM-HFC.pdf, Last acessed February 2020).

as refrigerant replenishment, electricity and RMP compliance are all expected to be the same as those for the main proposal and yield some savings to the end-user.

As discussed in Section A.5.a, only 20 to 26 percent of new systems in any given year are installed in newly constructed or remodeled facilities, and the remaining 74 to 80 percent are used to replace retiring equipment in existing facilities. Since Alternative 1 would require all of the new systems to use refrigerants with GWP values below 10, all existing facilities would face very high incremental upfront costs.

For Stationary AC, the key difference between the main proposal and Alternative 1 is the potential for higher cost as the compliance options are more limited to newer A2L refrigerants. Staff estimate higher upfront costs if all manufacturers were to transition to an A2L with a GWP limit less than 500 by 2023. Under this scenario, manufacturers may not be able to leverage their investments in refrigerant options below 750 but above 500.

When provided with different refrigerant options for compliance, equipment manufacturers have the ability to select a compliance pathway, which minimizes their cost. In addition, the compliance options that exist today are newer refrigerant HFO blends, which comes with higher costs, especially initially, and the higher costs for installation, service and maintenance of an A2L system would also apply. Room ACs using R-290 (propane) are being introduced to the market in Asia, however codes and standards are farther behind in allowing this technology in California. Recently, a new window AC design was introduced using an HFO with a GWP below 10, which would not require any codes or standards changes and the manufacturer has indicated it will be at cost parity with R-410A when commercially available. However, major manufacturers have not begun a redesign or testing products to release a comprehensive line of room ACs using HFOs, likely because other refrigerants provide more cost-effective options. In addition, other refrigerants such as R-290 offer energy efficiency gains without additional design changes for energy efficiency. Without any codes and standards changes proposed to allow for the use of propane, a 2023 compliance date for room ACs would likely be infeasible.

Table 51. Alternative 1 Incremental Costs for New AC Equipment

Cost Categories	Room AC/HP	Residential Central AC/HP	Commercial AC/HP
Equipment Retail (Upfront)	No change from baseline	+ $250	+ $1,400
Installation (Upfront)	No change from baseline	+$50	+$140
Servicing and Maintenance (ongoing)	No change from baseline	+$90	+$950

The overall costs associated with Alternative 1 for the refrigeration systems is given in ***Table 52***. For both refrigeration and AC, the upfront costs are estimated to be much higher than the main proposal, ranging between $28 million and over $850 million per year, from 2022 to 2040, with an average cost of $566 million per year.

Table 52. Total Costs for Alternative 1 (million 2018$)

Year	Refrigeration		AC		Total Costs ($ / year)
	Upfront[a]	Ongoing[b]	Upfront[c]	Ongoing[d]	Refrigeration + AC
2022	32.2	-$2.6	$0	$0.0	29.6
2023	64.6	-$5.1	$234	$5.5	299
2024	97.3	-$7.8	$235	$11.1	336
2025	130	-$10.4	$236	$16.8	373
2026	163	-$13.0	$238	$22.5	410
2027	197	-$15.7	$239	$28.3	448
2028	230	-$18.4	$240	$34.2	487
2029	264	-$21.1	$242	$40.1	525
2030	298	-$23.8	$243	$46.1	564
2031	333	-$26.5	$244	$52.1	603
2032	367	-$29.3	$246	$58.2	642
2033	402	-$32.1	$247	$64.4	682
2034	437	-$34.9	$248	$70.6	721
2035	473	-$37.7	$250	$76.9	761
2036	508	-$40.5	$251	$83.2	802
2037	526	-$41.9	$252	$89.6	826
2038	544	-$43.4	$253	$92.2	846
2039	562	-$44.8	$254	$94.8	867
2040	581	-$46.2	$255	$97.4	887

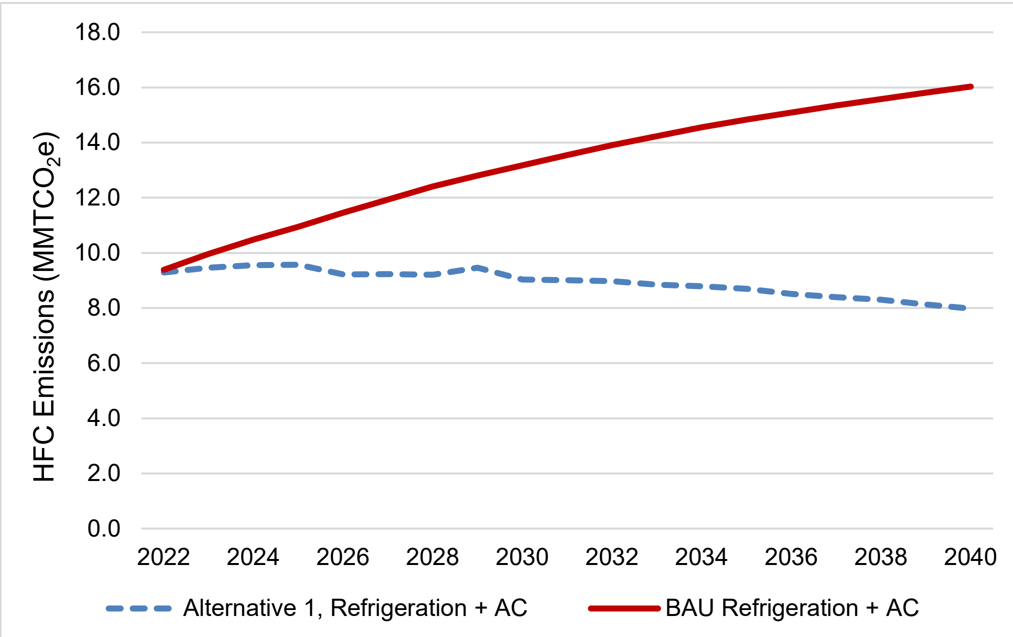
[a]Annualized equipment and installation costs for refrigeration systems.
[b]Annual ongoing savings for refrigeration systems for refrigerant replenishment, electricity and RMP compliance.
[c]Annualized equipment and installation costs for AC.
[d]Annual maintenance and repair costs for AC.

b. Benefits

For refrigeration systems, Alternative 1 is expected to get the highest expected emissions reductions, since it would use the natural turn-over of refrigeration equipment to transition the industry towards the lowest-GWP refrigerants available today. This means that all new systems, including those being installed in existing facilities would have to use refrigerants with GWP values less than 10 (i.e., all new systems shown in Figure 3 would be required to use ultra-low GWP refrigerants). This alternative is the quickest way to achieve emissions reductions and transitioning this sector to refrigerants with the lowest warming potentials possible within the next two decades. While two decades seems long, it is worth noting that commercial and industrial refrigeration systems are large, complex, and designed to last for a long time. For AC equipment, Alternative 1 is expected to get the highest expected emissions reductions because it would require the lowest GWP technologically possible at this time.

Between 2022 and 2040, Alternative 1 results in average annual emissions reductions of 6.2 $MMTCO_2e$ and cumulative reductions equaling 117 $MMTCO_2e$ combined from the refrigeration and AC sectors (***Table 53***).

Figure 12. Projected Annual Baseline Emissions and Expected Reductions from Alternative 1



The annual GHG emission reductions multiplied by the SC-CO_2 values shown in ***Table 53***, summed across the regulatory lifetime and adjusted for inflation gives a monetary estimate of the benefit of GHG emission reductions from this alternative. These benefits range from about $2.6 billion to $11.3 billion through 2040, depending on the chosen discount rate.

Table 53. Projected Emissions Benefits from Alternative 1

Year	GHG Emissions Reductions ($MMTCO_2e$)	Avoided Social Cost of Carbon (Million 2018$)		
		5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2022	0.9	$15.0	$49.7	$74.0
2023	1.4	$23.6	$79.9	$118
2024	2.0	$32.7	$113	$166
2025	2.6	$45.4	$149	$220
2026	3.2	$55.9	$188	$276
2027	3.8	$71.3	$228	$333
2028	4.4	$83.1	$271	$393
2029	5.1	$95.0	$310	$456
2030	5.7	$114	$356	$519
2031	6.3	$126	$402	$583
2032	6.9	$147	$449	$648
2033	7.5	$161	$502	$719
2034	8.1	$184	$551	$785

Year	GHG Emissions Reductions ($MMTCO_2e$)	Avoided Social Cost of Carbon (Million 2018$)		
		5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2035	8.7	$196	$598	$848
2036	9.3	$221	$652	$920
2037	9.8	$234	$702	$998
2038	9.9	$249	$723	$1,022
2039	10.5	$264	$778	$1,094
2040	11.0	$291	$831	$1,163
Total	117	$2,610	$7,930	$11,340

c. Economic Impacts

Alternative 1 is more stringent compared to the Proposed Amendments, requiring AC equipment to achieve a lower GWP standard and requiring commercial refrigeration system to all achieve less than 150 GWP. This results in higher incremental cost as passed-through to end-users, relative to the Proposed Amendments. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed Amendments, but of a larger magnitude as shown in **Table** 54. Figure 13 and Figure 14 show the job and economic impact changes of Alternative 1, respectively.

Table 54. Change in Growth of Economic Indicators for Alternative 1

Description	Impact	2020	2025	2030	2035	2040
GSP	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-123	-455	-790	-1,020
Personal Income	% Change	0.00%	-0.01%	-0.03%	-0.04%	-0.05%
	Change (2019M$)	0	-289	-814	-1,367	-1,740
Employment	% Change	0.00%	0.00%	-0.02%	-0.02%	-0.03%
	Change in Jobs	0	-1,136	-3,852	-6,275	-7,566
Output	% Change	0.00%	0.00%	-0.01%	-0.02%	-0.03%
	Change (2019M$)	0	-206	-746	-1,303	-1,711
Private Investment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-93	-215	-271	-272

Figure 13. Job Impacts of Alternative 1 by Major Sector

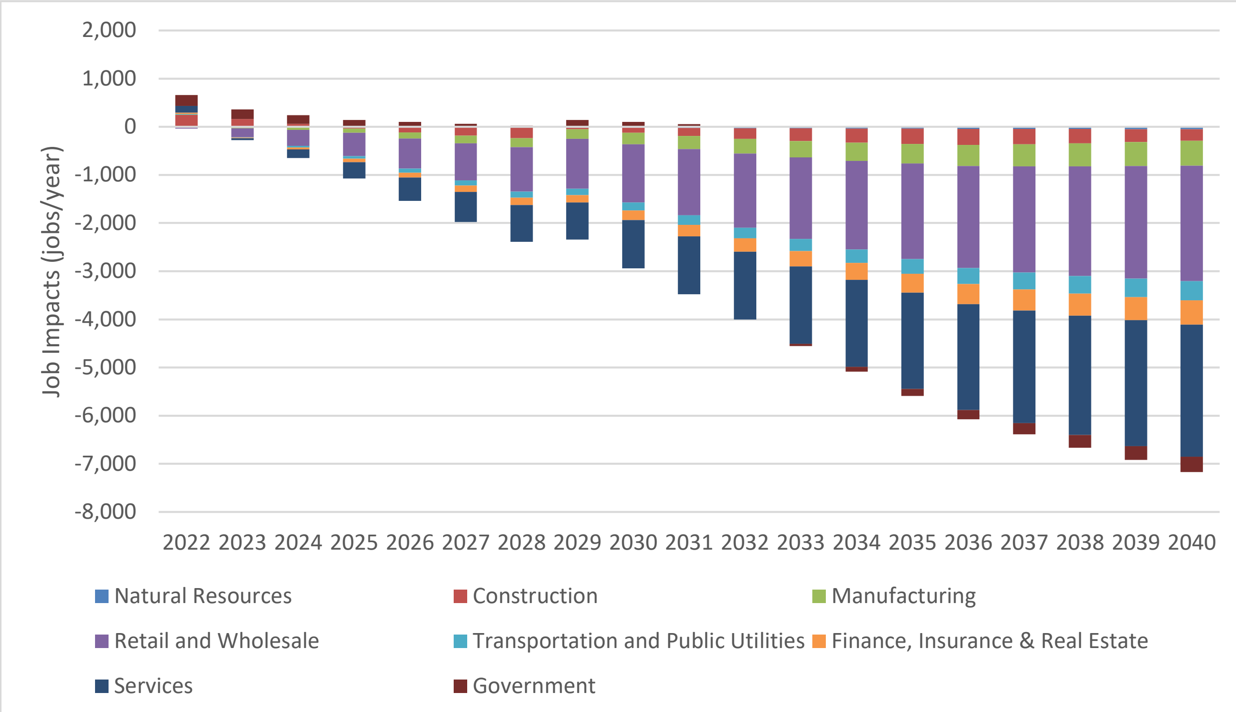
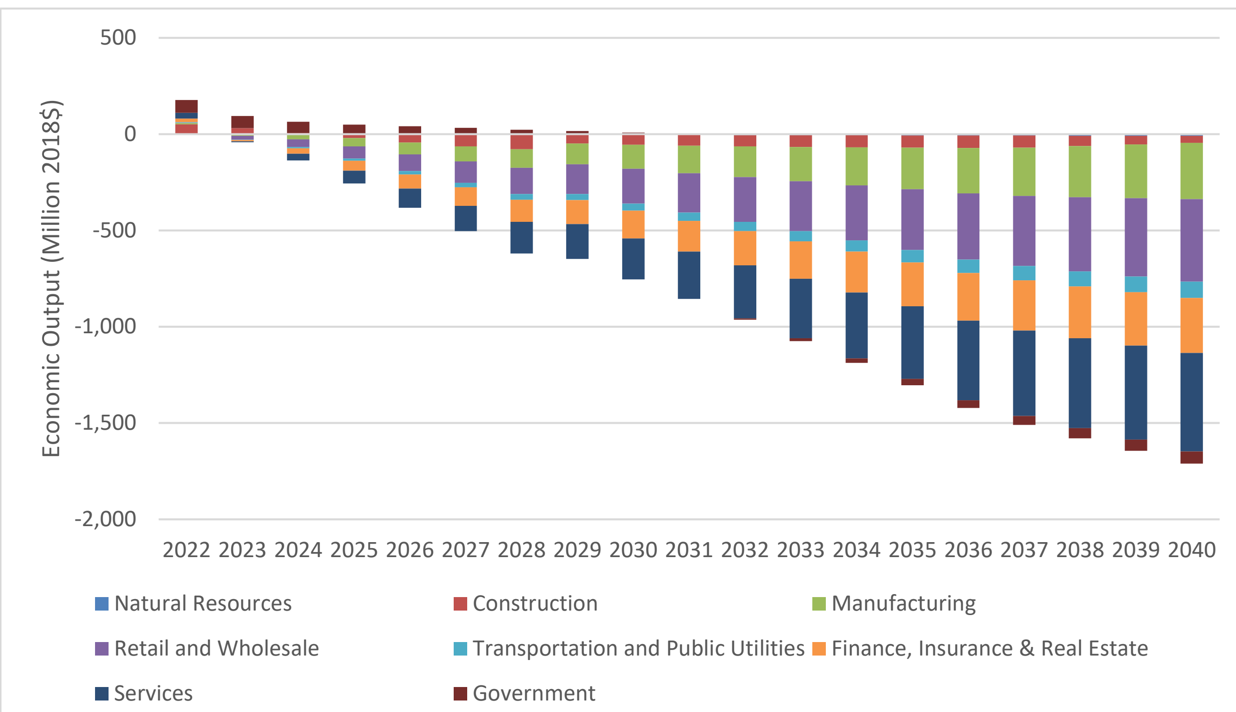


Figure 14. Economic Impacts of Alternative 1 by Major Sector



d. Cost-Effectiveness

Cost-effectiveness is a measure of the cost of a regulation per ton of expected emissions reduction. There are multiple approaches to calculating cost-effectiveness. For the Proposed Amendment, staff calculated the cost-effectiveness (in \$/MTCO_2e) by dividing the net direct cost of the regulation from 2022 to 2040 by the expected GWP-weighted emissions reductions over that time-period. Cost-effectiveness for the Proposed Amendments and Alternative 1 is summarized in Table 55. Staff estimated that Alternative 1 would be less cost-effective than the Proposed Amendments due to the higher upfront and ongoing costs.

Table 55. Cost Effectiveness of the Proposed Amendments and Alternative 1

Proposal	Cost-Effectiveness (\$/MTCO2e)
Proposed Amendments	\$58
Alternative 1	\$82
Difference in Cost-Effectiveness	\$24

e. Reason for Rejecting

For refrigeration, as the details of the proposal were discussed during stakeholder engagements and the economic impacts analyzed, it became increasingly clear that the direct costs associated with this alternative are very high. The main reason is the incompatibility of equipment using refrigerants with GWP < 10 with the currently installed equipment suitable for HFCs. This poses a significant systems integration problem which currently can only be resolved with a 100 percent replacement of equipment. Additionally, if a facility owner were to carry out a full system replacement, doing so is logistically onerous without shutting the facility down. Facility owners avoid store closures for any length of time to prevent losses in customer loyalty and revenue. While estimated emissions reductions from this alternative are significantly higher than the main proposal, this alternative proposal could result in a shift in the behavior of the owners/operators - fewer system replacements would occur and as a result, old leaky systems that are in dire need of replacement and upgrades would likely not be updated, especially in facilities owned by small businesses. Due to high associated costs associated with this alternative and to avoid shifts in consumer behavior that could lead to higher emissions, CARB has rejected this alternative.

CARB is rejecting this alternative for AC for two main reasons. First, a GWP less than 10 for room AC is not feasible in the near-term. This GWP limit would require the use of either an HFO or an A3 (highly flammable) refrigerant such as R-290. Using an HFO refrigerant to achieve a GWP of less than 10 for room ACs would likely need substantial redesign to achieve the same level of energy efficiency. Transitioning room AC product lines to an HFO with a GWP under 10 would be more costly and without the added benefit to manufacturers of increased energy efficiency. As for using an A3 refrigerant in room ACs, there is no proposal currently to revise product standards to allow for their use in the U.S., which is a precursor to adopting new building codes which allow for their use. CARB rejected this proposal for a GWP less than 10 for room ACs because of the infeasibility of using an A3 refrigerant and the cost of an HFO alternative for this category of equipment.

CARB rejected the proposal of 500 GWP by 2023 for all residential and commercial ACs because it would limit the compliance options significantly and would result in higher cost impacts. This

GWP limit would exclude an A1 alternative, effectively limiting the options to newer A2L refrigerant blends. In addition, this limit further excludes A2L options with GWP values less than 750 but above 500 which are either being sold in the market today or are in the process of being commercialized. This could increase costs of the Proposed Amendments for manufacturers which have selected this refrigerant to pivot to another option and be ready with compliant equipment by 2023. A range of compliance options allows manufacturers to minimize cost impacts by leveraging their investments in refrigerant technology less than 750 to transition products for California and other markets by 2023.

2. Alternative 2

Alternative 2 comprises less stringent requirements for both refrigeration and AC than the Proposed Amendments. Under this alternative, all of the new regulated refrigeration systems would have to use mid-GWP (i.e., GWP < 1,500) refrigerants like R-448A and R-449A, irrespective of whether the systems are installed in newly constructed, remodeled or existing facilities. This would not require a transition to low-GWP refrigerants like CO_2, NH_3, hydrocarbons or the low-GWP fluorocarbon refrigerants in newly constructed and remodeled facilities. This is aligned with stakeholders advocating for the least stringent requirements for these sectors and instead rely on external market forces to propel the transition to low-GWP refrigerants. Alternative 2 does not set a GWP limit for AC systems and instead expands leak management and reporting requirements under South Coast AQMD Rule 1415 to AC equipment across the rest of the state.

Some stakeholders have suggested tightening the leaks of refrigerants from this equipment instead of applying restrictions on refrigerant GWP values in new equipment. For regulated refrigeration systems, CARB's Refrigerant Management Program has now been in effect since 2011. In Alternative 2, CARB also considers a statewide program similar to South Coast AQMD Rule 1415 for Stationary AC equipment. Rule 1415 expands RMP requirements to AC equipment over 50 pounds. Facilities with AC equipment with a full charge capacity of greater than 50 pounds of refrigerant are required to register their facility, conduct annual leak inspections, repair leaks within 14 days and keep records on site. This is business as usual for the 40 percent of the state population within the jurisdiction of South Coast AQAMD. This proposal would expand these requirements statewide, which is aligned with stakeholder request for more government oversight of the management of high-GWP refrigerants in commercial equipment. More specifically, this proposal includes an annual report and filing fee, and quarterly leak inspections. However, even if this program cut leak rates 30 percent, this is a less effective strategy for AC than for refrigeration systems because commercial AC is less leaky and charge sizes are smaller than refrigeration systems affected by RMP. While these ACs contribute significantly to HFC emissions, there is less potential to reduce emission per unit through improved management and a greater implementation challenge because of the sheer number of ACs. Additionally, this would not cover residential AC.

a. Costs

Incremental costs associated with Alternative 2 are summarized in tables below. For refrigeration, there are small increases expected for equipment used in industrial refrigeration and the ongoing costs of refrigerant replenishment for all systems. Regarding AC, the costs predominately affects existing systems, unlike the main proposal which only affects new equipment. The costs for

Alternative 2 include an annual leak inspection for large commercial AC equipment, and recordkeeping and reporting consistent with the requirements set in South Coast AQMD Rule 1415 adopted as a statewide regulation. The requirements would be consistent with South Coast AQMD, and as such, neither costs nor are emissions reductions from equipment within this region included in the analysis for Alternative 2.

Table 56. Alternative 2 Incremental Costs for Regulated Refrigeration Systems

Cost Categories	Incremental Cost Percentages	Incremental Annual Costs ($ / year)
Equipment (Upfront)	No change from baseline for commercial refrigeration and cold storage; +10% for IPR	+$795 to +$7,320 [a]
Installation (Upfront)	No change from baseline	+$0
Refrigerant Replenishment (ongoing)	+ 50% for commercial refrigeration and IPR; no change for cold storage	+$33 to +$2,800 [b]
Maintenance (ongoing)	No change from baseline	+$0
Electricity (ongoing)	No change from baseline	+$0
RMP Compliance (ongoing)	No change from baseline	+$0
Total Annual Cost ($ / year)		+$830 to +$9,850 [c]

[a] Annual amortized upfront incremental cost for IPR systems, including a 5 percent rate reflecting end-user financing. See Cost Appendix tables for more details.)

[b] Annual incremental costs for replenishing leaked refrigerant. The range of values represents the different incremental costs based on system size (i.e., small, medium, large) and system type (i.e., commercial, industrial process, cold storage). See

Table 66 in the Appendix for more details.
[c] Total annual incremental costs for Alternative 2. The range of values represents the different incremental costs based on system size (i.e., small, medium, large) and system type (i.e., commercial, industrial process, cold storage).

Table 57. Alternative 2 Incremental Costs for Regulated AC Equipment

Cost Category	Commercial AC Systems > 50 lb.
AC Leak Management Program (ongoing)	+$267 per system

The overall costs associated with Alternative 2 for the refrigeration systems is given in Table 58. The annual average costs associated with alternative 2 are estimated to be $118 million, between 2022 and 2040. The main source of the costs for this alternative are the high implementation costs associated with a refrigerant management program for reducing refrigerant leaks from commercial AC equipment.

Table 58. Total Costs for Alternative 2 (million 2018$)

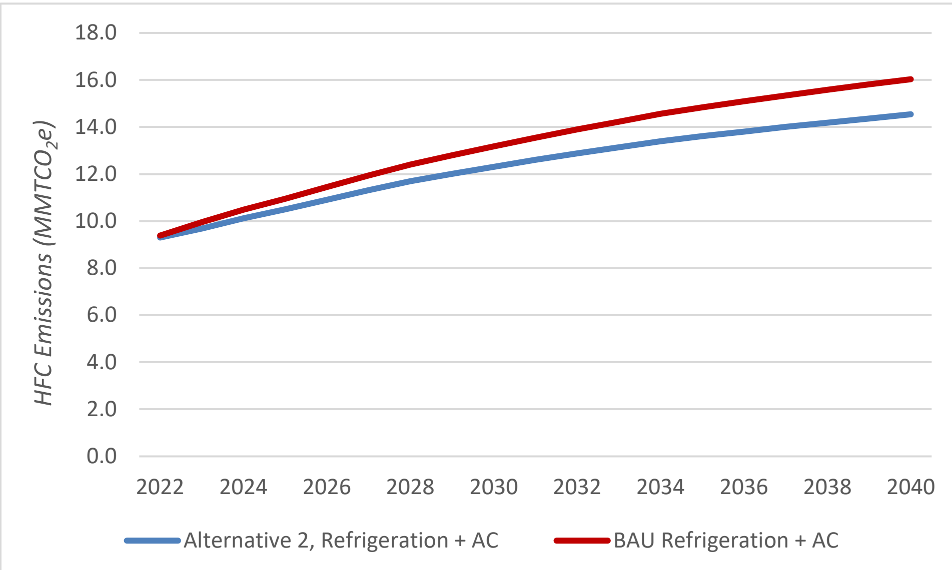
Year	Refrigeration		AC	Total Costs ($ / year)
	Upfront[a]	Ongoing[b]	Ongoing[c]	Refrigeration + AC
2022	0.53	0.81	0.0	1.34
2023	1.07	1.6	101	103
2024	1.61	2.5	102	106
2025	2.15	3.3	103	108
2026	2.70	4.1	104	111
2027	3.26	5.0	105	113
2028	3.81	5.8	106	116
2029	4.37	6.7	108	119
2030	4.94	7.5	109	121
2031	5.51	8.4	110	124
2032	6.08	9.3	111	127
2033	6.66	10.2	113	129
2034	7.24	11.0	114	132
2035	7.82	11.9	115	135
2036	8.41	12.8	116	137
2037	9.0	13.1	117	139
2038	9.6	13.3	118	141
2039	10.2	13.6	120	143
2040	10.8	13.9	121	145

[a]Annualized equipment and installation costs for refrigeration systems.
[b] Annual ongoing costs for refrigerant replenishment for refrigeration systems.
[c] Annual recordkeeping, reporting, leak inspection and filing costs for commercial AC.

b. Benefits

For refrigeration and AC, Alternative 2 is expected to get the lowest expected emissions reductions. Between 2022 and 2040, Alternative 2 results in average annual emissions reductions of less than 1 $MMTCO_2e$ and cumulative reductions equaling 17 $MMTCO_2e$ from the refrigeration and AC sectors.

Figure 15. Projected Annual Baseline Expected Reductions from Alternative 2



The annual GHG emission reductions multiplied by the SC-CO_2 values shown in Table 59 summed across the regulatory lifetime and adjusted for inflation gives a monetary estimate of the benefit of GHG emission reductions from this alternative. The benefits range from about 0.3 billion to $1.6 billion through 2040, depending on the chosen discount rate.

Table 59. Projected Emissions Benefits from Alternative 2

Year	GHG Emissions Reductions ($MMTCO_2e$)	Avoided Social Cost of Carbon (millions 2018$)		
		5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2022	0.1	$1.40	$4.50	$6.80
2023	0.3	$4.50	$15.4	$22.7
2024	0.4	$6.00	$20.6	$30.3
2025	0.5	$8.00	$26.1	$38.6
2026	0.5	$9.50	$31.8	$46.7
2027	0.6	$11.8	$37.6	$54.9
2028	0.7	$13.3	$43.6	$63.1
2029	0.8	$14.9	$48.6	$71.4
2030	0.9	$17.5	$54.6	$79.7
2031	0.9	$19.0	$60.6	$87.9
2032	1.0	$21.8	$66.7	$96.2
2033	1.1	$23.3	$73	$104

Year	GHG Emissions Reductions ($MMTCO_2e$)	Avoided Social Cost of Carbon (millions 2018$)		
		5% Discount Rate	3% Discount Rate	2.5% Discount Rate
2034	1.2	$26.2	$79	$112
2035	1.2	$27.7	$85	$120
2036	1.3	$30.6	$90	$127
2037	1.3	$32.0	$96	$136
2038	1.4	$35.0	$101	$143
2039	1.4	$36.2	$107	$150
2040	1.5	$39.2	$112	$157
Total	17	$378	$1,150	$1,650

c. Economic Impacts

Alternative 2 imposes less stringent requirements compared to the Proposed Amendments. This results in lower incremental cost passed-through to end-users, but also achieves less emission reductions. The macroeconomic impact analysis results are qualitatively similar to the results of the Proposed Amendments, but of a smaller magnitude as shown in Table 60. Figure 16 and Figure 17 show the job and economic impact changes of Alternative 2, respectively.

Table 60. Change in Growth of Economic Indicators for Alternative 2

Description	Impact	2020	2025	2030	2035	2040
GSP	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-21	-37	-50	-60
Personal Income	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-35	-57	-77	-93
Employment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change in Jobs	0	-87	-211	-296	-351
Output	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-31	-55	-75	-94
Private Investment	% Change	0.00%	0.00%	0.00%	0.00%	0.00%
	Change (2019M$)	0	-11	-13	-13	-13

Figure 16. Job Impacts of Alternative 2 by Major Sector

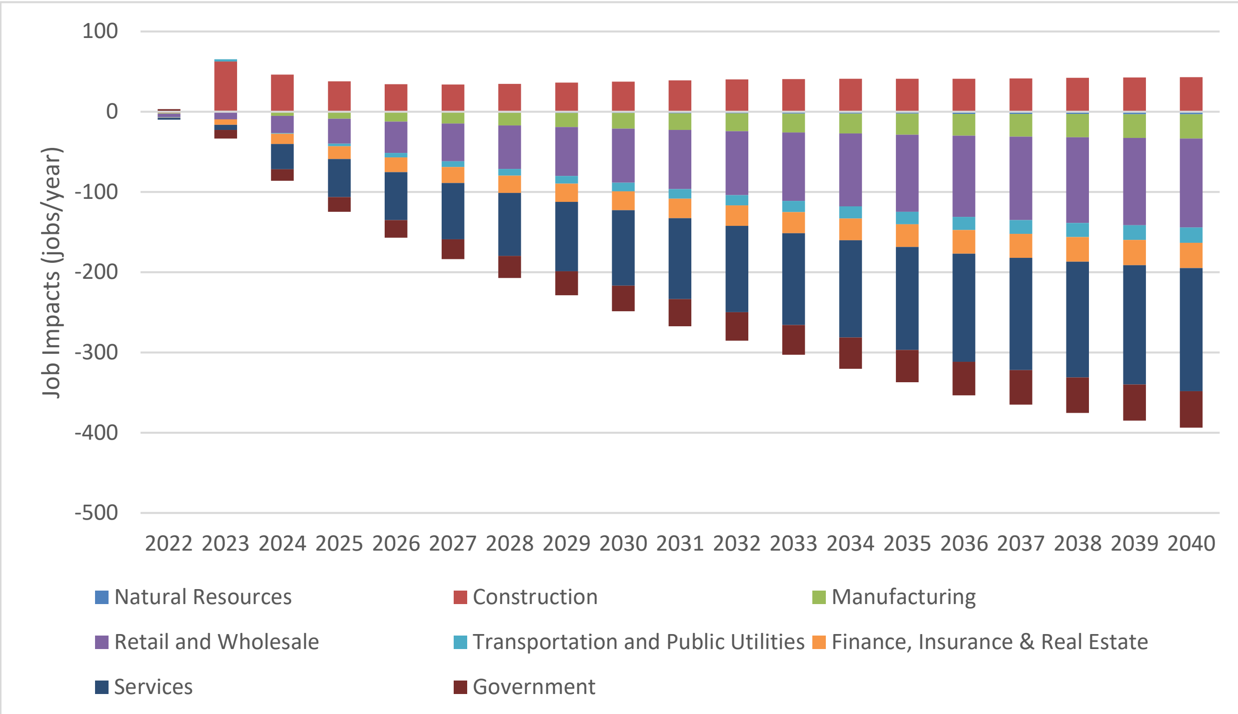
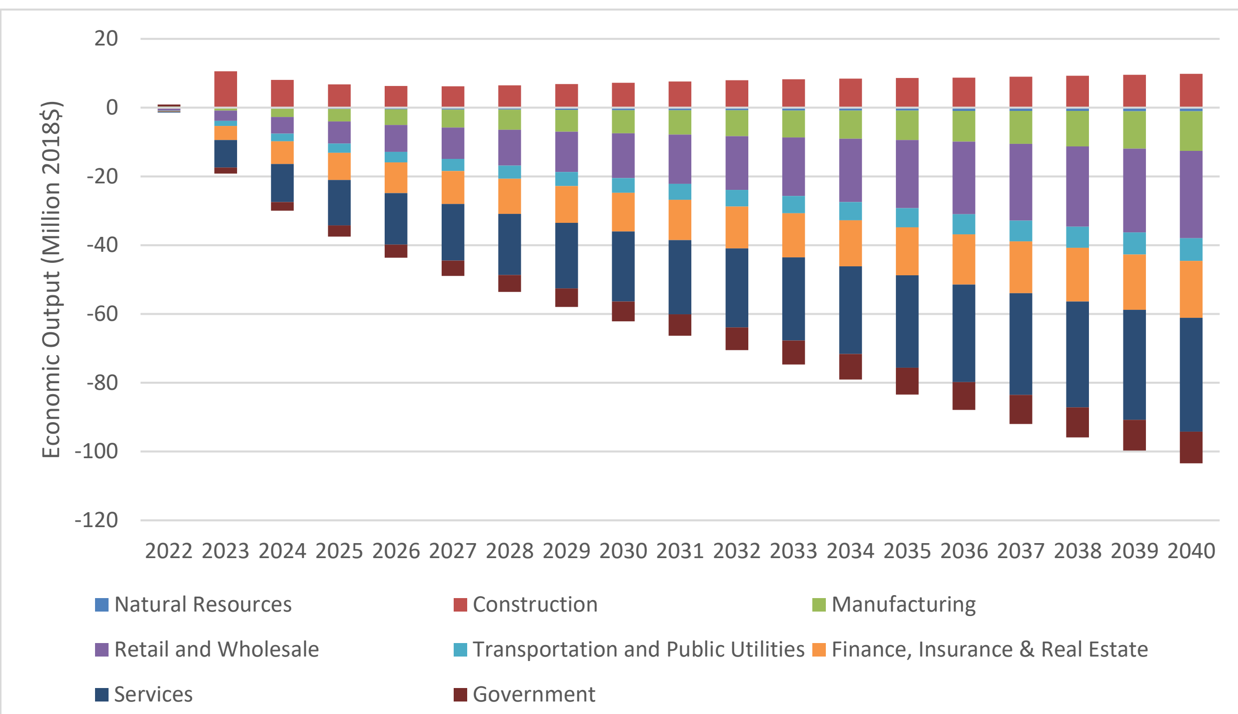


Figure 17. Economic Impacts of Alternative 2 by Major Sector



d. Cost-Effectiveness

Cost-effectiveness values for the Proposed Amendments and Alternative 2 were calculated as described in this section and are summarized in Table 61 below. Staff estimated that Alternative 2 would be less cost-effective than the Proposed Amendments because it achieves fewer emissions reductions relative to the cost.

Table 61. Cost-Effectiveness of the Proposed Amendments and Alternative 2, 2022 – 2040

Proposal	Cost-Effectiveness ($/MMT$CO_2$e)
Proposed Amendments	$58
Alternative 2	$276
Difference in Cost-Effectiveness	$218

e. Reason for Rejecting

The requirements under Alternative 2 are expected to yield significantly lower emissions reductions than the main proposal. Just from the refrigeration sector, the annual emissions reductions are, on average 50 percent lower than the main proposal and cumulative reductions until 2040 and lower by nearly 40 percent. For the AC sector, both the annual emissions and cumulative reduction are 90 percent lower on average compared to the main proposal.

In addition, some stakeholder have suggested that CARB propose measures, which lower the leak rate from refrigeration and AC equipment. To address leaks from refrigeration systems, CARB already has an existing program (RMP) which is more stringent that any current federal rules. There is an existing program, South Coast AQMD Rule 1415 which applies to the nearly 40 percent of large commercial equipment in the state which are in this district. In this Alternative, CARB analyzed the costs and benefits of expanding South Coast AQMD Rule 1415 to cover the remaining 60 percent of the state. The costs of implementing this program include conduction of leak inspections, recordkeeping and submitting reports. Since the leak rates from commercial ACs are already much lower than for residential ACs, there is less room for improving leak rates in existing AC systems as for refrigeration systems, which generally have higher leak rates and substantially higher charge sizes (hundreds to thousands of pounds). Even if the leak rates for large commercial ACs were minimized, the cost would be relatively high compared to the emissions reductions achieved and the implementation challenge would be large considering there are about 200,000 ACs that would need to report compared to the approximately 30,000 regulated refrigeration systems registered in RMP. In addition, Alternative 2 does not address the most significant source of emission from the AC sector, which is residential equipment. Thus, it is more feasible and cost-effective to reduce refrigerant emissions by lowering the GWP of the refrigerant type across all categories of AC equipment.

G. APPENDIX TABLES

1. Cost Appendix

Table 62. Facility-to-system cost conversion for baseline equipment and installation costs

Facility	Average Total Charge at Facility (lb.)[a]	Average Baseline Equipment Cost at Facility[b]	Average $/lb. for Facility[c]	System Size[d]	Inventory System Average Charge (lb.)[e]	Average Baseline Equipment Cost per system[f]	Average Baseline Installation Cost per System[g]
Retail Food	3,500	1,000,000	$286	Large	3,352	$958,000	$431,000
Retail Food	2,500	800,000	$320	Medium	684	$219,000	$98,500
Retail Food	350	260,000	$743	Small	103	$76,500	$34,400
IPR and Cold Storage	10,300	$1,600,000	$155	Large	5,873	$912,000	$411,000
IPR and Cold Storage	1,800	$800,000	$444	Medium	660	$293,000	$132,000
IPR and Cold Storage	420	$400,000	$952	Small	104	$99,000	$44,600
IPR and Cold Storage	10,300	$1,600,000	$155	Large	7,252	$1,130,000	$507,000
IPR and Cold Storage	1,800	$800,000	$444	Medium	552	$245,000	$110,000
IPR and Cold Storage	420	$400,000	$952	Small	113	$108,000	$48,400

[a] Average total refrigerant charge used at the facility across all systems containing more than 50 pounds of refrigerant.
[b] Average baseline costs for equipment per facility type and size, estimated by staff using publicly available estimates and discussed with stakeholders in public meetings.

[c] Average cost per pound of refrigerant at each type of facility, calculated by dividing column *b* (average baseline equipment cost per facility) by column *a* (average refrigerant charge at facility in pounds).
[d] Corresponding system size in the RMP database, if one system were to serve the cooling needs of the whole facility.
[e] Average system refrigerant charge by system type and size, based on RMP database in 2018.
[f] Average baseline cost per system, calculated by multiplying column *c* (average cost per pound at facility) and column *e (average system charge in pounds).*
[g] Average baseline installation charge per system, calculated as 45% x baseline equipment charge per system (based on stakeholder input).

Table 63. New refrigeration systems in new construction per year

Sub-sector	Number of operational units in 2018[a]	Average Lifetime (years)[b]	New units in existing facilities in 2018[c]	New units in new construction in 2018[d]	Total new units in 2018[e]	% new units in new construction[f]
CR Retail Large	204	15	14	2	15	10%
CR Retail Medium	10,927	15	728	83	811	10%
CR Retail Small	27,065	20	1353	206	1559	13%
CR Other Large	87	15	6	1	6	10%
CR Other Medium	4,683	15	312	36	348	10%
CR Other Small	11,599	20	580	88	668	13%
IPR Large	366	20	18	3	21	13%
IPR Medium	2,408	20	120	18	139	13%
IPR Small	13,943	20	697	106	803	13%
Cold Storage Large	69	20	3	1	4	13%
Cold Storage Medium	2,230	20	112	17	128	13%
Cold Storage Small	2,247	20	112	17	129	13%

[a] Number of operational refrigeration systems by type in 2018 (source: CARB F-Gas Inventory).
[b] Average system lifetime (source: CARB F-Gas Inventory).
[c] Calculated by dividing Operational units in 2018 by the average lifetime. This is the number of new units needed annually to replace retiring equipment in existing facilities.
[d] Calculated as 0.76% of the operational units in 2018 (correlated with annual average population growth in California).
[e] Total new units = 'new units replacing retiring equipment' (footnote c) + 'new units in new construction' (footnote d).
[f] Calculated by dividing 'new units in new construction' (footnote c) by 'total new units' (footnote e).

Table 64. Projected Populations of Regulated Refrigeration Systems - Refrigeration systems containing more than 50 pounds of high-GWP ǂ refrigerant

Year	Commercial Retail Food Systems	Commercial Other (Excluding Retail Food Systems)	Industrial Process	Cold Storage
2022	36,791	15,768	15,804	2,550
2023	37,132	15,914	15,967	2,576
2024	37,467	16,058	16,127	2,602
2025	37,798	16,199	16,284	2,628
2026	38,124	16,340	16,438	2,653
2027	38,449	16,478	16,591	2,677
2028	38,770	16,615	16,741	2,702
2029	39,086	16,751	16,888	2,725
2030	39,400	16,885	17,034	2,749
2031	39,712	17,020	17,178	2,772
2032	40,023	17,153	17,321	2,795
2033	40,333	17,286	17,462	2,818
2034	40,641	17,417	17,601	2,841
2035	40,946	17,547	17,739	2,863
2036	41,247	17,678	17,875	2,885
2037	41,547	17,806	18,010	2,907
2038	41,844	17,933	18,142	2,928
2039	42,139	18,060	18,274	2,949
2040	42,431	18,185	18,404	2,970

Table 65. Baseline and Incremental Upfront Costs for New GWP < 1,500 Refrigeration Systems used in Industrial Process Refrigeration and Cold Storage (2018$)

End-Use Sector	System Size	Baseline Costs (HFC DX system)[a]		Incremental Costs (GWP < 1,500 system)[b]	
		Equipment	Installation	Equipment	Installation
Commercial Refrigeration	Large	$958,000	$431,000	$0	$0
	Medium	$219,000	$98,500	$0	$0
	Small	$76,500	$34,400	$0	$0
Industrial Process Cooling	Large	$912,000	$411,000	+$91,200	$0
	Medium	$293,000	$132,000	+$29,300	$0
	Small	$99,000	$44,600	+$9,900	$0
Cold Storage	Large	$1,130,000	$507,000	$0	$0
	Medium	$245,000	$110,000	$0	$0
	Small	$108,000	$48,400	$0	$0

[a] Baseline equipment and installation costs per system discussed in Table 62 above.

[b] Incremental costs above baseline, calculated as baseline cost x incremental cost percentage. For commercial refrigeration no incremental costs are expected because there are no fundamental equipment- or installation-related differences between systems using refrigerants like R448A/R449A and those using baseline refrigerants like R-407A. For IPR, 10% incremental equipment costs above baseline are assumed. For cold storage, refrigerants with GWP greater than 1,500 are prohibited under SB1013 starting 2023, and thus no incremental cost is assumed.

Table 66. Baseline and Incremental Refrigerant Replenishment Costs for New Refrigeration Systems over the Baseline Scenario (2018$)

System Type	Average Full Charge[a] (lb.)	Average Annual Leak Rate[b] (%)	Baseline Refrigerant Costs[c] ($ / year)	Incremental Costs, GWP < 150[d] ($ / year)	Incremental Costs, GWP < 1,500[e] ($ / year)
Commercial, Retail Food – Large	3,352	24.2%	$5,700	– $2,800	+ $2,800
Commercial, Retail Food – Medium	684	22.9%	$1,100	– $550	+ $550
Commercial, Retail Food – Small	103	15.6%	$110	– $56	+ $56
Commercial, Other – Large	3,352	24.2%	$5,700	– $2,800	+ $2,800
Commercial, Other – Medium	684	22.9%	$1,100	– $550	+ $550
Commercial, Other – Small	103	15.6%	$110	– $56	+ $56
Industrial Process Refrigeration – Large	5,873	12.3%	$5,100	– $2,500	+ $2,500
Industrial Process Refrigeration – Medium	660	12.5%	$580	– $290	+ $290
Industrial Process Refrigeration – Small	104	9.1%	$70	– $33	+ $33
Cold Storage – Large	7,252	14.8%	$7,500	–$3,750	$0

System Type	Average Full Charge[a] (lb.)	Average Annual Leak Rate[b] (%)	Baseline Refrigerant Costs[c] ($ / year)	Incremental Costs, GWP < 150[d] ($ / year)	Incremental Costs, GWP < 1,500[e] ($ / year)
Cold Storage – Medium	552	10.3%	$400	– $200	$0
Cold Storage – Small	113	3.7%	$29	– $15	$0

[a] Average full charge per system (also given in Baseline section, Table 4).
[b] Average annual leak rate per system in 2018 (also given in Baseline section, Table 4).
[c] Baseline cost for refrigerant replenishment per year = Average full charge of system (in pounds) x Average Annual Leak Rate x Average baseline cost of refrigerant (i.e., $7 / pound). This is the estimated amount of money spent each year for replenishing leaked refrigerant from each system (rounded to two significant figures).
[d] For systems with refrigerant GWP less than 150, the cost per pound of refrigerant are assumed to be 50% lower than the baseline cost (for e.g., CO_2 is 50% cheaper than R-407A on a per-pound basis). Thus, annual costs for refrigerant replenishment are 50% lower than baseline.
[e] For systems with refrigerant GWP less than 150, the cost per pound of refrigerant is assumed to be 50% lower than the baseline cost (for e.g., R-448A/R-449A is 50% more expensive than R-407A on a per-pound basis). Thus, annual costs for refrigerant replenishment are 50% higher than baseline.

Table 67. Average Incremental Electricity Costs for New Refrigeration Systems over the Baseline Scenario (2018$)

System Type	Baseline Costs [a] ($ / year)	Incremental Costs, GWP < 150[b] ($ / year)	Incremental Costs, GWP < 1,500[c] ($ / year)
Cold Storage and Industrial Process Refrigeration Large (excluding chillers)	$350,000	– $35,000	$0

[a] Baseline electricity costs estimated as follows: Annual energy consumption for large cold storage warehouses varies between 2.0 and 3.3 million kWh per year,[157] with an average value of 2.7 million kWh per year. The 12-month annual average price of electricity for the industrial sector in California from June 2018 to May 2019 was $0.13 per kWh.[158] Thus, the average baseline electricity cost for a large cold storage facility is estimated to be 2.7 million kWh/year x $0.13/kWh = $350,000 per year (rounded to two significant digits). Due to lack of separate data sources, a similar baseline cost is assumed for large IPR systems.

[b] For new IPR and cold storage systems with refrigerant GWP less than 150 (required in newly constructed / remodeled facilities), an estimated 10% energy savings are expected due to more energy-efficient refrigerants like NH_3 and due to the superior build quality of the low-GWP systems. Thus, annual costs for electricity are estimated to be 10% lower than baseline. For more details, see Section C.

[c] For new IPR and cold storage systems with refrigerant GWP less than 1,500 (required in existing facilities), no changes are expected in electricity costs relative to the baseline, since energy performance of baseline, high-GWP HFCs is expected to be the same as HFC refrigerants with GWP just under 1,500 in new systems.

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[157] Specific energy consumption for cold storage warehouses ranges between 0.8 and 1.4 kWh per cubic feet per year (Becker Engineering Company, 2013. Greenguide For Sustainable Energy Efficient Refrigerated Storage Facilities. web link https://ww2.energy.ca.gov/2013publications/CEC-500-2013-145/CEC-500-2013-145.pdf, Last accessed: February 2020). Average size of cold storage facility is 2.4 million cubic feet (U.S. Department of Agriculture, 2016. Capacity of Refrigerated Warehouses 2015 Summary. web link https://downloads.usda.library.cornell.edu/usdaesmis/files/x059c7329/db78tf70f/9306t216s/CapaRefrWa-01-25-2016.pdf, Last accessed: February 2020). Thus, the energy consumption per facility ranges between 2.0 and 3.3 million kWh per year, with an average value of 2.7 million kWh per year.

[158] United States Energy Information Administration, 2019. (web link: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=epmt_5_6_a, Last accessed February 2020).

Table 68. Incremental RMP Compliance Costs for New Refrigeration Systems over the Baseline Scenario (2018$)

System Type	Baseline Costs[a] ($ / year)	Incremental Costs, GWP < 150[b] ($ / year)	Incremental Costs, GWP < 1,500[c] ($ / year)
Commercial, Retail Food – Large	$3,100	– $3,100	$0
Commercial, Retail Food – Medium	$650	– $650	
Commercial, Retail Food – Small	$150	– $150	
Commercial, Other – Large	$3,100	– $3,100	
Commercial, Other – Medium	$650	– $650	
Commercial, Other – Small	$150	– $150	
Industrial Process Refrigeration – Large	$3,100	– $3,100	
Industrial Process Refrigeration – Medium	$650	– $650	

[a] Baseline costs for RMP compliance are based on original estimates in the Initial Statements of Reason for CARB's RMP regulation,[159] converted to 2018 dollars. The original cost estimates were on a per-facility basis. These were converted to system costs based on the following assumptions: "small facilities with approximately 5 systems in the small refrigerant charge size category, medium facilities with approximately 5 systems in the medium refrigerant charge size category, and large facilities with approximately 2 systems in the large refrigerant charge size category".[160] NOTE: RMP-based costs are gross costs estimated in 2009. The RMP regulation is estimated to save end-users due to avoided refrigerant leakage costs. However, only the gross costs are used for this analysis.
[b] Compliant refrigeration systems in newly constructed and remodeled stores (i.e., GWP < 150) will be exempt from RMP regulation and thus will see a decline in compliance costs.
[c] Compliant refrigeration systems in existing facilities (i.e., GWP < 1,500) will remain subject to RMP. No changes in RMP-related compliance costs are expected.

[159] CARB, 2009. Appendix C, Economic Impact Estimates – High-Global Warming Potential Stationary Source Refrigerant Management Program. Table 10.(web link: https://ww3.arb.ca.gov/regact/2009/gwprmp09/refappc.pdf, Last accessed February 2020).
[160] Ibid.

Table 69. NAICS Codes Using Refrigeration Systems Affected by CARB's RMP Regulation and the Proposed Amendments (based on RMP registration data in 2018)

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
445110;Supermarkets and Other Grocery (except Convenience) Stores	3,243	59%
452910;Warehouse Clubs and Supercenters	440	5%
424480;Fresh Fruit and Vegetable Merchant Wholesalers	137	2%
452112;Discount Department Stores	272	2%
493120;Refrigerated Warehousing and Storage	148	2%
311999;All Other Miscellaneous Food Manufacturing	134	2%
312130;Wineries	267	2%
325412;Pharmaceutical Preparation Manufacturing	34	1.0%
424410;General Line Grocery Merchant Wholesalers	57	0.9%
115114;Postharvest Crop Activities (except Cotton Ginning)	67	0.8%
311991;Perishable Prepared Food Manufacturing	40	0.8%
541712;Research and Development in the Physical, Engineering, and Life Sciences (except Biotechnology)	33	0.7%
922140;Correctional Institutions	30	0.7%
424420;Packaged Frozen Food Merchant Wholesalers	43	0.6%
311812;Commercial Bakeries	42	0.6%
424470;Meat and Meat Product Merchant Wholesalers	44	0.6%
424810;Beer and Ale Merchant Wholesalers	45	0.6%
721110;Hotels (except Casino Hotels) and Motels	4	0.5%
334413;Semiconductor and Related Device Manufacturing	33	0.5%
622110;General Medical and Surgical Hospitals	39	0.4%
311412;Frozen Specialty Food Manufacturing	27	0.4%

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
325414;Biological Product (except Diagnostic) Manufacturing	10	0.4%
541711;Research and Development in Biotechnology	17	0.4%
493110;General Warehousing and Storage	23	0.4%
311612;Meat Processed from Carcasses	24	0.4%
325413;In-Vitro Diagnostic Substance Manufacturing	20	0.3%
713110;Amusement and Theme Parks	6	0.3%
424460;Fish and Seafood Merchant Wholesalers	29	0.3%
453998;All Other Miscellaneous Store Retailers (except Tobacco Stores)	44	0.3%
312120;Breweries	26	0.3%
722310;Food Service Contractors	17	0.3%
611310;Colleges Universities and Professional Schools	11	0.3%
424490;Other Grocery and Related Products Merchant Wholesalers	28	0.2%
311830;Tortilla Manufacturing	11	0.2%
221112;Fossil Fuel Electric Power Generation	30	0.2%
311511;Fluid Milk Manufacturing	10	0.2%
115116;Farm Management Services	5	0.2%
311411;Frozen Fruit Juice and Vegetable Manufacturing	13	0.2%
311421;Fruit and Vegetable Canning	15	0.2%
493190;Other Warehousing and Storage	13	0.2%
493130;Farm Product Warehousing and Storage	20	0.2%
311919;Other Snack Food Manufacturing	15	0.2%
928110;National Security	16	0.2%
311513;Cheese Manufacturing	13	0.2%
336411;Aircraft Manufacturing	9	0.2%

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
311911;Roasted Nuts and Peanut Butter Manufacturing	8	0.2%
326199;All Other Plastics Product Manufacturing	18	0.2%
326160;Plastics Bottle Manufacturing	16	0.2%
311712;Fresh and Frozen Seafood Processing	15	0.2%
311520;Ice Cream and Frozen Dessert Manufacturing	18	0.2%
517212;Cellular and Other Wireless Telecommunications	3	0.2%
311423;Dried and Dehydrated Food Manufacturing	12	0.2%
333295;Semiconductor Machinery Manufacturing	8	0.2%
311813;Frozen Cakes Pies and Other Pastries Manufacturing	8	0.1%
447110;Gasoline Stations with Convenience Stores	34	0.1%
325120;Industrial Gas Manufacturing	33	0.1%
311615;Poultry Processing	13	0.1%
312111;Soft Drink Manufacturing	18	0.1%
445299;All Other Specialty Food Stores	12	0.1%
111219;Other Vegetable (except Potato) and Melon Farming	12	0.1%
624210;Community Food Services	7	0.1%
111411;Mushroom Production	8	0.1%
424430;Dairy Product (except Dried or Canned) Merchant Wholesalers	14	0.1%
445230;Fruit and Vegetable Markets	9	0.1%
111422;Floriculture Production	3	0.1%
325411;Medicinal and Botanical Manufacturing	7	0.1%
541614;Process Physical Distribution and Logistics Consulting Services	6	0.1%
336415;Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing	1	0.1%
111998;All Other Miscellaneous Crop Farming	14	0.1%

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
424820;Wine and Distilled Alcoholic Beverage Merchant Wholesalers	7	0.1%
722110;Full-Service Restaurants	28	0.1%
221310;Water Supply and Irrigation Systems	6	0.1%
333415;Air-Conditioning and Warm Air Heating Equipment and Commercial and Industrial Refrigeration Equipment Manufacturing	5	0.1%
336414;Guided Missile and Space Vehicle Manufacturing	4	0.1%
323110;Commercial Lithographic Printing	11	0.1%
324110;Petroleum Refineries	8	0.1%
713940;Fitness and Recreational Sports Centers	18	0.1%
334516;Analytical Laboratory Instrument Manufacturing	6	0.1%
311611;Animal (except Poultry) Slaughtering	3	0.1%
112120;Dairy Cattle and Milk Production	12	0.1%
333294;Food Product Machinery Manufacturing	7	0.1%
327910;Abrasive Product Manufacturing	6	0.1%
312112;Bottled Water Manufacturing	4	0.1%
325211;Plastics Material and Resin Manufacturing	7	0.1%
445210;Meat Markets	7	0.1%
336413;Other Aircraft Parts and Auxiliary Equipment Manufacturing	11	0.1%
339999;All Other Miscellaneous Manufacturing	8	0.1%
221119;Other Electric Power Generation	10	0.1%
111336;Fruit and Tree Nut Combination Farming	9	0.1%
312113;Ice Manufacturing	8	0.1%
311941;Mayonnaise Dressing and Other Prepared Sauce Manufacturing	4	0.1%

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
334112;Computer Storage Device Manufacturing	1	0.1%
339112;Surgical and Medical Instrument Manufacturing	8	0.1%
112990;All Other Animal Production	4	0.1%
541990;All Other Professional Scientific and Technical Services	2	0.1%
211111;Crude Petroleum and Natural Gas Extraction	16	0.1%
332813;Electroplating Plating Polishing Anodizing and Coloring	7	0.1%
325320;Pesticide and Other Agricultural Chemical Manufacturing	3	0.1%
541512;Computer Systems Design Services	1	0.1%
311822;Flour Mixes and Dough Manufacturing from Purchased Flour	5	0.1%
334419;Other Electronic Component Manufacturing	5	0.1%
221330;Steam and Air-Conditioning Supply	4	0.1%
611710;Educational Support Services	3	0.1%
325998;All Other Miscellaneous Chemical Product and Preparation Manufacturing	5	0.1%
424990;Other Miscellaneous Nondurable Goods Merchant Wholesalers	2	0.1%
336111;Automobile Manufacturing	1	0.1%
221320;Sewage Treatment Facilities	7	0.1%
111421;Nursery and Tree Production	2	0.1%
561910;Packaging and Labeling Services	7	0.1%
326111;Plastics Bag Manufacturing	5	0.1%
541380;Testing Laboratories	5	0.1%
311111;Dog and Cat Food Manufacturing	3	0.1%

NAICS Codes 6-Digit and Descriptors	Number of Facilities Registered in R3 in 2018	Percent Refrigeration Systems under each NAICS in 2018 in R3[a]
221122;Electric Power Distribution	3	0.1%
311613;Rendering and Meat Byproduct Processing	3	0.1%

[a] NAICS codes using fewer than 0.1% of the total registered systems are not shown here. In total, 97% of all NAICS codes using refrigeration systems and registered with CARB are given in this table. Note: NAICS codes are reported by end-users into the R3 database and not checked for accuracy by CARB.

2. Macroeconomic Appendix

Table 70. REMI Inputs for the Main Proposal (Million 2017$)

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Consumer Spending	Reallocate Consumption: Household appliances	-	5.92	11.90	17.92	24.00	30.14	36.32	42.57	48.86	55.21	61.61	68.06	74.57	81.12	87.73	94.38	95.16	95.93	96.70
Consumer Price	Household appliances	-	12.75	25.60	38.55	51.61	64.77	78.03	91.40	104.87	118.44	132.12	145.90	159.78	173.75	187.82	201.99	203.49	204.99	206.47
Production Cost	Forestry, fishing, and agricultural services	-	0.01	0.01	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.12	0.12
Production Cost	Mining	-	0.23	0.46	0.69	0.92	1.15	1.39	1.62	1.85	2.09	2.32	2.56	2.80	3.04	3.28	3.52	3.76	4.00	4.24
Production Cost	Utilities	-	0.63	1.26	1.89	2.53	3.17	3.81	4.45	5.09	5.74	6.39	7.04	7.69	8.34	9.00	9.66	10.32	10.98	11.65
Production Cost	Manufacturing	-	0.54	1.09	1.63	2.18	2.73	3.29	3.84	4.40	4.95	5.51	6.08	6.64	7.21	7.77	8.34	8.91	9.48	10.06
Production Cost	Transportation and warehousing	-	0.39	0.79	1.19	1.59	1.99	2.39	2.79	3.20	3.60	4.01	4.42	4.83	5.24	5.65	6.06	6.48	6.89	7.31
Production Cost	Information	-	0.33	0.65	0.98	1.31	1.64	1.97	2.31	2.64	2.97	3.31	3.65	3.99	4.33	4.67	5.01	5.35	5.69	6.04
Production Cost	Finance and Insurance	-	0.21	0.42	0.63	0.84	1.05	1.27	1.48	1.70	1.91	2.13	2.34	2.56	2.78	3.00	3.22	3.44	3.66	3.88
Production Cost	Real estate and rental and leasing	-	0.68	1.36	2.04	2.72	3.41	4.10	4.79	5.48	6.17	6.87	7.57	8.27	8.98	9.69	10.40	11.11	11.82	12.53
Production Cost	Professional, scientific, and technical services	-	0.11	0.21	0.32	0.42	0.53	0.64	0.74	0.85	0.96	1.07	1.17	1.28	1.39	1.50	1.61	1.72	1.83	1.94
Production Cost	Management of companies and enterprises	-	0.02	0.03	0.05	0.06	0.08	0.09	0.11	0.13	0.14	0.16	0.17	0.19	0.21	0.22	0.24	0.26	0.27	0.29
Production Cost	Administrative and support and waste management	-	0.05	0.10	0.15	0.19	0.24	0.29	0.34	0.39	0.44	0.49	0.54	0.59	0.64	0.69	0.74	0.79	0.84	0.90
Production Cost	Educational services	-	0.28	0.56	0.84	1.13	1.41	1.69	1.98	2.27	2.56	2.84	3.13	3.42	3.72	4.01	4.30	4.60	4.89	5.19
Production Cost	Health care and social assistance	-	0.53	1.07	1.61	2.15	2.69	3.24	3.78	4.33	4.88	5.43	5.98	6.54	7.09	7.65	8.21	8.77	9.34	9.90

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Arts, entertainment, and recreation	-	0.13	0.25	0.38	0.51	0.64	0.76	0.89	1.02	1.15	1.28	1.41	1.55	1.68	1.81	1.94	2.07	2.21	2.34
Production Cost	Accommodation and food services	-	0.17	0.34	0.51	0.68	0.85	1.03	1.20	1.37	1.55	1.72	1.90	2.07	2.25	2.43	2.60	2.78	2.96	3.14
Production Cost	Other services (except public administration)	-	0.12	0.24	0.36	0.48	0.60	0.72	0.84	0.96	1.09	1.21	1.33	1.45	1.58	1.70	1.83	1.95	2.08	2.20
Exogenous Final Demand	Electric power generation, transmission and distribution (2211)	(0.15)	(0.29)	(0.44)	(0.59)	(15.41)	(15.55)	(15.76)	(16.03)	(26.17)	(26.33)	(26.49)	(26.65)	(26.82)	(26.98)	(12.21)	(12.37)	(12.54)	(12.71)	(3.00)
Exogenous Final Demand	Construction (23)	3.66	51.00	55.99	61.04	66.12	71.26	76.45	81.69	86.97	92.30	97.67	103.08	108.52	114.01	119.52	125.08	127.94	130.80	133.65
Exogenous Final Demand	Basic chemical manufacturing (3251)	0.55	1.11	1.67	2.24	5.14	5.72	6.29	6.88	8.94	9.53	10.12	10.72	11.32	11.93	10.20	10.36	10.51	10.66	9.35
State and Local Government Spending	State Government	0.49	5.49	5.41	5.30	10.71	5.01	4.89	4.79	6.98	4.54	4.44	4.34	4.23	4.13	4.11	4.01	3.91	3.81	3.76
State and Local Government Spending	Local Government	1.03	7.60	7.27	6.93	12.74	5.74	5.41	5.06	7.15	4.04	3.71	3.36	3.02	2.66	2.83	2.49	2.13	1.78	1.77
State and Local Government Employment	State Government	2	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Production Cost	Forestry; Fishing, hunting, trapping	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Support activities for agriculture and forestry	0.03	0.06	0.08	0.11	0.23	0.26	0.28	0.31	0.37	0.40	0.43	0.46	0.49	0.52	0.47	0.48	0.50	0.52	0.50
Production Cost	Oil and gas extraction	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Nonmetallic mineral mining and quarrying	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Production Cost	Support activities for mining	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Electric power generation, transmission, and distribution	0.01	0.02	0.03	0.04	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.17	0.18	0.16	0.17	0.17	0.18	0.17
Production Cost	Natural gas distribution	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Water, sewage, and other systems	0.01	0.01	0.02	0.02	0.04	0.05	0.05	0.06	0.07	0.08	0.08	0.09	0.09	0.10	0.09	0.09	0.10	0.10	0.10
Production Cost	Construction	0.00	0.03	0.05	0.08	0.11	0.14	0.16	0.19	0.22	0.25	0.28	0.30	0.33	0.36	0.39	0.42	0.45	0.48	0.50
Production Cost	Other wood product manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Glass and glass product manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Lime, gypsum and other nonmetallic mineral product manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Production Cost	Foundries	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Cutlery and handtool manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Boiler, tank, and shipping container manufacturing	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Machine shops; turned product; and screw, nut, and bolt manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Coating, engraving, heat treating, and allied activities	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Production Cost	Other fabricated metal product manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Industrial machinery manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Commercial and service industry machinery manufacturing, including digital camera manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Ventilation, heating, air-conditioning, and commercial refrigeration equipment manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Production Cost	Engine, turbine, power transmission equipment manufacturing	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Computer and peripheral equipment manufacturing, excluding digital camera manufacturing	0.00	0.01	0.01	0.01	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Production Cost	Semiconductor and other electronic component manufacturing	0.02	0.03	0.05	0.06	0.13	0.15	0.16	0.18	0.21	0.23	0.25	0.26	0.28	0.30	0.27	0.28	0.29	0.30	0.29
Production Cost	Navigational, measuring, electromedical, and control instruments manufacturing	0.00	0.01	0.01	0.01	0.03	0.03	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.06	0.06	0.07	0.07	0.07
Production Cost	Manufacturing and reproducing magnetic and optical media	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Other electrical equipment and component manufacturing	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Motor vehicle manufacturing	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.02	0.02	0.03	0.03	0.03
Production Cost	Motor vehicle body and trailer manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Aerospace product and parts manufacturing	0.01	0.03	0.04	0.05	0.10	0.12	0.13	0.14	0.17	0.18	0.20	0.21	0.22	0.24	0.21	0.22	0.23	0.24	0.23
Production Cost	Medical equipment and supplies manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04
Production Cost	Other miscellaneous manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Production Cost	Animal food manufacturing	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Grain and oilseed milling	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Production Cost	Sugar and confectionery product manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Production Cost	Fruit and vegetable preserving and specialty food manufacturing	0.03	0.05	0.08	0.10	0.21	0.24	0.26	0.29	0.35	0.37	0.40	0.43	0.46	0.48	0.43	0.45	0.47	0.48	0.47
Production Cost	Dairy product manufacturing	0.02	0.03	0.05	0.06	0.12	0.14	0.16	0.17	0.20	0.22	0.24	0.25	0.27	0.29	0.26	0.27	0.28	0.28	0.28
Production Cost	Animal slaughtering and processing	0.02	0.03	0.05	0.06	0.13	0.15	0.16	0.18	0.22	0.23	0.25	0.27	0.29	0.30	0.27	0.28	0.29	0.30	0.29
Production Cost	Seafood product preparation and packaging	0.00	0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.08
Production Cost	Bakeries and tortilla manufacturing	0.03	0.06	0.09	0.12	0.24	0.27	0.30	0.33	0.39	0.42	0.45	0.48	0.51	0.54	0.49	0.51	0.52	0.54	0.53
Production Cost	Other food manufacturing	0.08	0.16	0.24	0.33	0.66	0.75	0.83	0.91	1.09	1.18	1.26	1.35	1.44	1.53	1.37	1.42	1.47	1.52	1.48
Production Cost	Beverage manufacturing	0.06	0.12	0.18	0.25	0.50	0.57	0.63	0.69	0.83	0.89	0.96	1.02	1.09	1.16	1.04	1.08	1.11	1.15	1.12
Production Cost	Textile mills and textile product mills	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Pulp, paper, and paperboard mills	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Converted paper product manufacturing	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02
Production Cost	Printing and related support activities	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Production Cost	Petroleum and coal products manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.04	0.04	0.04	0.05	0.04
Production Cost	Basic chemical manufacturing	0.00	0.01	0.01	0.02	0.04	0.04	0.04	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.07	0.08	0.08	0.08	0.08
Production Cost	Resin, synthetic rubber, and artificial synthetic fibers and filaments manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04
Production Cost	Pesticide, fertilizer, and other agricultural chemical manufacturing	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Pharmaceutical and medicine manufacturing	0.05	0.09	0.14	0.19	0.38	0.43	0.48	0.53	0.63	0.68	0.73	0.78	0.83	0.88	0.79	0.82	0.85	0.88	0.86
Production Cost	Paint, coating, and adhesive manufacturing	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.02	0.02	0.02
Production Cost	Soap, cleaning compound, and toilet preparation manufacturing	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Production Cost	Other chemical product and preparation manufacturing	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Plastics product manufacturing	0.01	0.03	0.04	0.06	0.12	0.13	0.15	0.16	0.19	0.21	0.22	0.24	0.26	0.27	0.24	0.25	0.26	0.27	0.26
Production Cost	Rubber product manufacturing	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Wholesale trade	0.15	0.44	0.73	1.02	1.80	2.09	2.38	2.68	3.15	3.45	3.75	4.05	4.36	4.66	4.50	4.74	4.98	5.21	5.26

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Retail trade	1.69	3.76	5.85	7.94	15.40	17.54	19.65	21.72	25.81	27.99	30.19	32.40	34.62	36.86	33.95	35.41	36.88	38.36	37.84
Production Cost	Air transportation	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Rail transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Truck transportation	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Transit and ground passenger transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Pipeline transportation	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Scenic and sightseeing transportation and support activities for transportation	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02
Production Cost	Warehousing and storage	0.07	0.15	0.22	0.29	0.60	0.67	0.75	0.82	0.98	1.06	1.14	1.21	1.29	1.37	1.23	1.28	1.32	1.37	1.33
Production Cost	Software publishers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Data processing, hosting, related services, and other information services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Telecommunications	0.00	0.01	0.01	0.02	0.04	0.04	0.05	0.05	0.06	0.07	0.07	0.08	0.08	0.09	0.08	0.08	0.08	0.08	0.08
Production Cost	Monetary authorities, credit intermediation, and related activities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Real estate	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.02	0.02	0.02	0.03	0.02
Production Cost	Consumer goods rental and general rental centers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Architectural, engineering, and related services	0.00	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Computer systems design and related services	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04	0.04
Production Cost	Management, scientific, and technical consulting services	0.00	0.01	0.01	0.01	0.02	0.02	0.03	0.03	0.04	0.04	0.04	0.04	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Production Cost	Scientific research and development services	0.03	0.06	0.08	0.11	0.23	0.26	0.29	0.31	0.38	0.41	0.44	0.47	0.50	0.53	0.47	0.49	0.51	0.53	0.51
Production Cost	Other professional, scientific, and technical services	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Office administrative services; Facilities support services	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Production Cost	Business support services; Investigation and security services; Other support services	0.00	0.00	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.04	0.04	0.03	0.04	0.04	0.04	0.04
Production Cost	Travel arrangement and reservation services	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Waste management and remediation services	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Educational services; private	0.01	0.02	0.03	0.04	0.08	0.09	0.10	0.11	0.13	0.14	0.15	0.16	0.17	0.18	0.16	0.16	0.17	0.18	0.17
Production Cost	Outpatient, laboratory, and other ambulatory care services	0.00	0.00	0.01	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Production Cost	Hospitals; private	0.01	0.02	0.04	0.05	0.10	0.12	0.13	0.14	0.17	0.18	0.19	0.21	0.22	0.23	0.21	0.22	0.23	0.23	0.23
Production Cost	Nursing and residential care facilities	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

REMI Policy Variable	REMI Industry /Spending Category	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039	2040
Production Cost	Individual and family services; Community and vocational rehabilitation services	0.00	0.01	0.01	0.01	0.03	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06	0.06	0.06	0.06	0.06	0.06
Production Cost	Performing arts companies; Promoters of events, and agents and managers	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Spectator sports	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Production Cost	Museums, historical sites, and similar institutions	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Production Cost	Amusement, gambling, and recreation industries	0.01	0.02	0.03	0.05	0.09	0.11	0.12	0.13	0.16	0.17	0.18	0.19	0.21	0.22	0.20	0.20	0.21	0.22	0.21
Production Cost	Accommodation	0.01	0.03	0.04	0.05	0.11	0.13	0.14	0.15	0.18	0.20	0.21	0.23	0.24	0.26	0.23	0.24	0.25	0.25	0.25
Production Cost	Food services and drinking places	0.01	0.02	0.03	0.04	0.08	0.09	0.10	0.12	0.14	0.15	0.16	0.17	0.18	0.19	0.17	0.18	0.19	0.19	0.19
Production Cost	Electronic and precision equipment repair and maintenance	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00