Lower-GWP EE Solutions and Impacts

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Executive Summary

The purpose of this study was to provide SoCalREN with necessary information to identify and overcome barriers in implementing Lower-GWP measures. Starting with codes and standards, there were many misalignments between the CARB and EPA end-use definitions, timelines, and GWP thresholds. However, CARB timelines align with the California Mechanical Code (CMC). The CMC does not allow Lower-GWP refrigerants in High Probability Systems which means Lower-GWP refrigerants are not allowed in most buildings. However, the California legislature passed AB 209 which circumvents the CMC and essentially allows any Lower-GWP refrigerant approved for a specific end-use by the EPA. There will likely be confusion among contractors and AHJs regarding refrigerant requirements, end-use definitions, and timelines between CARB, EPA and CMC. The Study Team recommends that SoCalREN develop and host training on this topic, keep records of code issues found in installed projects, and monitor the developments CMC updates in 2025.

The Study Team scanned for Lower-GWP equipment alternatives and interviewed a handful of subject matter experts (SMEs) about the barriers and opportunities that SMEs see with Lower-GWP refrigerants and equipment. The interviews concluded that; Lower-GWP HVAC equipment will not be available until the latter part of 2025, there is a wide range of training needs in the contractor community, there is an opportunity for SoCalREN to support contractors in making the value-proposition for Lower-GWP equipment, and contractors do not directly engage with refrigerant reclaimers. The Study Team recommends that SoCalREN encourage contractors to seek Lower-GWP refrigerant training. The Study Team also recommends that SoCalREN connect with the CPUC to brainstorm ways to make sure incumbent refrigerant is properly reclaimed.

The Study Team compiled a list of Lower-GWP technologies and selected five (5) technologies for further analysis from this initial list. The five (5) technologies were selected by analyzing SoCalREN and CEDARs historical program data. The five selected technologies fell into three (3) end uses; commercial reach-in refrigerators and freezers, multifamily and commercial EHPWHs and commercial heat pump air-conditioning units. Each technology was mapped to existing measure packages. Then, the Study Team calculated kWh and GHG savings (when necessary), refrigerant costs, and TSBs for the Lower-GWP measures and compared them to the existing measures. The Lower-GWP measures saw an increase in TSB and measure cost compared to the existing. SoCalREN is already using Lower-GWP reach-in refrigerators and freezers for its Food Desert program, and the Study Team recommends the refrigerant and TSB be considered when approving other freezers and refrigerators for this program. For the EHPWHs and the heat pump and air conditioning units, the Study Team recommends that SoCalREN consider increased incentives in the short-term and revises or supports revisions of associated measure packages to take full advantage of the additional TSBs from refrigerant benefits and additional kWh savings where they exist. While the cost of Lower-GWP equipment may be prohibitive for some customers, the right incentives could persuade customers to implementing Lower-GWP equipment through SoCalREN programs.

Abbreviations and Acronyms

Abbreviation	Meaning
AB	Assembly Bill
AC	Air Conditioning
ACC	Avoided Cost Calculator
AHJ	Authority Having Jurisdiction
AIM	American Innovation and Manufacturing
ANSI	American National Standards Institute
AR	Accelerated Replacement
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ASM	Assembly
CAA	Clear Air Act
CARB	California Air Resources Board
CBC	California Building Code
CEDARS	California Energy Data and Reporting System
CET	Costs Effectiveness Tool
CFC	California Fire Code
CFC	Chlorofluorocarbons
CMC	California Mechanical Code
Com	Commercial
CPUC	California Public Utilities Commission
CRMP	California Refrigerant Management Program
DHW	Domestic Hot Water
DWHC	DEER Water Heater Calculator
DX	Direct Expansion
EPA	Environmental Protection Agency
EE	Energy Efficiency
EHPWH	Electric Heat Pump Water Heater
Ese	Education -Secondary School
eTRM	Electronic Technical Resource Manual
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbons
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin
HP AC	Heat Pump Air-Conditioning
HPWH	Heat Pump Water Heater
HSRP	Healthy Stores Refrigeration Program
HVAC	Heating, Ventilation and Air-Conditioning
HVACR	Heating, Ventilation, Air-Conditioning and Refrigeration
IAPMO	International Association of Plumbing and Mechanical Officials
ICC	International Code Council

kBtu/hr	100 British Thermal Units per hour
kWh	kilowatt-hour
LADBS	Los Angeles Department of Building and Safety
MAT	Measure Application Type
MFM	Multifamily
MSP	Metered Savings Pathway
NR	Normal Replacement
ODS	Ozone-Depleting Substances
Ofs	Office - Small
PIP	Program Implementation Plan
PTAC	Packaged Terminal Air Conditioning
RACC	Refrigerant Avoided Cost Calculator
SB	Senate Bill
SME	Subject Matter Expert
SNAP	Significant New Alternatives Policy
SSP	Streamlined Savings Pathway
TSB	Total System Benefit
UL	Underwriters Laboratories
UMC	Uniform Mechanical Code
VRF	Variable Refrigerant Flow
WSHP	Water Source Heat Pump

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1. Introduction

This study focuses on refrigerant use in heating ventilation and air conditioning (HVAC), Domestic Hot Water (DHW) heating, and refrigeration. The intersection of refrigerants and global warming has come into the forefront of climate change policy in recent years. Many of the refrigerants commonly used in HVAC systems have global warming potential (GWP) values that are thousands of times higher than CO_2. A goal of energy efficiency programs (EE) in California has historically been to decrease the electricity and natural gas use thereby reducing the amount of CO_2 released by burning fossil fuels at a power plant or at an end-use. However, the contribution of refrigerant leakage from HVAC/DHW/refrigeration systems to global warming is becoming an important topic in EE especially with the push in California for electrification which adds more HVAC/DHW/refrigeration equipment that has the potential to leak refrigerant.

The California Public Utilities Commission (CPUC) required all Program Administrators (PAs) to discuss their strategies for incorporating low global warming potential (Lower-GWP) refrigerants into their portfolio in their 2024-2031 business plans (1). The CPUC did not define Lower-GWP refrigerants, but Low-GWP refrigerants are defined by the state of California in in SB 1206 as a GWP of less than 150 (2). Additionally, the CPUC completed the "*Forward-Looking Low-GWP Refrigerant Transition Impacts* (3)," study and its content will likely be used to update tools necessary to calculate greenhouse gas (GHG) impacts from Lower-GWP EE measures such as the Refrigerant Avoided Cost Calculator (RACC). The CPUC has also released guidance related to refrigerants in the past few years. Taken together, these CPUC actions point to a likely future scenario where the CPUC will require Lower-GWP refrigerants to be incorporated into EE programs in some way.

1.1 Objectives and Outcomes

There are most likely barriers and gaps to incorporating Lower-GWP refrigerants in SoCalREN portfolios if the time should come that a large portion of EE savings or measures is required to come from Lower-GWP measures. These barriers could include the following:

- Codes & standards gaps and/or misalignment between federal, state, and local codes
- Additional design considerations for Lower-GWP systems
- Higher costs for Lower-GWP equipment
- Lack of training for market actors
- Availability of Lower-GWP alternative equipment and/or refrigerants that meet EPA and CARB limits

1.1.1 Objectives

This study will provide SoCalREN with information necessary to identify and overcome these barriers so their programs are prepared to implement Lower-GWP measures. The specific objectives of this study are:

1. To provide an overview of Lower-GWP options, their market availability, and the policies impacting their use
2. To identify measures already being used in SoCalREN's portfolio that can utilize Lower-GWP options
3. To identify Lower-GWP refrigerant potential in SoCalREN's territory

4. To identify impacts on energy savings, GHG savings, measure Total System Benefits (TSBs), and costs if Lower-GWP options were incorporated into the portfolio
5. To identify gaps to incorporating Lower-GWP options into SoCalREN's portfolio

1.1.2 Outcomes

The specific outcomes of this study are:

1. SoCalREN staff will have high-level knowledge of the policies affecting Lower-GWP options as well as the different options available in HVAC, DHW and small commercial refrigeration.[1]
2. SoCalREN will have an actionable list of Lower-GWP options that could be incorporated into their portfolio and the potential impacts on portfolio goals (TSB, energy savings, etc....) if the CPUC should mandate Lower-GWP measures in the future.
3. SoCalREN will have a list of actions needed to prepare for incorporation of Lower-GWP options.

1.2 Medium, High, and Low-GWP Refrigerant Definitions

Federal standards, laws and factsheets talk about the refrigerant transition to Lower-GWP in terms of "technology transition", "phasedown" or "Lower-GWP". The GWP level of a "Low-GWP" refrigerant is not defined at the federal level. California has defined a Low-GWP refrigerant as one having a GWP value of less than 150 (2). However, both CARB and EPA have set GWP limits for HVAC and retail food refrigeration equipment at 750 and 700 respectively which indicates this threshold is an important part of the transition to Lower-GWP refrigerants. Additionally, California's ultimate goal is a GWP value of 10 or less which has been defined as "Ultra-Low-GWP" (2).

For this study the following definitions are used in the rest of this document:

ULTRA-LOW-GWP REFRIGERANT: A refrigerant with a GWP value of 10 or less

LOW-GWP REFRIGERANT: A refrigerant with a GWP value between 10 and 150

MEDIUM-GWP REFRIGERANT: A refrigerant with a GWP value between 150 and 700

LOWER-GWP REFRIGERANT: A refrigerant with a GWP value of 700 or less (this encompasses **ULTRA-LOW-GWP, LOW-GWP, AND MEDIUM-GWP**).

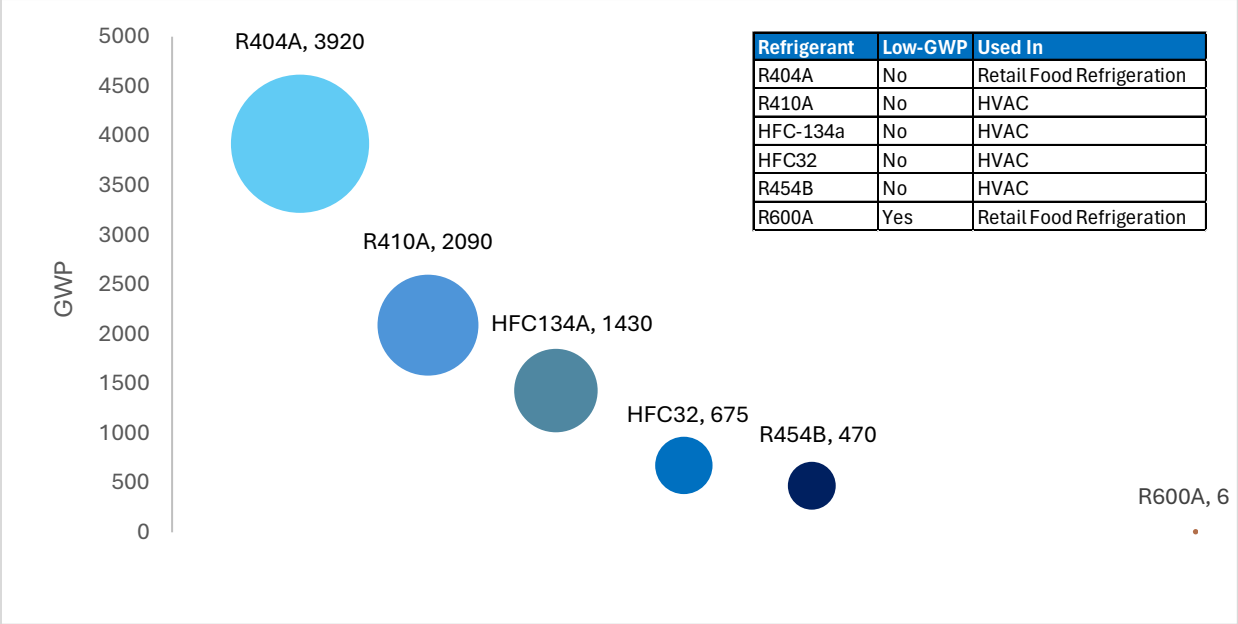
2. Federal and State Codes & Standards

This section summarizes the background of refrigerants, GWP of refrigerants, federal legislation on refrigerants, California state legislation on refrigerants, and industry standards on refrigerants. A refrigerant is a chemical substance that can change from liquid to gas phase and back at certain temperatures and pressures and is used for heat transfer purposes. Refrigerants are used in refrigeration, air conditioning in vehicles and refrigerated transport, foam products, aerosols, fire

[1] Small commercial refrigeration is refrigeration used in convenience stores (to support SoCalREN's Food Desert Energy Efficiency Equity Program). It doesn't include refrigeration systems used in chain grocery stores or industrial applications

protection systems, and solvents (4). Just as CO_2 has a global warming potential (GWP) when released into Earth's atmosphere, so do refrigerants. CO_2 has a GWP equal to 1 and the GWP of all refrigerants is measured by the GWP of CO_2. For example, R404A, a commonly used refrigerant in refrigeration applications, has GWP equal to 3,920. This means, every molecule of R404A released into the atmosphere has the same impact as 3,920 molecules of CO_2. Figure 1 below shows the GWP of three (3) commonly used refrigerants (R404A, R410A and HFC-134A), two (2) Medium-GWP refrigerants (HFC32 and R454B), and one (1) Ultra-Low-GWP refrigerant (R-600A) (5).

Figure 1: GWP Values of Various Refrigerants



Refrigerant	Low-GWP	Used In
R404A	No	Retail Food Refrigeration
R410A	No	HVAC
HFC-134a	No	HVAC
HFC32	No	HVAC
R454B	No	HVAC
R600A	Yes	Retail Food Refrigeration

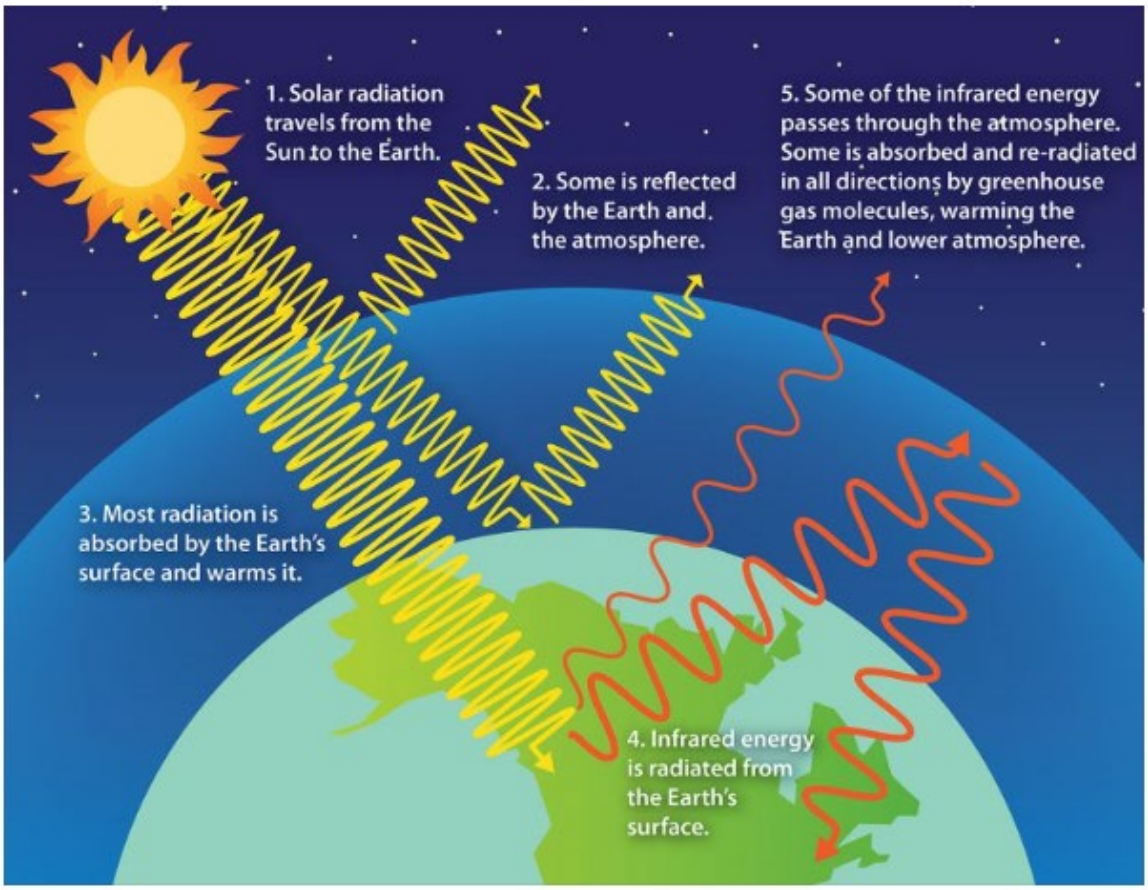
Refrigerants must operate in pressurized systems which means there is potential for refrigerant to leak out over the life of its equipment. Therefore, even if a piece of HVAC equipment operated with 100% renewable energy (i.e., it generates no CO_2) it would still contribute to global warming via leaking refrigerant. The goal of federal and state regulations on refrigerants is to reduce the overall global warming potential of equipment utilizing refrigerants.

2.1 Refrigerant Background

2.1.1 Global Warming Potential (GWP) (6)

Greenhouse gases (GHGs) absorb energy and slow the release of energy into space from Earth's atmosphere. Figure 2 shows how *short wave* or *solar radiation* travels from the sun to the Earth and is absorbed or reflected. Most of the radiation is absorbed by the Earth's surface and some is reflected by the atmosphere. As radiation is absorbed, it increases the temperature of Earth's surface, warming the Earth, and the Earth's surface *re-radiates* this absorbed energy as *long-wave* or *infrared radiation*. Some of this infrared radiation passes through Earth's atmosphere into space, but some of it is absorbed by GHG molecules and re-radiated back to Earth's surface. This re-radiation of infrared energy back to Earth's surface further warms the surface. Figure 2 gives an example of this from UC Berkeley's website on Global Change.

Figure 2: The Earth's Greenhouse Effect (7)



GHGs have a *radiative efficiency* and a *lifetime*. The *radiative efficiency* is their ability to absorb energy and re-radiate it to Earth's surface and the *lifetime* is how long they stay in the atmosphere. The Global Warming Potential (GWP) is the measure of how much energy a GHG will absorb and re-radiate over a certain period of time compared to CO_2. In other words, the GWP value for a GHG is how much **more** energy 1 ton of a GHG will **absorb and re-radiate** compared to 1 ton of CO_2. This allows analysts to compare the impacts of GHGs to each other. The *lifetime* used for GWP calculations is usually 100 years.

> GWP is the measure of how much energy 1 ton of a GHG will absorb and re-radiate compared to 1 ton of CO_2.

2.1.2 CFCs, HCFCs, HFCs, and HFOs

The reader may have heard of Ozone-Depleting Substances (ODSs) or threats to the Earth's ozone layer. In the 1970s and 1980s the international community was concerned that ODSs would harm Earth's ozone layer. Many countries agreed to cooperate to reduce the amount of ODSs in Earth's atmosphere by signing the **Montreal Protocol on Substances that Deplete the Ozone Layer** in 1987 (8). In 1990, three years later, congress amended the **Clean Air Act (CAA)** to include provisions to protect the ozone layer in Title VI of the law (9). Under the CAA, ODS are split into two groups: *Class I* and *Class II*. Chlorofluorocarbons (CFC) fall under *Class I* and hydrochlorofluorocarbons (HCFCs) fall under *Class II*. CFCs and HCFCs have largely been phased

out due to the Title VI regulations of the CAA. There are many CFCs and HCFCs, but R-22 (an HCFC) was the most commonly used refrigerant in the early 1990s with a GWP of 1,810.

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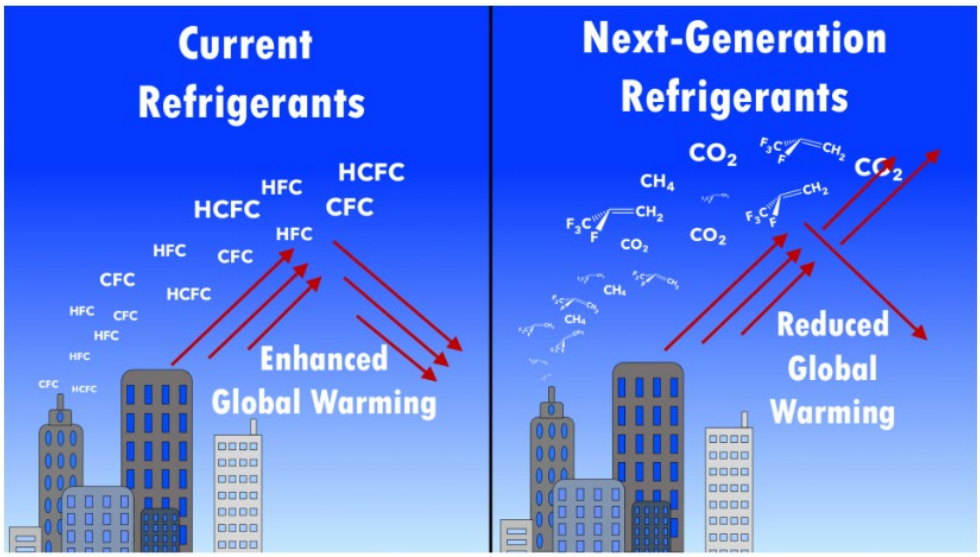
The phase out of CFCs and HCFCs have led to the growing use of Hydrofluorocarbons (HFCs) to replace them. According to the EPA "HFCs are anthropogenic fluorinated chemicals that have no known natural sources (4 p. 195)." HFCs do not threaten the ozone layer but, *HFCs often have GWP values that are thousands of times that of CO_2.* Additionally, the GWP of HFCs is sometimes higher than their CFC/HCFC counterparts. For example, a common replacement for R-22 (GWP 1,810) is R410a with a higher GWP of 2,090[2]. HFCs were previously projected to increase substantially over the next 20-30 years. In 2016, countries once again came together and agreed to a global phase-down of HFCs by adopting the **KIGALI AMENDMENT TO THE MONTREAL PROTOCOL**3. *Hydrofluoroolefins (HFOs) have emerged as the Lower-GWP replacements for HFCs*. HFOs have lower GWP values than HFCs meaning they re-radiate less infrared energy back to Earth's surface (see Figure 3).

Figure 3: Re-Radiation of CFCs, HCFCs, HFCs, and HFOs (10).



2.2 Alignment of Federal & State Regulations

Federal and California state regulations both affect the use of HFCs and HFOs in HVAC and refrigeration equipment in California. The Environmental Protection Agency (EPA) was beginning to use its authority under the **SIGNIFICANT NEW ALTERNATIVES POLICY (SNAP)** program in 2015 to phaseout HFCs. Similarly, in 2016, California Senate Bill 1383 was signed into law which requires a 40 percent reduction of HFC emissions below 2013 levels by the year 2030. However, in 2017, the D.C. District Circuit Court issued a ruling in the court case **MEXICHEM FLUOR. V. U.S. EPA**, which

[2] In some cases, the GWP of HFCs is less than its counterpart. For instance another replacement for R-22 is R134a with a lower GWP of 1,430.
[3] The amendment adoption took place in Kigali, Rwanda

limited the EPA's ability to regulate refrigerants based on GWP. The ruling effectively stalled EPA's efforts to transition away from high-GWP refrigerants. The EPA's authority to regulate refrigerants by GWP was clarified when the **American Innovation and Manufacturing (AIM) Act** was passed in 2020, and transition efforts have progressed on the federal level since then. California was counting on EPA SNAP rules to help meet its state-level HFC reduction goals. Since the EPA was unable to regulate refrigerants after Mexichem Fluor v. U.S.EPA, California opted to move forward with a state-led phasedown of HFCs in 2018. Therefore, the *regulations in California do not exactly align with federal regulations in both transition timelines and GWP limits*.
Federal regulations are discussed first, then California regulations, next industry standards, and then Federal and California standards are compared.

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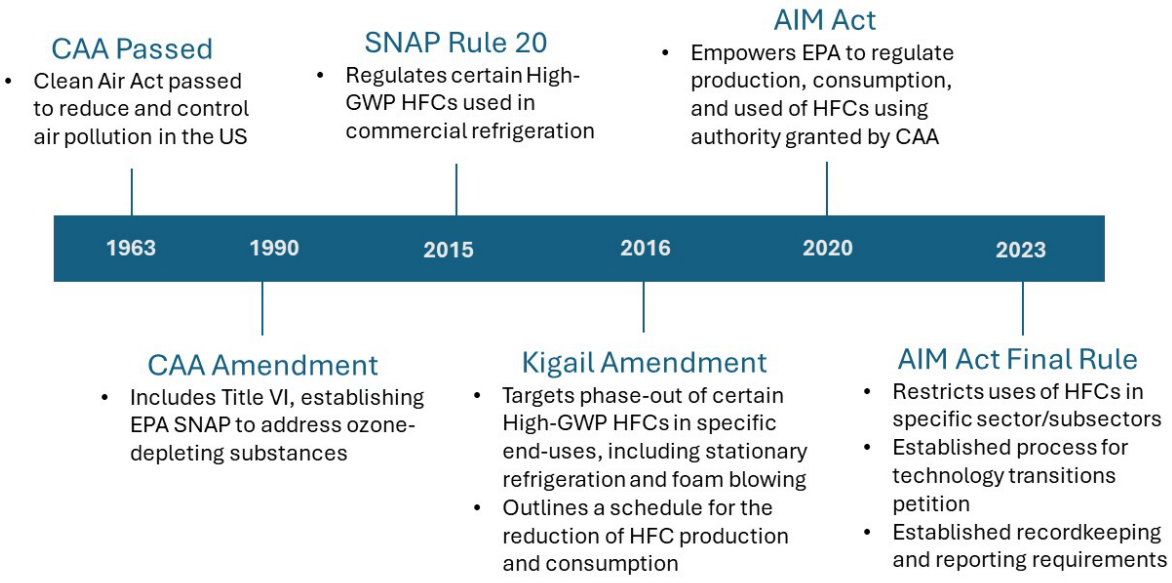
2.2.1 Federal Regulations

Figure 4 shows a brief overview of the timeline for federal regulations regarding ODSs, HFCs, and HFOs. This timeline is by no means complete or exhaustive and is meant to give a high-level overview.

Figure 4: Brief Timeline of Federal Regulations Addressing ODS and HFCs (4)



2.2.1.1 SNAP

Regulation of the GWP of refrigerants is accomplished through the EPA's **SIGNIFICANT NEW ALTERNATIVES POLICY (SNAP)[4] PROGRAM** and the **AMERICAN INNOVATION AND MANUFACTURING (AIM) ACT** of 2020. Recall that the CAA was amended in 1990 (in response to the Montreal Protocol) to include Title VI with provisions to protect the ozone layer. Title VI set up the SNAP program and was originally used to phase out ODSs. The SNAP program has introduced many rules under its authority since its inception. SNAP Rule 20 (11), published on July 20, 2015, was the first rule explicitly prohibiting High-GWP HFCs in certain end-uses. Other SNAP rules that address refrigerant GWP are as follows:

The SNAP program was originally used to phase out ODSs. SNAP Rule 20 was the first rule prohibiting substances based on their GWP.

- SNAP Rule 21 (2016) (12) : This rule targeted phase-out of certain High-GWP HFCs in specific end-uses including stationary refrigeration and foam blowing. It also Outlined a schedule for the reduction of HFC production and consumption.
- SNAP Rule 23 (2021) (13) : This rule regulates certain HFOs which are Lower-GWP alternatives to HFCs.
- SNAP Rule 25 (2023) (14) : This rule focuses on management of refrigerants in retail food sector.
- SNAP Rule 26 (2024) (15): This supports the transition from HFCs in certain end-uses

The EPA continues to issue new rules under the SNAP program that address HFCs and HFOs. SNAP Rule 26 for example, was a proposed rule in the beginning of 2024 and was codified in May 2024.

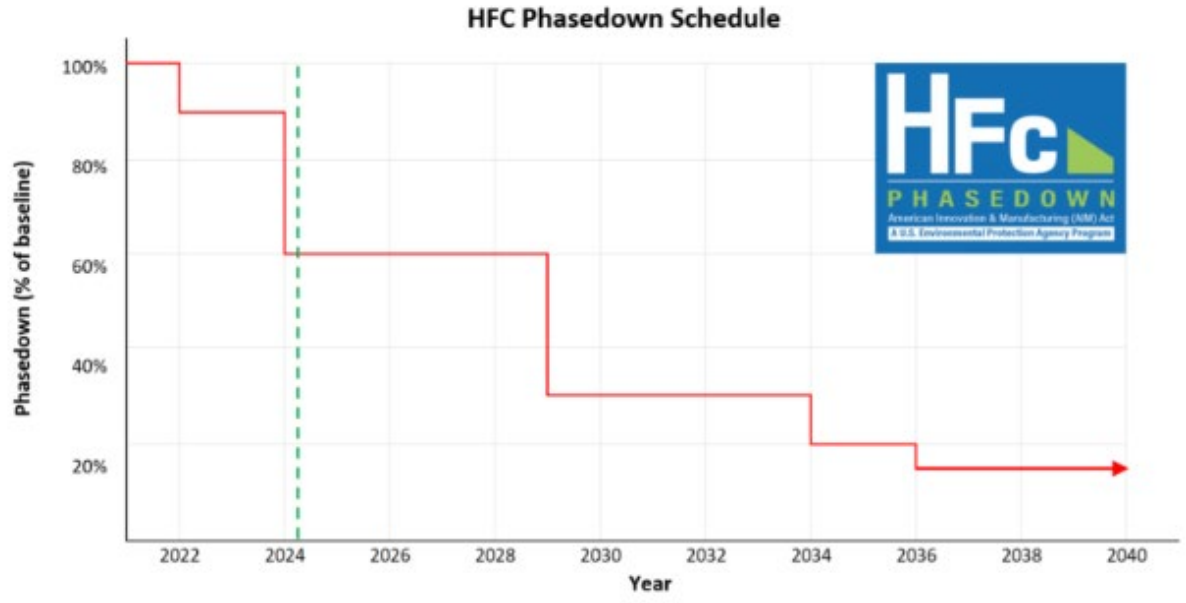
2.2.1.2 AIM ACT

The **AMERICAN INNOVATION AND MANUFACTURING (AIM) ACT** was passed by congress on December 27, 2020. The AIM Act is in line with the **KIGALI AMENDMENT** and directs the EPA to address HFCs. Specifically, the AIM act directs EPA to phase down production and consumption of HFCs by 85% from 2011-2013 baseline levels in a stepwise manner by 2036 as shown in Figure 5 below, through an allowance allocation and trading program.

[4] Note that federal food benefits also have the acronym SNAP (Supplemental Nutrition Assistance Program) but they are completely unrelated programs

Figure 5: AIM Act HFC Phasedown Schedule (16)

(16)



The AIM act authorizes the EPA to address HFCs in the following ways:

- Phasing down production and consumption of HFCs
- Promulgating regulations to maximize reclamation and minimize release of HFCs from equipment and ensuring the safety of consumers and technicians
- Facilitating the transition to HFOs and other next-generation technologies and refrigerants using sector-based restrictions

Subsection i of the AIM act, subtitled "Technology Transitions," allowed the EPA to use a rule to restrict HFCs on a full, partial, or graduated schedule (17) to address bullet #3 on the above list. The EPA released a *proposed* rule for the *Technology Transition* in July 2023, and it adopted the *Final Rule* on October 5, 2023. The name of the rule is "**PHASEDOWN OF HYDROFLUOROCARBONS: RESTRICTIONS ON THE USE OF CERTAIN HYDROFLUOROCARBONS UNDER THE AMERICAN INNOVATION AND MANUFACTURING ACT OF 2020**" and it went into effect on December 27, 2023. This rule does the following things (18):

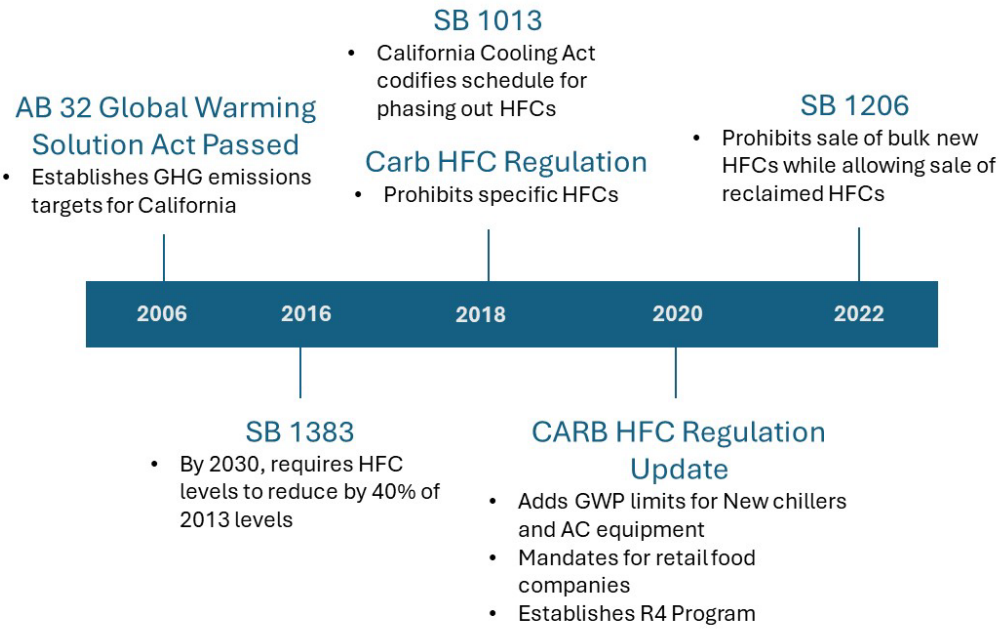
- Restricts use of HFCs in specific sectors/subsectors
- Establishes process for technology transitions petitions
- Establishes recordkeeping and reporting requirements

Later in this document, the use of HFCs in specific sectors and subsectors will be discussed. Before the specific sector and subsector restrictions are discussed, California State regulations are discussed.

2.3 State Regulations

This section outlines relevant California State regulations and Figure 6 provides a concise timeline of those regulations.

Figure 6: Brief Timeline of California State Regulations Addressing HFCs



2.3.1 California SNAP (CASNAP) (19)

California Assembly Bill 32 (AB32) was passed in 2006 which created a comprehensive program to reduce GHG emissions in California. In 2016, **California Senate Bill 1383 (SB 1383)** (20) was passed which required a 40% reduction in HFCs from 2013 levels. At that time, California was relying on the EPA SNAP rules to meet most of the HFC reductions required by SB1383. However, the court decision on **Mexichem Fluor. v. U.S. EPA**, discussed previously, limited the EPA's ability to regulate HFCs using SNAP rules.

In 2018, California adopted a new **California Air Resources Board (CARB) HFC Regulation** (21) and passed **Senate Bill 1013 (SB1013)** (22) also known as the **California Cooling Act**. SB1013 established a Fluorinated Gases Emission Reduction Incentive Program. The HFC regulation prohibits specific HFCs in specific end-uses forcing the use of Lower-GWP refrigerants in those end-uses. *The HFC Regulation and SB1013 together are known as the* **California Significant New Alternatives Program (CA SNAP)**. In 2020, CARB modified the 2018 HFC regulation to incorporate GWP limits for new refrigeration and new air conditioning equipment. This change moves industry away from high-GWP refrigerants and ensures it rapidly adopts technologies with the lowest GWP that are viable. The amendments also mandate that retail food companies owning existing systems with over 50 pounds of refrigerant in retail food facilities must achieve company-wide reductions in HFCs. Lastly, the HFC Regulation amendments established the Refrigerant Recovery, Reclaim, and Reuse Requirements (R4 Program). The R4 Program requires that manufacturers of air conditioning (AC) and variable refrigerant flow

The HFC Regulation and California Cooling Act (SB1013) are known together as the **California Significant New Alternatives Program**.

(VRF) systems incorporate a designated minimum quantity of reclaimed refrigerant in both new and existing equipment. In 2022, California Senate Bill 1206 (SB1206) (23) was passed which prohibits the sale of virgin HFCs in bulk but still allows the sale of reclaimed HFCs. This ensures HFCs are still available for equipment which uses them while continuing to encourage the transition to Lower-GWP HFOs.

2.3.2 California Refrigerant Management Program

Like CASNAP, the California Refrigerant Management Program (CRMP) is also a Lower-GWP program. This program is part of the California Global Warming Solutions Act of 2006 and its aim is to reduce emissions of ozone-depleting substances (ODS) and GHGs. CRMP targets facilities with systems containing more than 50 lbs of high-GWP refrigerants. It requires these facilities to:

- Conduct and report periodic leak inspections
- Promptly repair leaks
- Keep service records on site

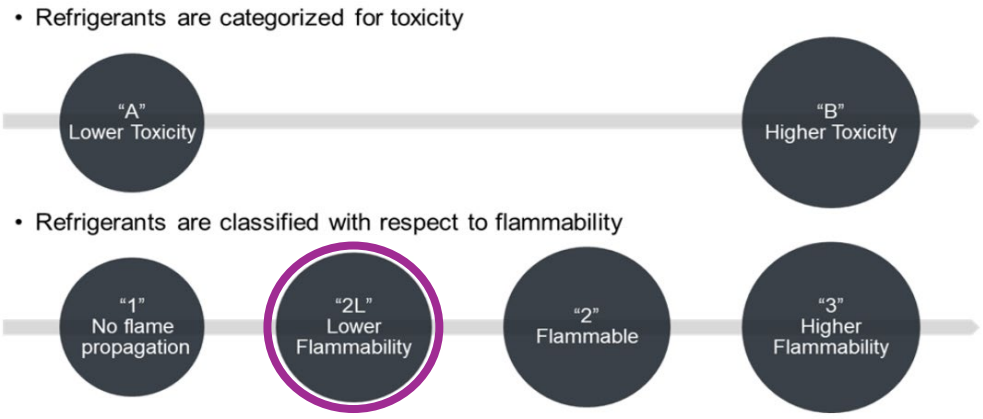
2.4 Industry Standards

The use of refrigerants is also governed by industry standards. Industry standards are often referenced in state or federal standards. The American Society for Heating, Refrigeration and Air-Conditioning Engineers (ASHRAE) Standard 34 titled "**Designation and Safety Classification of Refrigerants**" establishes a standardized method for naming refrigerants and assigns safety classifications and concentration limits based on:

- Toxicity
- Flammability

Refrigerants with the letter "A" are *lower toxicity* and refrigerants with the letter "B" are *higher toxicity*. Flammability of refrigerants ranges from 1 to 3 for "*no flame propagation*" to "*higher flammability*." Figure 7 gives details on this classification naming convention.

Figure 7: ASHRAE Standard 34 Refrigerant Classification (24)



Many Lower-GWP refrigerants are classified as "*2L - lower flammability"* which requires updates to safety standards and codes since traditional HFCs are generally classified as "*No flame propagation*". This has required extensive research on flammable refrigerants for updates to standards and codes using these flammable Lower-GWP refrigerants. Industry groups including ASHRAE, American National Standards Institute (ANSI), Department of Energy (DOE), CARB, and Underwriters Laboratory (UL) have been researching flammable refrigerants for over a decade and working together to update safety standards (25) for use with flammable refrigerants.

Many Lower-GWP refrigerants are classified as "*2L - lower flammability"* which requires updates to safety standards and codes since traditional HFCs are generally classified as "*No flame propagation*".

The approach to mitigate hazards from flammable refrigerants is based on these principles (24):

- Limit refrigerant charge
- Detect leaks
- Close safety shut-off valves
- Ventilate the space
- Appropriate equipment labeling
- Technician training

Requirements for the safe installation and operation of HVAC and refrigeration (HVACR) equipment is regulated by:

- Installation codes and standards (including model codes & standards)
- Equipment and testing standards
- Equipment certifications
- Manufacturer instructions

2.4.1 Model Codes & Standards

The United States, the international community, and industry organizations *create Model Codes & Standards* that other entities can reference for their own codes & standards. For example, A US state may adopt the **Uniform Mechanical Code (UMC)** as its State Mechanical Code eliminating the cost to create or update a code using state resources. Model codes and standards for HVACR equipment include the following:

- ASHRAE 15 Safety Standard
- Uniform Mechanical Code (Chapter 11)
- National Fire Code (Chapter 53)

ASHRAE 15 and the **UMC** regulate refrigerant piping design and installation for systems containing refrigerant. **The UMC** and other mechanical codes generally reference **ASHRAE 15**. The Mechanical Codes are discussed in Section 3 since they also affect local codes & standards.

ASHRAE Standard 15-2022 "Safety Standard for Refrigeration Systems" is an ANSI-approved safety standard for refrigeration systems, providing precise criteria for designing,

constructing, installing, and operating such systems. The 2022 edition introduces several technical advancements (26):

- Revisions regarding the utilization of non-A1 refrigerants
- Implementation of novel overpressure protection mechanisms
- Introduction of updated piping specifications
- Refinements to volume and refrigerant charge limit calculations
- Enhancements in refrigerant detector deployment and associated mitigation procedures.

ASHRAE 15.2-2022 "SAFETY STANDARD FOR REFRIGERATION SYSTEMS IN RESIDENTIAL APPLICATIONS" was released to accommodate the utilization of A2L-classified refrigerants in low-rise residential environments. Residential systems were previously restricted to A1 refrigerant use, so safety standards were not applied as rigorously to residential HVAC systems. ASHRAE 15.2 was released to give appropriate safety standards for A2L refrigerant use in residential HVAC systems.

2.4.2 Certifications

Factory-built, self-contained HVACR equipment must be certified (or listed), labeled, and installed according to the certification and manufacturer instructions. Table 1 shows applicability of different UL standards.

Table 1: UL Standards

Equipment	UL Standard
Air-Conditioning Equipment	UL 1995 or UL/CSA 60335-2-40
Commercial refrigerators, freezers, beverage coolers and walk-in coolers	UL 471 or UL/CSA 60335-2-89
Packaged terminal air conditioners and heat pumps	UL/CSA 60335-2-40
Refrigerating units and walk-in coolers	UL 471 or UL/CSA 60335-2-89
Split-system air conditioners and heat pumps	UL 1995 or UL/CSA 60335-2-89

UL Standards 471 and 1995 are legacy standards that are being replaced by the UL 60335 standards listed in Table 6.1 (27).

2.4.3 Household Refrigeration Safety Standards

The current UL safety standard for households is "**UL 60335-2-40: STANDARD FOR SAFETY FOR HOUSEHOLD AND SIMILAR ELECTRICAL APPLIANCES – SAFETY – PART 2-40**." This standard reduces the risk associated with HVAC and refrigeration refrigerant leakage. The standard was updated in 2019 to its third edition and some highlights of the update are (28), (29), (30), (31):

- Refrigerant charge limits (typically 4 lbs or less)
- Ignition source control
- Leak mitigation
- Leak detection
- System design and testing
- Marking and labeling

2.4.4 Commercial Refrigeration Safety Standards

The current UL safety standard for commercial refrigeration is "**UL 60335-2-89: Commercial Refrigerating Appliances with an Incorporated or Remote Refrigerant Unit or Compressor**." This standard focuses on the following areas to mitigate risks from flammable refrigerants (32):

- Refrigerant charge limits (33)
  - 500g for A3 refrigerants
  - 1200 g for A2 and A2L refrigerants
- Ignition source control
- Leak mitigation
- Leak detection
- System design and testing
- Marking and labeling
- Ventilation and exhaust requirements
- Training and certification to technicians and installers

2.4.5 Testing Standards

AHRI does not set safety standards, but AHRI does support the adoption of HFO refrigerants by the following activities:

- Flammable Refrigerants Research Initiative: This initiative generates publicly available technical data to support code and standard activities related to using flammable refrigerants (25)
- Low-GWP Alternative Refrigerants Evaluation Program: This program evaluates Lower-GWP refrigerant performance in major HVAC and refrigeration product categories (34)

2.5 Comparison of California and Federal Standards

As discussed previously, California adopted the **CARB HFC Regulation** and passed **SB1013** in 2018 before the **AIM Act** was passed in 2020. CARB and EPA therefore have different definitions of subsectors and end-uses, different GWP thresholds, and different timelines. The Study Team reached out to CARB to inquire if they plan to align state standards with federal standards. CARB's HFC Reduction Team indicated in an e-mail that CARB has no plans to update or change the GWP limits or effective dates in the CARB regulation. However, they noted that California Senate Bill 1206 directs CARB to post an assessment by 1/1/2025 specifying how to transition the state's economy away from HFCs to Ultra-Low-GWP. Table 2 through Table 7 below give a comparison of the CARB and EPA standards for end-uses and subsectors that are relevant to SoCalREN. Figure 10, and Figure 11 show CARB and EPA regulations on a graph to show the differences in a visual manner. The figures have one or two commonly used refrigerants in each application to visually show the sharp decline in allowable GWP in each sector/end-use. These tables do not include

CARB and EPA have different definitions of subsectors and end-uses, different GWP thresholds, and different timelines.

regulations on industrial facility refrigeration (as it is defined by CARB)[5], vending machines, cold storage warehouses, motor vehicle air conditioning, foam products, or aerosol products. Table 2 shows the main areas of misalignment between CARB and EPA on Lower-GWP refrigerants.

While there is misalignment in both HVAC and retail food refrigeration, there is more misalignment in retail food refrigeration which may lead to confusion in the market. Training of contractors and other stakeholders in this area is recommended. Additionally, the GWP limits by CARB and EPA are drastic reductions from existing refrigerant GWP values. This means customers in SoCalREN territory may need assistance to understand and meet these requirements.

Table 2: Areas of Misalignment Between State and Federal Codes

CARB	EPA	Relevant Table(s)/Figure(s)
Defines GWP limits by *General End-Use* and *Specific End-Use*	Defines limits by *Sector* and *Sub-Sector.*	Table 3, Table 4, Table 5, Table 6, Table 7, Table 8
Permits 750 GWP in air conditioning equipment	Permits only 700 GWP	Table 3, Figure 8, Figure 9
Limits for air conditioning equipment go into effect in 2023, 2024, or 2025 depending on the end-use	Limits go into effect in 2025	Table 3, Figure 8, Figure 9, Figure 10
Has prohibitions on new supermarket systems and remote condensing units with any refrigerant charge and additional prohibitions on these systems if they have 50lbs+ of refrigerant	Permits 150 GWP, 300 GWP, or 700 GWP depending upon the refrigerant charge and evaporator entering temperature	Table 4, Table 8, Figure 11
Permits only 150 GWP in New Retail Refrigeration in equipment with a charge of 50lbs or more		
Regulates retrofits of supermarket systems and condensing units separately from installation of new equipment	Regulates retail refrigeration by regulating "*stand-alone refrigeration units*," "*refrigerated food processing and dispensing equipment,* "and "*Industrial process refrigeration products, other than chillers"*	Table 4, Table 5, Figure 11
Regulates existing retail refrigeration by requiring that companies reduce their weighted-average GWP (in equipment containing 50+ lbs of refrigerant) below certain levels		

[5] EPA includes refrigeration for retail food stores under 40 CFR, Part 84, subpart B, § 84.54(a)(12): Industrial process refrigeration products, other than chillers.

based on how many stores are owned		
Regulates stand-alone retail refrigeration units by specific end-use and prohibits certain substances (no specific GWP limit)	Regulates all stand-alone retail refrigeration units with a single 150 GWP limit	Table 5
Has a single sector and sub-sector for Refrigerated Food Processing and Dispensing Equipment	Has three (3) sectors to regulate Refrigerated Food Processing and Dispensing Equipment	Table 6
Regulates household refrigerators and freezers by three (3) specific end-uses	Regulates all household refrigerators and freezers by a single sector	Table 7

Table 3: State and Federal Regulation Comparison Table: Air Conditioning

CARB					AIM Act			
General End-Use	Specific End-Use	Code/Standards (CARB)	Prohibited Substances	Prohibition Effective Date	Sector	Code/Standards	Prohibited Substances	Prohibition Effective Date
Air-conditioning Equipment	Room/wall/window air-conditioning equipment, PTACs, PTHPs, portable air-conditioning equipment, and residential dehumidifiers (new)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (c)	750+ GWP	1/1/2023	Self-contained residential and light commercial air conditioning and heat pump products	40 CFR, Part 84, subpart B, § 84.54(a)(1)	700+ GWP	1/1/2025
	Other air-conditioning (new) equipment, residential and non-residential			1/1/2025				
	Variable Refrigerant Flow (VRF) System (New)			1/1/2025				
Chillers – Air-conditioning	Chillers (new)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (c)	750+ GWP	1/1/2024	Chillers for comfort cooling	40 CFR, Part 84, subpart B, § 84.54(a)(10)(i)	700+ GWP	1/1/2025

Table 4: State Regulations- Retail Food Refrigeration

CARB				
General End-Use	**Specific End-Use**	**Code/Standards (CARB)**	**Prohibited Substances**	**Prohibition Effective Date**
Retail Food Refrigeration Equipment	Supermarket Systems (new)[a]	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	HFC-227ea, R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	1/1/2019
Retail Food Refrigeration Equipment	Remote Condensing Units (new)[a]	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	HFC-227ea, R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	1/1/2019
Retail Food Refrigeration (New Facilities)	Refrigeration equipment (new), containing more than 50 pounds refrigerant	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (d)	150+ GWP	1/1/2022
Companies owning or operating 20 or more retail food facilities in California, and national supermarket chains operating in California (in Existing Facilities)	Refrigeration equipment containing more than 50 pounds refrigerant	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (d)	Attain a company-wide weighted-average GWP of less than 2,500 or a 25% or greater reduction in GHGp below 2019 levels	12/31/2026
			Attain a company-wide weighted-average GWP of less than 1,400 or a 25% or greater reduction in GHGp below 2019 levels	1/1/2030
Companies owning or operating fewer than 20 retail food facilities in California (in Existing Facilities)			Attain a company-wide weighted average GWP of less than 1,400 or a 55% or greater reduction in GHGp below 2019 levels	1/1/2030
Retail Food Refrigeration Equipment	Supermarket Systems (refrigerant retrofit)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	1/1/2019
Retail Food Refrigeration Equipment	Remote condensing units (refrigerant retrofit)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, R-507A	1/1/2019

Table 5: State and Federal Regulation Comparison Table: Retail Food Refrigeration

CARB					AIM Act			
General End-Use	Specific End-Use	Code/Standards (CARB)	Prohibited Substances	Prohibition Effective	Sector	Code/Standards	Prohibited Substances	Prohibition Effective
Retail Food Refrigeration Equipment	Stand-alone medium-tempeature units with a compressor capacity below 2,200 btu/hr and not containing a flooded evaporator (new)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	FOR12A, FOR12B, HFC-134a, HFC227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5),R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, THR-03	1/1/2019	Retail food refrigeration—stand-alone units	40 CFR, Part 84, subpart B, § 84.54(a)(4)	150+ GWP	1/1/2025
Retail Food Refrigeration Equipment	Stand-alone medium-tempeature units with a compressor capacity below 2,200 btu/hr and containing a flooded evaporator (new)			1/1/2020				
Retail Food Refrigeration Equipment	Stand-alone medium-tempeature units with a compressor capacity ≥ 2,200 btu/hr (new)			1/1/2020				
Retail Food Refrigeration Equipment	Stand-alone low-temperature units (new)		HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-428A, R-434A, R-437A, R-438A, R-507A, RS44 (2003 formulation)	1/1/2020				
Retail Food Refrigeration Equipment	Stand-alone units (refrigerant retrofit)		R-404A, R-507A	1/1/2019	Retail food refrigeration—stand-alone units	40 CFR, Part 84, subpart B, § 84.54(a)(4)	150+ GWP	1/1/2025

Table 6: State and Federal Regulation Comparison Table: Retail Food Refrigeration - Refrigerated Food Processing and Dispensing Equipment

CARB					AIM Act			
General End-Use	Specific End-Use	Code/Standards (CARB)	Prohibited Substances	Prohibition Effective Date	Sector	Code/Standards	Prohibited Substances	Prohibition Effective Date
Retail Food Refrigeration Equipment	Refrigerated food processing and dispensing equipment (new)	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (a)	HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-428A, R-434A, R-437A, R-438A, R-507A, RS44 (2003 formulation)	1/1/2021	Self-contained refrigerated food processing and dispensing products with 500g or less of refrigerant (excluding ice cream makers)	40 CFR, Part 84, subpart B, § 84.54(a)(9)(i)	150+ GWP	1/1/2027
					Self-contained refrigerated food processing and dispensing products greater than 500g of refrigerant (excluding ice cream makers)	40 CFR, Part 84, subpart B, § 84.54(a)(9)(ii)	R–402A, R–402B, R–404A, R–407A, R–407B, R–407C, R–407F, R–407H, R–408A, R–410A, R–410B, R–411A, R–411B, R–417A, R–417C, R–420A, R–421A, R–421B, R–422A, R–422B, R–422C, R–422D, R–424A, R–426A, R–427A, R–428A, R–434A, R–437A, R–438A, R–507A, HFC–134a, HFC–227ea, R–125/290/134a/600a (55/1/42.5/1.5), RB–276, RS–24 (2002 formulation), RS–44 (2003 formulation), GHG–X5, or Freeze 12	1/1/2027
					Self-contained refrigerated food processing and dispensing products: Ice Cream Makers	40 CFR, Part 84, subpart B, § 84.54(a)(9)(iii)		1/1/2028

Table 7: State and Federal Regulations Comparison Table: Household Refrigerators and Freezers

CARB					AIM Act			
General End-Use	Specific End-Use	Code/Standards (CARB)	Prohibited Substances	Prohibition Effective	Sector	Code/Standards	Prohibited Substances	Prohibition Effective
Household refrigerators and freezers	Compact residential consumer refrigeration products	California Code of Regulations, Title 17, Division 3, Chapter 1, Article 4, Subarticle 5, §95374 (b)	FOR12A, FOR12B, HFC-134a, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, and THR-03	1/1/2021	Household refrigerators and freezers	40 CFR, Part 84, subpart B, § 84.54(a)(3)	150+ GWP	1/1/2025
	Residential consumer refrigeration products			1/1/2022				
	Built-in residential consumer refrigeration products			1/1/2023				

Table 8: Federal Regulation Table – Industrial Process Refrigeration

AIM Act			
Sector	**Code/Standards**	**Prohibited Substances**	**Prohibition Effective**
Industrial process refrigeration products, (excluding chillers) containing more than 200 pounds and with the refrigerant temperature entering the evaporator > −30 °C (−22 °F)	40 CFR, Part 84, subpart B, § 84.54(a)(12)(ii)	300+ GWP	1/1/2026
Industrial process refrigeration products (excluding chillers) containing less than 200 pounds or greater and with the refrigerant temperature entering the evaporator higher than −30 °C (−22 °F)	40 CFR, Part 84, subpart B, § 84.54(a)(12)(i)	150+ GWP	1/1/2026
Industrial process refrigeration products, (excluding chillers) where the temperature of the refrigerant entering the evaporator is ≥ −50 °C (−58 °F) and ≤−30 °C (−22 °F)	40 CFR, Part 84, subpart B, § 84.54(a)(12)(iii)	700+ GWP	1/1/2028

The figures below show a visual comparison of the GWP limits and effective dates between the state and federal standards. Figure 8 below shows the state and federal standards comparison for residential HVAC equipment that falls under CARBs end-use "*Room/wall/window air-conditioning equipment, PTACs, PTHPs, portable air-conditioning equipment, and residential dehumidifiers (new)*" and EPAs sector "*Self-contained residential and light commercial air conditioning and heat pump products.*" A commonly used refrigerant in this type of equipment is R134a with a GWP of 1,430. The CARB and EPA GWP limits are roughly half of this incumbent refrigerant.

Figure 8: Residential HVAC Equipment – CARB and EPA Comparison

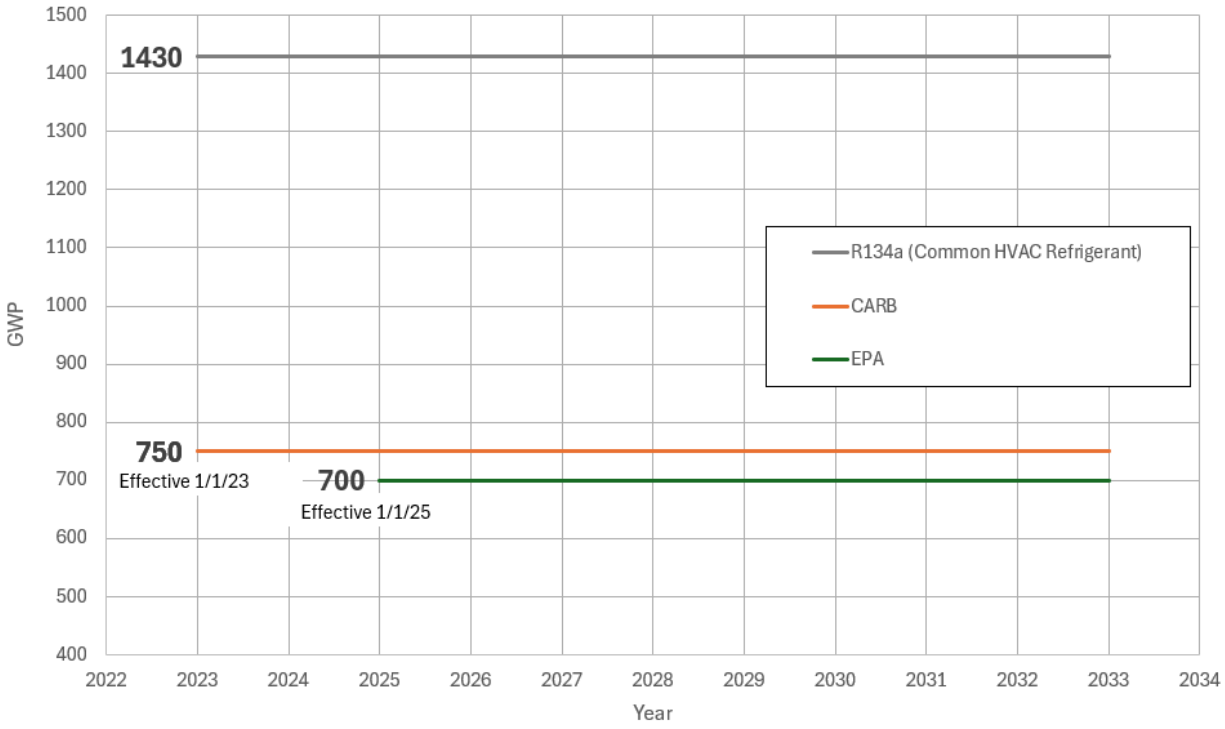


Figure 9 below state and federal standards comparison for light commercial HVAC equipment (i.e. commercial HVAC equipment other than chillers) that falls under CARB's end-uses "Other *air-conditioning (new) equipment, residential and non-residential*" and "*Variable Refrigerant Flow (VRF) System (New)*" and EPA's sector "*Self-contained residential and light commercial air conditioning and heat pump products.*" Once again, a commonly used refrigerant in this type of equipment is R134a with a GWP of 1,430. The CARB and EPA GWP limits are roughly half of this incumbent refrigerant. In this end-use, the CARB and EPA effective dates are aligned.

Figure 9: Light Commercial HVAC Equipment – CARB and EPA Comparison

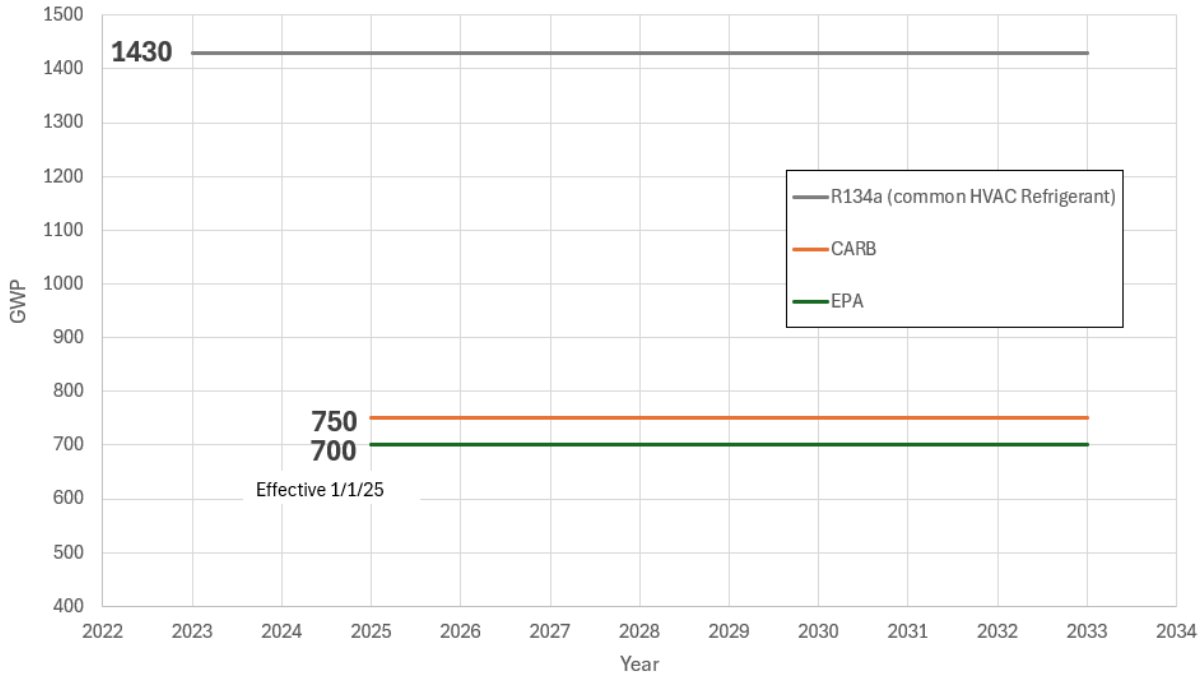


Figure 10 below shows the state and federal standards comparison for chillers used in HVAC applications that fall under CARB's end-use "*Chillers – Air Conditioning*" and EPA's sector "*Chillers for comfort cooling.*" Two commonly used refrigerants in chillers are R134a with a GWP of 1,430 and R410a with a GWP of 2090. The CARB and EPA GWP limits are roughly half of R134a and a third of R410a's GWP.

Figure 10: Chillers – CARB and EPA Comparison

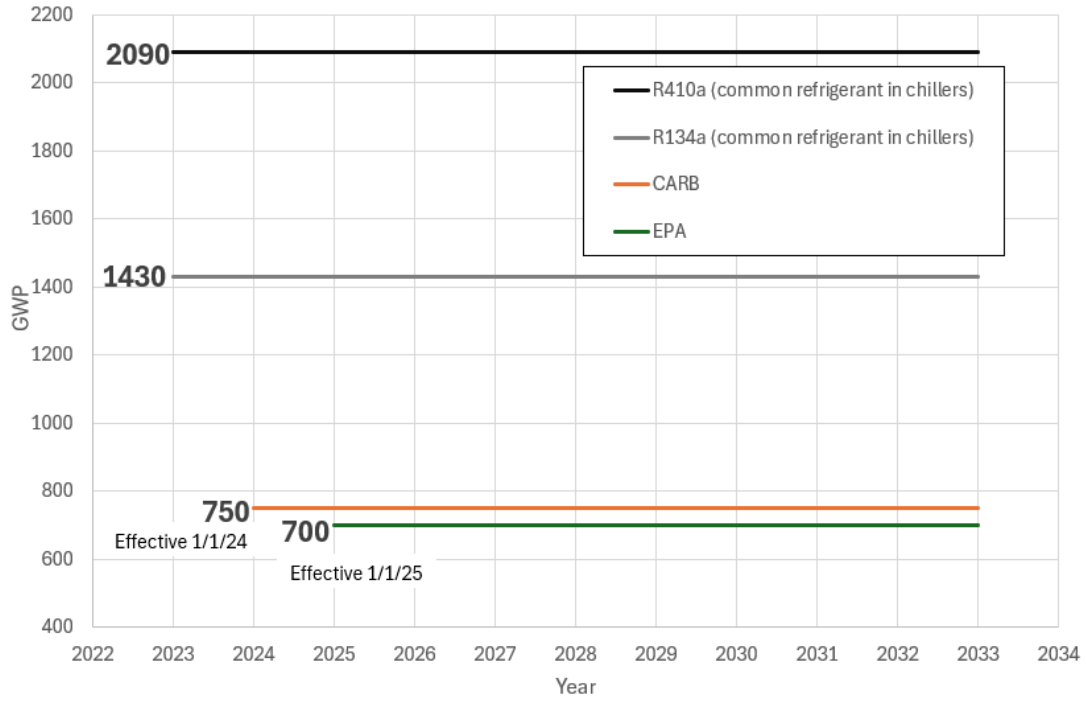
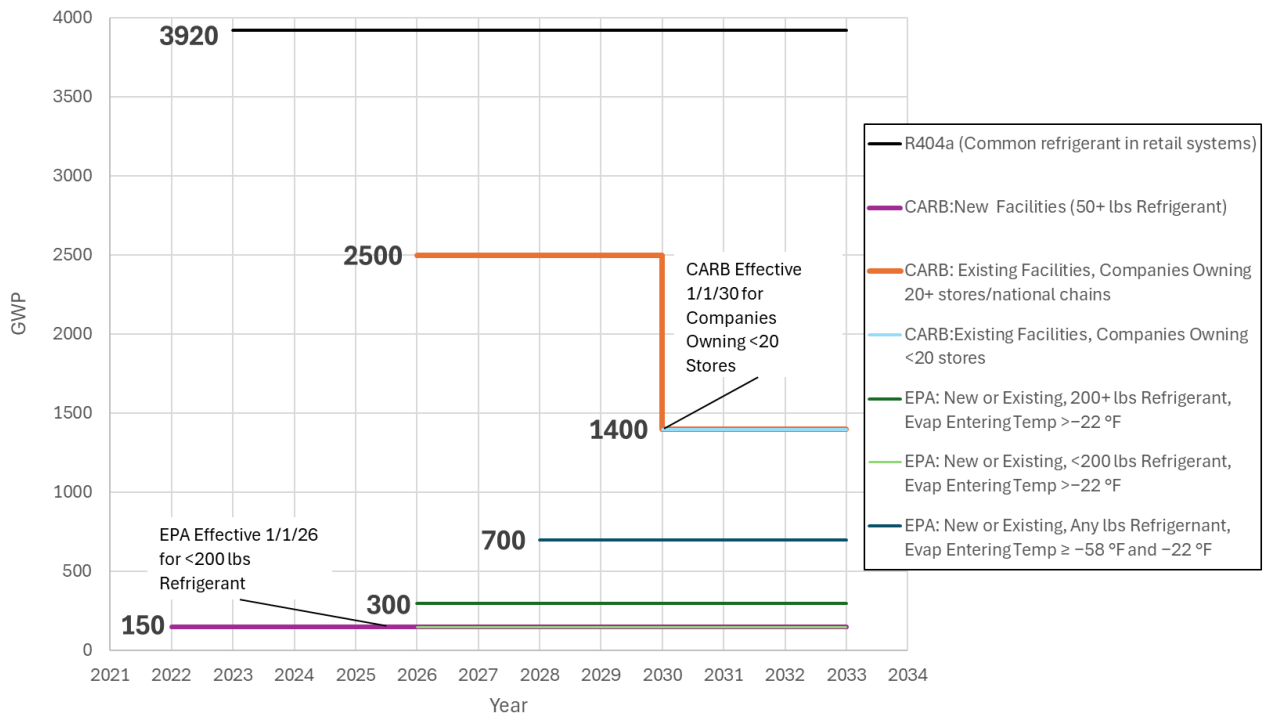


Figure 11 below shows the state and federal standards comparison for retail food refrigeration. This includes CARBs requirements for "Refrigeration equipment containing more than 50 pounds of refrigerant" for companies that own less than 20 stores and more than 20 stores in California. It also includes EPA's regulations for "Industrial process refrigeration." There is a lot of misalignment between CARB and EPA in this end-use due to the vastly different ways each regulatory body defines a sector or end-use. Additionally, the effective dates of GWP limits range between 1/1/2022 to 1/1/2030. Lastly, a commonly used refrigerant in retail food refrigeration is R404a with a GWP of 3,920. The final CARB and EPA limits on this type of equipment are 150 GWP which is less than 10% of the existing GWP. It is likely that contractors and customers in this space will need training and support to understand and meet the CARB and EPA refrigerant limits.

Figure 11: Retail Food Refrigeration



3. Local Codes & Standards

EPA and CARB set refrigerant GWP limits at the national and state levels. However, refrigerants are also regulated by state and local-level mechanical codes and fire codes because they are both toxic and flammable.

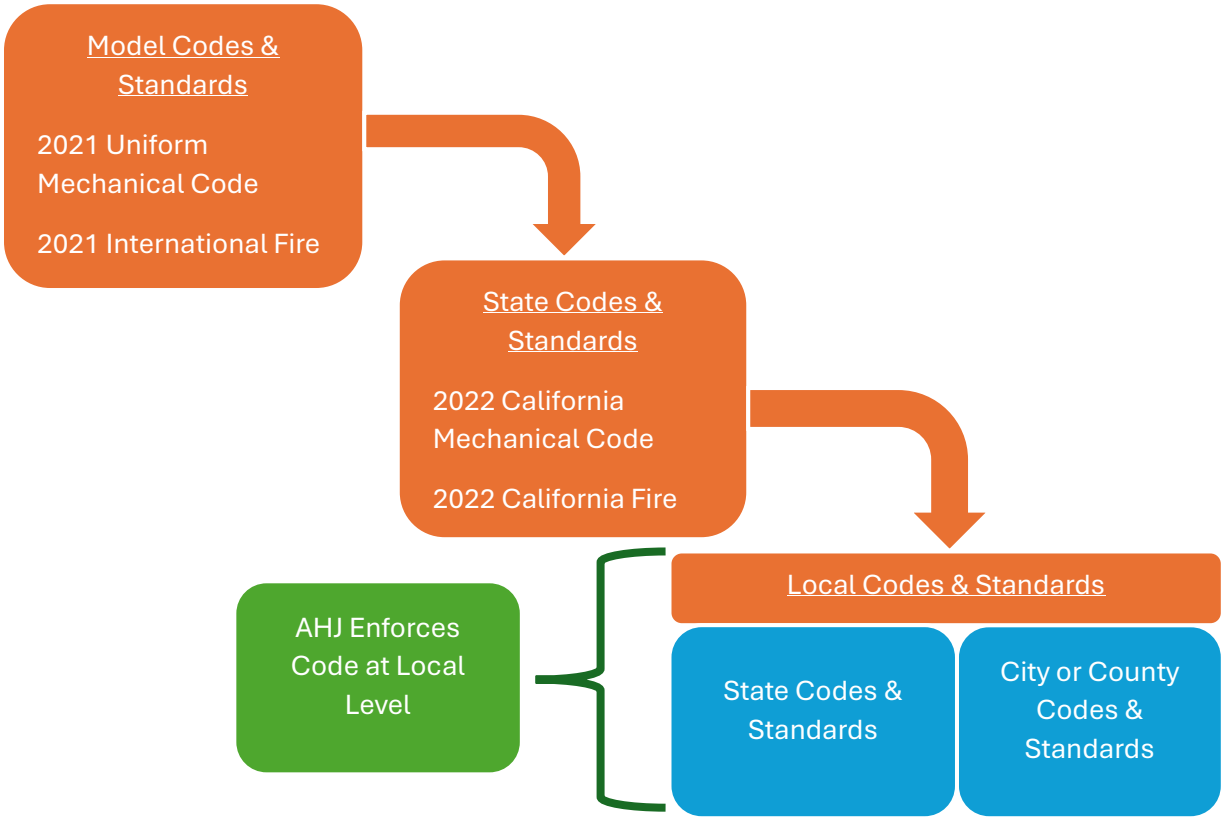
As discuss in Section 2.4, ASHRAE classifies refrigerants by their toxicity and flammability. A means the refrigerant is "*lower toxicity*," and B means the refrigerant is "*higher toxicity*." The numbers 1 – 3 indicate the flammability of the refrigerant. 1 means the refrigerant has "*no flame propagation*[6]", 2L means the refrigerant is of "*lower flammability*" and 3 means the refrigerant has "*higher flammability*." Most Lower-GWP refrigerants are either A2L or A3 meaning they are lower toxicity but flammable. Ammonia is an exception to this rule because it has higher toxicity but has no flame propagation (i.e. it is a B1 refrigerant).

Most Lower-GWP refrigerants are either A2L or A3

Mechanical & fire codes at the state level are adopted from model codes created by professional code-setting bodies. Mechanical & fire codes at the local level are then adopted from mechanical codes at the state level. There are a handful of professional code-setting bodies out there. California has adopted the **2021 Uniform Mechanical Code** put forth by the International Association of Plumbing & Mechanical Officials (IAPMO) and the **2021 International Fire Code** put forth by the International Code Council (ICC). Therefore, the **2022 California Mechanical Code** (CMC) and **2022 California Fire Code** (CFC) mirror the **2021 Uniform Mechanical Code** and **2021 International Fire Code**, respectively. The Authority Having Jurisdiction (AHJ) is the local-level code authority. Most of the time, the AHJ simply enforces the code requirements at the state level, but sometimes they enforce a local code that has adopted the state level codes with some amendments. Therefore, the local code is either the state code or it is truly a local code. Figure 12 below shows how these code adoptions flow down.

[6] No flame propagation means the refrigerant doesn't burn at certain test conditions. A refrigerant will burn under the right conditions, so it is still technically flammable.

Figure 12: Mechanical & Fire Codes & Standards



For example, a building in the City of Los Angeles needs to get a building permit from the City of Los Angeles Department of Building and Safety (LADBS). In the City of Los Angeles, LADBS is the AHJ. The City of Los Angeles has its own mechanical code, **LOS ANGELES MUNICIPAL CODE**, that mirrors the CMC with some amendments (35). The **LOS ANGELES MUNICIPAL CODE** is the local code in this case.

However, in the City of Rancho Cucamonga, a building needs to get a permit from the City of Rancho Cucamonga Building & Safety Department. Rancho Cucamonga Building and Safety is the AHJ in this case. Rancho Cucamonga does not have its own mechanical code. Instead, it enforces the CMC. In this case, the CMC is the local code. See Table 9 below for a summary of these two examples.

Table 9: Example AHJ and Local Code in Two California Cities

City	AHJ	Local Code
Los Angeles	LADBS	Los Angeles Municipal Code
Rancho Cucamonga	Rancho Cucamonga Building & Safety	California Mechanical Code

The Study Team searched for AHJs in SoCalREN territory and found the following AHJs organized by county in Table 7.2. Within each county, there are certain cities that have their own AHJ which is

usually a Community Development Department or Building & Safety Department. Rather than list the exact name of each city department, Table 10 lists the city name in the third column. There may be additional AHJs outside of this list. Many city AHJs enforce the CMC and CFC. There are some that enforce a local city mechanical or fire code.

Table 10: AHJs in SoCalREN Territory

County	County AHJ	Cities with an AHJ
Imperial	Imperial County Planning & Development Services	El Centro, Calexico, Brawley, Imperial, Holtville
Inyo	Inyo County Building & Safety	Bishop
Kern	Kern County Public Works	Bakersfield, Delano, Ridgecrest, Wasco, Shafter, Tehachapi, Arvin, California City
Kings	Kings County Community Development Agency	
Los Angeles	Los Angeles County Building & Safety	Pomona, Santa Monica, Glendale, Burbank, Torrance, Culver City, Beverly Hills, West Hollywood, Pasadena, City of Los Angeles
Orange	Orange County Building & Safety	Anaheim, Santa Ana, Irvine, Huntington Beach, Garden Grove, Orange, Fullerton, Costa Mesa, Mission Viejo, Newport Beach
Riverside	County of Riverside Building & Safety	Riverside, Moreno Valley, Corona, Temecula, Murrieta, Indio, Palm Springs, Hemet, Perris, Menifee
San Bernardino	San Bernardino County Building & Safety	San Bernardino, Fontana, Ontario, Rancho Cucamonga, Victorville, Rialto, Hesperia, Chino, Redlands, Upland
San Luis Obispo	County of San Luis Obispo Planning & Building	San Luis Obispo, Paso Robles, Arroyo Grande, Grover Beach, Morro Bay, Atascadero, Templeton
Santa Barbara	County of Santa Barbara Building & Safety Division	Santa Barbara, Goleta, Carpinteria, Santa Maria, Lompoc, Buellton, Solvang
Tulare	Tulare County Building Department	Visalia, Tulare, Porterville, Dinuba, Exeter, Lindsay, Farmersville, Woodlake
Ventura	County of Ventura Building & Safety	Ventura, Oxnard, Thousand Oaks, Simi Valley, Camarillo, Moorpark, Fillmore, Ojai, Port Hueneme, Santa Paula

3.1 California Mechanical & Fire Code

The Chapter 11 of the California Mechanical Code (CMC) covers refrigeration systems (35). The last code update was 2022.

3.1.1 Ammonia

Ammonia must comply with IIAR 2 "*American National Standard for Design of Safe Closed-Circuit Ammonia Refrigeration Systems*", IIAR 3 "*Ammonia Refrigeration Valves*", IIAR4 "*American National Standard for Installation of Closed-Circuit Ammonia Refrigeration Systems*", and IIAR5 "*American National Standard for Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems*" and is not required to comply with CMC Chapter 11 (36). Ammonia systems have specific ventilation and access requirements in the machine room where the ammonia-based equipment is located and require a refrigerant leak alarm (37), (38). Ammonia systems have been used for decades in commercial buildings and many contractors are already familiar with how to design and install them. They will not be discussed in detail here because they are well-understood in the end-uses where ammonia is commonly used.

3.1.2 Refrigerants Other Than Ammonia

Refrigerants other than ammonia must comply with CMC Chapter 11 as well as ASHRAE 15. Refrigerants used in California buildings must be listed in CMC Table 1102.3 or must be listed in ASHRAE 34 if they have been approved by the Authority Having Jurisdiction (AHJ). Table 1102.3 lists various refrigerants, their chemical formula, chemical name, safety group, and the allowable pounds per 1000 feet of cubic space. The full table is shown in Appendix I. A snapshot of Table 1102.3 is shown below in Table 11. Table 11 also shows the GWP values of the refrigerant (from CARB or ASHRAE 34) and whether the refrigerant is Ultra-Low GWP, Low-GWP or Mid-GWP. Table 1102.3 lists A2L, A3, B2L, and B2 refrigerants. This means *Lower-GWP refrigerants are allowed by the CMC when certain conditions are met. However, the CMC does not allow Lower-GWP refrigerants in all cases.*

Lower-GWP refrigerants are allowed by the CMC when certain conditions are met. However the CMC does not allow Lower-GWP refrigerants in all cases

All refrigerants allowed by CMC must meet the concentration limits set forth in Table 1102.3 in the column "Pounds Per 1000 Cubic Feet of Space" except in the following circumstances (36):

- The refrigerant is in "Listed[7]" equipment containing 6.6 lbs or less of refrigerant (regardless of safety classification) and the equipment was installed according to the listing and manufacturer's instructions
- The refrigerant is in Listed equipment in laboratories with more than 100 square feet of space per person and the equipment was installed according to the listing and the manufacturer's installation instructions

[7] Appears in a list published by an approved testing or listing agency

Table 11: Refrigerant Safety Classification, Allowable Amounts from CMC Table 1102.3 and GWP Values from CARB or ASHRAE (36), (39), (40)

REFRIGERANT	SAFETY GROUP	OEL2 (ppm)	POUNDS PER 1000 CUBIC FEET OF SPACE	GWP	Ultra Low GWP (<10)	Low-GWP (≤150, >10)	Mid-GWP (≤700, >150)
R-717	B2L	25	0.014	-	x		
R-1132a	A2	500	2	-	x		
R-1224yd(Z)	A1	1000	23	0.88	x		
R-1233zd(E)	A1	800	5.3	1	x		
R-1234yf	A2L	500	4.7	1	x		
R-1234ze(E)	A2L	800	4.7	1	x		
R-744	A1	5000	3.4	1	x		
R-1270	A3	500	0.11	2	x		
R-514A	B1	320	0.86	2	x		
R-1336mzz(Z)	A1	500	5.4	2	x		
R-600	A3	1000	0.15	3	x		
R-600a	A3	1000	0.59	3	x		
R-290	A3	1000	0.56	4	x		
R-443A	A3	580	0.19	4	x		
R-601	A3	600	0.18	5	x		
R-601a	A3	600	0.18	5	x		
R-441A	A3	1000	0.39	5	x		
R-511A	A3	1000	0.59	5	x		
R-30	B1	—	—	9	x		
R-40	B2	—	—	13		x	
R-50	A3	1000	—	25		x	
R-123	B1	50	3.5	77		x	
R-444A	A2L	850	5.1	89		x	
R-41	—	—	—	116		x	
R-445A	A2L	930	4.2	118		x	
R-152a	A2	1000	2	124		x	
R-451A	A2L	520	5.3	133		x	
R-451B	A2L	530	5.3	146		x	
R-21	B1	—	—	148		x	
R-440A	A2	1000	1.9	156			x
R-512A	A2	1000	1.9	196			x
R-454A	A2L	690	28	238			x
R-444B	A2L	890	4.3	295			x
R-744A	—	—	—	298			x
R-446A	A2L	960	2.5	461			x
R-454B	A2L	850	22	465			x

R-447A	A2L	900	2.6	572	x
R-450A	A1	880	20	601	x
R-124	A1	1000	3.5	609	x
R-513A	A1	650	20	630	x
R-32	A2L	1000	4.8	675	x
R-452B	A2L	870	23	698	x

3.1.3 Refrigerant System Classification

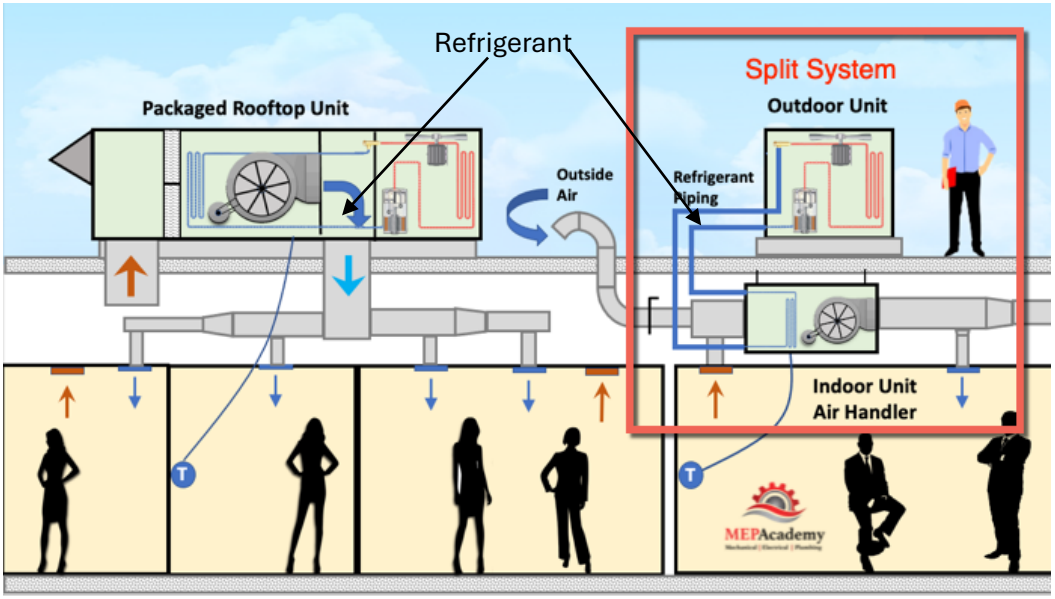
The CMC classifies refrigerant systems as **HIGH-PROBABILITY SYSTEMS** or **LOW-PROBABILITY SYSTEMS**. The definitions of each of these are listed below along with examples in Table 12.

Table 12: High and Low-Probability System Definitions and Examples

System Type	Definition	Examples
High-Probability System	"*Systems in which the basic design, or the location of components, is such that a leakage of refrigerant from a failed connection, seal, or component will enter the occupied space…A high-probability system shall be a direct system or an indirect open spray system in which the refrigerant is capable of producing pressure that is more than the secondary coolant*" (36)	• Variable refrigerant flow (VRF) (41) • Direct-Expansion (DX) Split-System • Packaged Rooftop Unit • Packaged Terminal Air Conditioner (PTAC) • Water Source Heat Pump (WSHP) (42)
Low-Probability System	*Systems in which the basic design, or the location of the components, is such that a leakage of refrigerant from a failed connection, seal, or component is not capable of entering the occupied space… A low-probability system shall be an indirect closed system, double indirect system, or an indirect open spray system. In a low-probability indirect open spray system, the secondary coolant pressure remains more than the refrigerant pressure in operating and standby conditions*" (36)	• Chillers located outdoors or in a "machinery room" (43)

Below in Figure 13 is an example of two **HIGH-PROBABILITY SYSTEMS**: a *DX Spilt System* and a *Packaged Rooftop Unit*.

Figure 13: Package Rooftop Unit and Split System Unit Examples (44)



In both systems, the blue lines represent the refrigerant lines. In the *Packaged Rooftop Unit* system the refrigerant lines are all on the roof of the building outside of occupied spaces. In the *Split System*, the refrigerant lines come into the occupied space through the roof. In both cases, a fan blows air across the refrigerant lines to cool it, and that air ends up in the occupied space. If there was a leak in a refrigerant line, it could potentially enter the occupied space via the conditioned air. This is why it is a **HIGH-PROBABILITY SYSTEM**; *there is a high-probability that a refrigerant leak could lead to refrigerant entering occupied spaces.* If the refrigerant was flammable or toxic, this could pose a safety risk to the occupants inside. Therefore, the CMC controls which HVAC systems are allowed to have flammable or toxic refrigerants based on the probability that a leak will lead to refrigerant entering occupied spaces.

A high-probability system means there is a high-probability that a refrigerant leak could lead to refrigerant entering occupied spaces.

3.1.4 Allowed Refrigerant Safety Classifications

3.1.4.1 CMC

The CMC controls the allowable refrigerants in buildings using Table 1104.1, which lists what refrigerant safety classifications are allowable in each occupancy group by **HIGH-PROBABILITY** and **LOW-PROBABILITY** Systems. Table 13 shows this table along with two additional columns which describe the meaning of the occupancy group. The “Type of Occupancy” and “Example Buildings” from Table 13 come from the 2022 California Building Code (CBC).

Table 13: Allowable Refrigerant Safety Classifications by Occupancy Group and High/Low Probability (36), (45)

TYPE OF OCCUPANCY	EXAMPLE BUILDINGS	OCCUPANCY GROUP	HIGH-PROBABILITY SYSTEM	LOW PROBABILITY SYSTEM	MACHINERY ROOM
Assembly buildings with fixed seating	Theaters, concert halls, TV studio with an audience	A-1	Group A1 only	Any	Any
Assembly buildings intended for food/drink consumption	Banquet halls, casinos, restaurants, bars	A-2	Group A1 only	Any	Any
Assembly buildings intended for worship, recreation or amusement and other not classified elsewhere	Libraries, waiting areas in transportation terminals, gymnasiums	A-3	Group A1 only	Any	Any
Assembly buildings intended for viewing indoor sporting events	arenas, swimming pools, tennis courts	A-4	Group A1 only	Any	Any
Buildings or portions of buildings used for professional or service-type transactions	Civic administration, electronic data processing, laboratories	B	Group A1* only	Any	Any
Buildings or portions of buildings used by more than (6) people at a time for K-12 education	High schools, elementary schools	E	Group A1 only	Any	Any
Moderate-hazard factory buildings	Aircraft manufacturing, bakeries, clothing manufacturing	F-1	Group A1* only	Any	Any
Low-hazard factory buildings	Beverage manufacturing, foundries, metal fabrication & assembly	F-2	Any*	Any	Any
Buildings or portions of buildings that involve manufacturing, processing, generation, or storage of materials that constitute a detonation hazard		H-1	Any	Any	Any
Buildings or portions of buildings that involve manufacturing, processing, generation, or storage of materials that constitute a deflagration hazard		H-2	Any	Any	Any

Buildings or portions of buildings that involve manufacturing, processing, generation, or storage of materials that constitute a physical hazard		H-3	Any	Any	Any
Buildings or portions of buildings that involve manufacturing, processing, generation, or storage of materials that constitute a health hazard		H-4	Group A1 only	Any	Any
Semiconductor fabrication facilities where hazardous production materials are used		H-5	Group A1 only	Any	Any
Not used in building code		I-1	None	Any	Any
Buildings used for medical care on a 24-hr basis for 5+ people who are incapable of self-preservation	Nursing homes, detoxification facilities, hospitals	I-2	Group A1 only	Any	Any
Building that receives people for outpatient medical care which may render the patent incapable of self-preservation and where each tenant space accommodate**s** 5+ people		I-2.1	Group A1 only	Any	Any
Buildings inhabited by one or more people who are under restraint or security	Jails, prisons, correctional facilities	I-3	None	Any	Any
Buildings occupied by 6+ people who receive custodial care less than 24 hours/day	Adult day care, child care	I-4	Group A1 only	Any	Any
Buildings used for the display and sale of merchandise	Department stores, drug stores, retail stores	M	Group A1* only	Any	Any
Buildings used for sleeping when not classified as institutional where occupants are transient in nature	Boarding homes, transient hotels, transient motels	R-1	Group A1 only	Any	Any
Buildings used for sleeping when not classified as institutional with 2+ dwellings where occupants are permanent in nature	Apartments, dormitories, non-transient hotels	R-2	Group A1 only	Any	Any
Residential units where occupants are permanent in nature and not classified as R-1, R-2 or R-4		R-3	Group A1 only	Any	Any

Buildings used 6+ ambulatory clients who reside on a 24-hour basis in a supervised setting	Assisted living facilities, group homes, halfway house	R-4	Group A1 only	Any	Any
Buildings used for storage of moderate-hazard materials	Aircraft hangar, storage of clothing, storage of furniture	S-1	Group A1* only	Any	Any
Buildings used for storage of low-hazard materials	Beverage storage, dairy product storage, fresh fruit storage	S-2	Any*	Any	Any
Miscellaneous	Agricultural buildings, private garages, carports	U	Any	Any	Any

The CMC allows the use of flammable and toxic refrigerants in all **LOW-PROBABILITY SYSTEMS.** The CMC allows the use of flammable and toxic refrigerants in the following **HIGH-PROBABILITY SYSTEMS** in industrial occupancies and refrigerated rooms under certain conditions:

- Occupancy Group B (Business buildings)
- Occupancy Group F-1 (Moderate-Hazard Factory Buildings)
- Occupancy Group F-2 (Low-Hazard Factory Buildings)
- Occupancy Group M (Merchandise Buildings)
- Occupancy Group S-1 (Moderate-Hazard Storage)
- Occupancy Group S-2 (Low-Hazard Storage)

The asterisk in Table 13 in the "**HIGH-PROBABILITY SYSTEM**" column indicates that refrigerants other than A1 can be used when certain conditions are met. These conditions are not discussed because they are in industrial occupancies and refrigerated rooms and are, therefore, not applicable to most buildings in SoCalREN's programs.

In buildings found in SoCalREN's programs, the CMC allows any refrigerants in **LOW-PROBABILITY SYSTEMS** (subject to some additional regulations). However, the CMC does not allow flammable or toxic refrigerants (A2L, A2, A3, B1, B2, B2L, or B3) in **HIGH-PROBABILITY SYSTEMS**. However, many common HVAC systems are **HIGH-PROBABILITY** such as VRF, rooftop units, and DX split-system. Ultimately, this means A2L refrigerants cannot be used in many California buildings even though they appear in Table 1102.3 of the CMC. The CMC would need to be updated to allow refrigerants other than A1 in **HIGH-PROBABILITY SYSTEMS**. **In other words, most Lower-GWP refrigerants are not allowed by CMC in the buildings found in SoCalREN's portfolio because the HVAC systems in those buildings are usually High-Probability System like the kinds shown in Figure 13.**

Most Lower-GWP refrigerants are not allowed by the CMC in SoCalREN's portfolio because the HVAC systems are High-Probability Systems.

3.1.4.2 California State Legislature

The most recent version of the CMC was updated in 2022 and, as discussed above, those updates do not allow the use of most Lower-GWP refrigerants in most buildings. There are exceptions to this, but this is generally the case. The CMC will not be updated again until 2025.

Therefore, the California legislature, passed Assembly Bill 209 (AB 209) that was signed into law on 9/6/22 which circumvents the CMC. In Section 4, AB 209 states:

> "*This bill would require the [California Building Standards Commission], on or before July 1, 2023, to consider whether to adopt specified consensus safety standards. If the commission does not adopt the consensus safety standards, then the bill would prohibit a state or local building code from prohibiting the use of a refrigerant listed as acceptable under specified provisions of the federal Clean Air Act if the use is installed in accordance with specified standards, effective July 1, 2024.*"

There will be confusion in the market about what refrigerants are allowed in HVAC systems because AB 209 circumvents the current CMC

The California Building Standards Commission did not adopt consensus safety standards so a state or local building code AHJ must allow refrigerants listed as acceptable by EPA SNAP effective 7/1/24.

It is very likely that there will be confusion in the market about what refrigerants are allowed in what HVAC systems and occupancies because AB 209 circumvents the current CMC. The Study Team recommends that SoCalREN inform contractors and AHJs of the implications of AB 209 via training, webinars, or fact sheets.

3.2 Other

There are other nuances and requirements related to refrigerants in the CMC that were researched for this study but are not as important as the major points discussed in this section. Those requirements are detailed in Appendix I. Additionally, the Study Team summarized the requirements in the California Fire Code (CFC) that apply to Lower-GWP refrigerants, and that is also listed in Appendix I. Lastly, the Study Team researched the local fire code and mechanical codes of Los Angeles County and the City of Los Angeles and compared them to the CFC and CMC, and that information is also in Appendix I.

3.3 Codes & Standards Summary

The CARB regulations are aligned with state codes. State codes **do not** allow most Lower-GWP refrigerants in most buildings because flammable and toxic refrigerants are not allowed **IN HIGH-PROBABILITY** systems. However, AB 209 passed in 2022 circumvented the CMC and essentially allows any refrigerant approved by EPA SNAP to be installed. EPA SNAP has approved many Lower-GWP refrigerants. Therefore, Lower-GWP refrigerants **are allowed** in California buildings and specifically in SoCalREN's portfolio of buildings because of AB 209. This is likely to lead to

confusion among contractors and AHJs about what refrigerants are allowed and why. **The Study Team recommends that SoCalREN inform contractors about the implications of AB 209 via webinars, fact sheets, or training in 2024.**

The Study Team also recommends that the SoCalREN Measure Working Group keep a record or database of code issues that come up during energy efficiency projects. The purpose of this database is to identify common sources of confusion around code language to refine training, webinars, and factsheets for contractors. This database should capture the following information:

- Project City
- AHJ
- Local Code name, date, and section that applies
- Description of the nuance/issue

It seems that CARB purposely pushed out some High-GWP refrigerant prohibition dates because the 2022 CMC would not allow most Medium-GWP and Low-GWP refrigerants in many HVAC systems. **It is recommended that SoCalREN monitor developments with the 2025 CMC updates to determine if changes are planned that will allow these refrigerants in HIGH PROBABILITY SYSTEMS.**

4. Lower-GWP Solutions

This section summarizes information collected via online scanning and screening and from contractors and distributors regarding the readiness and availability of implementing lower-GWP solutions. This section also lists and summarizes the available lower-GWP technology solutions for a variety of end uses across residential, commercial, and industrial sectors.

4.1 Interviews

A handful of subject matter experts (SMEs) were interviewed on knowledge of Lower-GWP refrigerants and equipment including the following:

- Installation and/or distribution of any equipment that uses Lower-GWP refrigerants
- Barriers and opportunities with implementing Lower-GWP equipment in the near and long-term future
- Awareness of refrigerant reclaim locations
- Trainings received on Lower-GWP refrigerants and equipment

4.1.1 Recruitment and Response

SME contacts were gathered from SoCalREN and Lincus professional connections. A total of (94) SMEs were reached out to via email. All (94) were followed up with via email at least once and a handful of warmer connections were followed up with by phone. A total of five (5) SMEs answered the interview questionnaire. Four (4) SMEs answered the interview questionnaire via an online Teams call and one (1) answered via an online form with no call. One (1) SME is a distributor of HVAC and water heating equipment, three (3) were contractors who installed HVAC equipment,

water heating equipment, or both, and (1) was a building superintendent who has many years of experience maintaining HVAC equipment. The project scope did not include extensive outreach to gather many interviewees. However, each SME provided valuable information on the state of the market concerning Lower-GWP equipment.

4.1.2 Questions

The SMEs were asked the following questions:

1) General Information
    a. What is your main area of work? HVAC, Water heating, refrigeration or other?
    b. What size/type of equipment do you or your company work with?
    c. What is your role at your company?
2) What types of refrigerants does your company work with?
3) Does your company install any equipment that uses Low-GWP refrigerants (A2L or A3 refrigerants).
    a. If yes, what are the positives and negatives of working with this equipment for you and the customer?
    b. If no, why not?
4) What percentage of your customers have inquired about Low-GWP refrigerants or Low-GWP equipment?
5) What barriers and opportunities do you see for Low-GWP equipment in the near and long-term future?
6) Do you know of any refrigerant reclaim locations in your service area?
7) Are you aware of refrigerant reclaim requirements?
8) Have you or your technicians received any training on Low-GWP refrigerants or equipment?
9) Do you know what types of buildings and equipment can use A2L or A3 refrigerants in California?
10) Is there any other information you want to add about Low-GWP refrigerants?
11) Do you know anyone else who I could survey about Low-GWP refrigerants?

Raw survey responses can be found in Appendix II.

4.1.3 Summary of Interview Responses

4.1.3.1 Types of Refrigerants

Only one (1) SME currently works with equipment that uses Lower-GWP refrigerant. This SME was a distributor that represents a CO_2 electric heat pump water heater (EHPWH). The other four (4) SMEs do not work with Lower-GWP refrigerant, but (3) indicated their willingness or plans to work with Lower-GWP refrigerants in 2025. One (1) of these SMEs was an EHPWH installer and wanted to know more about CO_2 EHPWHs. The other two (2) SMES were primarily HVAC contractors who currently don't work on Lower-GWP equipment or install it, but plan to in 2025 or 2026.

4.1.3.2 Barriers and Opportunities

The SMEs noted many barriers and opportunities for Lower-GWP refrigerants.

Opportunities

- Contractor Differentiation: One (1) SME (an HVAC contractor) thought that Lower-GWP equipment represents a way to differentiate yourself from other companies and capture more revenue from a job. According to this SME, additional cost for a Lower-GWP job could be justified by the environmental benefits. Another SME (an EHPWH installer) noted that contractors are looking for opportunities to be specialists in certain systems alluding to the previous contractor's note about differentiating yourself. An EHPWH distributor noted that Lower-GWP equipment is the future. Therefore, it seems that Lower-GWP equipment gives contractors and distributors a way to differentiate themselves from others and generate more revenue.

Barriers

Three (3) SMEs discussed several barriers and concerns they have with Lower-GWP refrigerants and equipment.

- Additional Requirements and Coordination: An HVAC contractor noted that Lower-GWP equipment requires additional refrigerant leak detection sensors which have to be installed by another trade. He noted that smoke sensors already have to be installed by another trade for existing HVAC installations and there is already an issue with one trade blaming the other when things don't work right. He is concerned the requirement for more sensors will exacerbate this issue.
- Quality of HVAC System: Three (3) SMEs (two contractors and one maintenance person) were concerned with the quality of new HVAC equipment using Lower-GWP refrigerants. One of these SMEs had experience with the R-22 phase out and noted that drop-in refrigerant replacements did not work well in that phase out and was doubtful drop-in replacements will work for this refrigerant transition. This SME noted that the operating pressures of the refrigerants are often not the same with drop-ins and impact equipment performance so much that it has to be replaced anyway. Another SME indicated that his company tests units before recommending them to customers and has not been able to purchase a unit to test. All three (3) of these SMEs seemed wary of trusting manufacturers to provide information on Lower-GWP systems and wanted to see how the Lower-GWP equipment actually performs.
- Safety: An HVAC contractor was concerned about the safety of the new equipment. A specific example he gave was his uncertainty about whether or not an A2L refrigerant will ignite if there is a leak in the refrigerant line the gas furnace is operating.
- Lead Times: Two (2) HVAC contractors noted that manufacturers are not currently selling Lower-GWP equipment. They both thought that HVAC manufacturers are manufacturing as much R410a and R134a equipment as possible in 2024 and plan to sell it into 2025. One of these SMEs got a quote for a chiller using R454b and the lead-time was over 1 year. The contractor noted that a chiller with a lead time that is over 1 year might as well not exist because a customer cannot wait that long for new equipment. The other contractor noted they plan to stock up on R410a equipment in 2025 so they can continue to sell it into late

2025. This is the same contractor who wanted to test out an R32 unit to confirm its quality before selling it to customers.

4.1.3.3 Refrigerant Reclaim

All three (3) HVAC SMEs indicated that refrigerant can be turned into refrigerant distributors or HVAC distributors. They all also mentioned that anyone servicing or purchasing HVAC equipment or purchasing refrigerant canisters must have an EPA 608 card. This card means the person has gone through EPA training on handling and disposing of refrigerants with includes information about fines if refrigerant is not handled properly. All of these SMEs drop off used refrigerant with another party that is then required to bring the refrigerant to a reclamation facility certified by the EPA. *In other words, HVAC contractors and technicians do not directly interact with refrigerant reclaimers*. When pressed, one of the SMEs who works on units that are 25 tons or less indicated that if the compressor of an HVAC unit is still operating, they pump the refrigerant into the condenser and give the condenser to a scrapper who is responsible for the refrigerant reclamation at that point. This is consistent with the finding in the CPUCs "*Forward-Looking Low-Global Warming Potential Refrigerant Transition Study"* (46) (CPUC Low-GWP Study)that many contractors do not use recovery machines to pull refrigerant into recovery cylinders.

4.1.3.4 Training and Knowledge of Lower-GWP Codes & Standards

Training on and knowledge of Lower-GWP refrigerants and systems was a mixed bag of responses. One SME didn't need training because he was an EHPWH installer and didn't work with HVAC equipment. One HVAC contractor had his technicians trained by distributors on Lower-GWP refrigerants multiple times over the past two years. The other HVAC contractor had received no training but thought distributors would offer it in Fall 2024. The HVAC SME didn't know of any training offered on Lower-GWP refrigerants by any organization. The EHPWH distributor had received training on Lower-GWP refrigerants from the manufacturers whose equipment he reps. This is also consistent with the findings of the CPUC Low-GWP study that found some contractors had received no training and some had received more than 8 hours of training (46).

When questioned about what types of equipment and buildings can use Lower-GWP equipment, all answers indicated the SMEs did not have a deep grasp of the ins and outs of the California Mechanical Code requirements for A2L refrigerants as discussed in Section 3.1 above.

4.1.4 Interview Summary

Although the SMEs represent a small sample, some valuable insights and recommendations were gained from the interviews.

- Lower-GWP HVAC equipment may not be available for purchase until the second half of 2025. This insight was confirmed during the scanning and screening process in later sections and with discussions with one of SoCalREN's implementers.
- Training on Lower-GWP refrigerants and equipment is still needed. Only one (1) SME had training on Lower-GWP refrigerants and the other two (2) did not. SoCalREN should encourage their contractor network to seek this training from distributors. Training on handling the refrigerants is needed along with training on requirements from the CMC.

- Manufacturers and distributors could do a better job of assuring contractors about the quality and safety of Lower-GWP refrigerant. All three (3) HVAC SMEs had concerns about equipment performance and one of them was additionally concerned about safety because the Lower-GWP refrigerants are flammable.
- Some contractors see the possibility of making a value-proposition to their clients using Lower-GWP refrigerants. SoCalREN could capitalize on this by providing support to contractors to calculate GHG reductions when Lower-GWP systems are used.
- Contractors do not directly interact with refrigerant reclaimers. Scrappers, HVAC distributors, or refrigerant distributors are the middle-men in this process. The CPUC Lower-GWP Study suggested that documentation from smart phone app named "Visual Service" and a bill of lading from a refrigerant reclaimer could effectively prove that refrigerant was reclaimed (46). However, the results of these interviews seem to indicate that a contractor would not be able to get a bill of lading since they do not interact with the refrigerant reclaimer directly.

4.2 Technology Solutions

The following technology solutions in Table 14 were found based on their Lower-GWP refrigerants, sector applications, market segments, and availability in the market. The data collected was found using public sources and estimations. Each solution was also mapped to any applicable measure packages. A detailed spreadsheet was provided to SoCalREN with additional information on each solution's:

- Capacity range
- Voltage requirements
- Operating weight
- Technology Readiness Level
- Current manufacturers
- Load shifting capability (if any)
- Cost estimate
- Refrigerant reclaim requirements
- Site/location requirements
- Whether or not an engineered solution is required for the technology
- Key barriers to implementation

This information is not included in this report for the sake of brevity.

Table 14: Low-GWP Solutions collected and analyzed

Solution	Low-GWP Measure Name	Applicable Measure Packages	Refrigerant	Sector

#1	R-290 and R-600a Standalone Display-Cases	SWCR014 SWCR018 SWCR019 SWCR020 SWCR021	Propane (R-290) Isobutane (R-600a)	Com
#2	Lower-GWP Residential Refrigerators	SWAP001	R-600a	Res
#3	CO2 Central Refrigeration Systems	None	CO_2	Com Ind
#4	CO2 and Ammonia Central Refrigeration Systems	None	CO_2 Ammonia (NH_3)	Com Ind
#5	Ammonia Air/Water Source Gas Absorption Heat Pump	SWHC057	Ammonia (NH_3)	Res Com Ind
#6	Lower-GWP Split System Air Source Heat Pump	SWHC013 SWHC014 SWHC044 SWHC045 SWHC049 SWHC050	R-32	Res Com
#7	Lower-GWP Packaged Air Source Heat Pump	SWAP020 SWHC013 SWHC014 SWHC027 SWHC045 SWHC046 SWHC049	R-454B	Res Com
#8	CO2 Air/Water Source Domestic Hot Water Heat Pump	SWWH014 SWWH025 SWWH027 SWWH028 SWWH031	CO_2	Res Com Ind
#9	Lower-GWP Air Source Domestic Hot Water Heat Pump	SWWH014 SWWH025 SWWH027 SWWH028 SWWH031	R-513A	Res Com
#10	Lower-GWP Refrigerant Magnetic Bearing Centrifugal Water-Cooled Chillers	SWHC005	R-1233zd (E) R-1234ze R-513A R-525B	Com Ind
#11	Lower-GWP Magnetic Bearing Centrifugal Air-Cooled Chillers	SWHC020 SWHC052	R-513A	Com

#12	Lower-GWP Screw Air-Cooled Chillers	SWHC020 SWHC052	R-513A R-1234ze	Com Ind
#13	Lower-GWP Scroll Air-Cooled Chillers	SWHC020 SWHC052	R-454B	Com Ind
#14	Retrofit Existing Systems with a New Lower-GWP Refrigerant	SWSV014	RS-51 (R-470B) RS-53 (R-470A) RS-20 (R-480A) R-1224yd(Z) R-1233zd(E) R-450A R124 R-513A R-515B	Res Com Ind

4.2.1 Standalone Display-Cases

With the move to phase out HFCs like R404A and R-134A, refrigeration systems are moving towards natural refrigerant solutions, specifically to propane (R-290, 3 GWP) and isobutane (R-600A, 4 GWP). Most self-contained refrigerators have already transitioned to one of these natural refrigerant options. This can be seen with the current ENERGY STAR® commercial refrigerator and freezer list, where 93.6% of ENERGY STAR® certified equipment is charged with R-290 or R-600a (47). These refrigerants are currently limited to charges less than 150g, which includes any self-contained refrigerator technology that has a built-in condensing unit.

4.2.2 Residential Refrigerators

Like the commercial refrigerators and freezers, residential refrigerators are shifting towards Lower-GWP options, namely R600A. While only 27.7% of the listed ENERGY STAR® certified equipment (48) is charged with R-600A (also including a majority of refrigerators that do not have any refrigerant listed), these are popular among residential programs, making them a viable technology for future Lower-GWP efforts.

4.2.3 Central Refrigeration Systems

Commercial and industrial refrigeration systems have started to turn to CO_2 refrigerant (also known as “trans critical booster systems”), although it is currently more industry-wide accepted in Europe (49). However, CO_2 system have significant barriers such as expensive installation costs as well as additional technical knowledge needed to install and maintain CO_2 systems (49).

There has also been a recent rise in ammonia (NH_3, 0 GWP) charged systems. There are concerns over NH_3 systems since it is a B1 refrigerant (50). However, many systems using NH_3 also employ another refrigerant (sometimes CO_2) for a cascade system, lessening the amount of ammonia in the system (51).

4.2.4 Air Source Heat Pump

Currently, most split-system and packaged light commercial HVAC systems are charged with R-410A or R-134A. However, with the transition away from High-GWP refrigerants as explained in Section 2, the shift in HVAC technology has turned to Lower-GWP refrigerants such as R-454B (466 GWP) and R-32 (675 GWP). The initial screening of Lower-GWP HVAC technologies only found one (1) set of specification sheets for packaged air-source HVAC units. However, additional technologies were found after a conversation with one of SoCalREN's implementers.

4.2.5 Domestic Hot Water Heat Pump

Both residential and commercial EHPWH systems still use R-134A. The commercially available Lower-GWP EHPWHs chosen for this study are charged with CO_2 (1 GWP), a natural refrigerant, or R-513A (631 GWP), an HFO based replacement for R-134A. These EHPWHs also substitute the incumbent natural gas-fired water heaters.

4.2.6 Chillers

Air-cooled and water-cooled chillers offer an energy efficient way to cool a space. Although limited in the US market, some manufacturers have moved towards charging chillers with R-513A (572 GWP) and R-1234ze (7 GWP), the latter being an Ultra-Low-GWP refrigerant specifically used in chiller applications for its efficiency (52).

4.2.7 Retrofit Existing Systems with a New Lower-GWP Refrigerant

While not a specific technology, this Lower-GWP option served as a catch-all for incentivizing retrofits of existing refrigerants systems with Lower-GWP and system-compatible refrigerants (53). The purpose is to reduce installation costs by not replacing the system as a whole, but by replacing the refrigerant in the equipment with a Lower-GWP option. While it may be challenging to find compatible replacements (in terms of energy efficiency), there are many refrigerant manufacturers and distributors who provide new and blended Lower-GWP refrigerants for such retrofit projects. There are also certified refrigerant reclaimers who are trained to properly handle the removed refrigerants, aiding in the overall safety and sustainability of refrigerant reclamation (54). However, as discussed in Section 4.1.4, the market may be resistant to Lower-GWP drop-in replacements of existing refrigerant because of bad experiences during the R-22 refrigerant phase out.

5. Program Data Review

Available SoCalREN program data from 2020 to 2023 was analyzed to determine what measures are already used in SoCalREN programs that have a Lower-GWP option. Data was analyzed from the following programs:

- Multifamily Program
- Metered Savings Pathway (MSP)
- Streamlined Savings Pathway (SSP)
- Healthy Stores Refrigeration Program

5.1 Multifamily Program

The Multifamily program included data from 2021 to 2023. Measure names, kWh savings, kW savings, therm savings, and measure costs were collected from individual project submissions and entered into a summary table which was organized by measure name. Table 15 below shows the total claimed kWh, kW, therm, and measure cost over all 3 years for those measures with a Lower-GWP option. Other measures in the individual project files were omitted because they do not have a Lower-GWP option (for example, lighting retrofits were omitted because they do not have a Lower-GWP option).

In Table 15, High Efficiency DHW Heaters yielded the most kWh, therm, and kBtuh savings, but also the most measure cost. However, all three (3) measures can be mapped to existing measure packages that this program could implement if the measure packages had Lower-GWP permutations. EHPWHs fall under "High Efficiency DHW Heaters" in Table 15 and they were of interest to the multifamily SoCalREN implementer, so this measure was selected for deeper analysis in Section 6.

Table 15: Multifamily HVAC, DHW & Refrigeration Summary

Measure Name	Potential Measure ID	kWh Savings	kW Savings	Therm Savings	Measure Cost
ENERGY STAR Refrigerators	SWCR018	5,970.4	0.5	(37.9)	$165,360
High Efficiency DHW Heaters[8]	SWWH014 SWWH025 SWWH028	83,1824.8	0.0	208,961.9	$5,569,423
High Efficiency Heating and Cooling Systems	SWHC044 SWHC050	12,6164.6	(50,367.2)	28,365.4	$2,821,430
Total		**963,959.8**	**(50,366.6)**	**237,289.4**	**$8,556,213**

5.2 MSP and SSP Program

The MSP and SSP programs included data from 2020, 2023, and 2024, with the various chiller replacement projects being excluded from the final analysis. Table 16, below, shows a summary of the total claimed kWh and measure cost for each measure claimed in the MSP or SSP program that is related to HVAC, DHW, or refrigeration. Table 16 shows that the EHPWH Replacement measure had the most kWh savings while the Packaged HVAC Replacement measure had the highest measure cost. The EHPWH and Packaged HVAC replacement were selected for further analysis in Section 6, but these programs could also implement Lower-GWP chillers if those measure packages are updated with Lower-GWP permutations.

[8] Traditional boilers and EHPWHs

Table 16: MSP and SSP HVAC, DHW & Refrigeration Summary

Program Name	Measure Name	Measure ID	kWh	Measure Cost
MSP	Chiller Replacement	SWHC005 SWHC020 SWHC052	224,157.0	$595,700.00
SSP	EHPWH Replacement	SWWH027 SWWH028	2,017,085.8	$1,550,875.40
MSP, SSP	Packaged HVAC Replacement	SWHC013 SWHC046	207,317.0	$4,456,643.00
Total			**2,448,559.8**	**$6,603,218.40**

5.3 Commercial Direct Install Program

SoCalREN will be launching a new Small Commercial Direct Install program. This is a brand-new program so it did not have existing program data to draw from. The measures in the program implementation plan (PIP) that are related to HVAC or refrigeration are as follows:

- SWHC013
- SWSV002
- SWSV003
- SWSV005
- SWSV010
- SWSV004
- SWCR002
- SWCR007
- SWCR008

The Study Team was advised by SoCalREN that other low-cost commercial measures could be included in the program later on, and the Study Team should not limit its analysis to only the measures listed in the PIP. The Study Team made the following list of low-cost[9] commercial measures which are HVAC or refrigeration related shown in Table 17. The Study Team used California Energy Data and Reporting System (CEDARs) data from 2020 to 2023 to determine the claimed kWh savings for the measures listed in Table 17 because there was no previous SoCalREN program data to analyze. The results from that analysis are in Table 18 below.

[9] Usually only low-cost measures are used in direct install programs

Table 17: Low-Cost Commercial Measures Related to HVAC or Refrigeration

Measure Package ID	Measure Name	In current PIP [Y/N]
SWCR001	Anti Sweat Heater Controls	N
SWCR002	Low-Temperature Display Case Doors With No Anti-Sweat Heaters	Y
SWCR003	Fan Motor Retrofit for a Refrigerated Display Case	N
SWCR004	ECM Retrofit for a Walk-in Cooler or Freezer	N
SWCR007	Floating Head Pressure Controls, Multiplex	Y
SWCR008	Floating Suction Controls, Multiplex	Y
SWCR010	Bare Suction Line Insulation	N
SWCR014	Medium or Low-Temperature Display Case	N
SWCR015	Medium-Temperature Case Doors	N
SWCR017	Ultra-Low Temperature Freezer	N
SWCR018	Reach-In Refrigerator or Freezer, Commercial	N
SWCR019	Low-Temperature Coffin To Reach-In Display Case Conversion	N
SWCR020	Medium-Temperature Open Display Case Retrofit	N
SWCR021	Medium or Low-Temperature Display Case With Doors	N
SWSV001	Duct Seal, Residential	N
SWSV002	Refrigerant Charge Adjustment, Commercial	Y
SWSV003	Evaporator Coil Cleaning, Commercial	Y
SWSV004	Condenser Coil Cleaning, Commercial	N
SWSV005	Economizer Repair, Commercial	Y
SWSV006	Refrigerant Charge Adjustment, Residential	N
SWSV007	Condenser Coil Cleaning, Residential	N
SWSV008	Evaporator Coil Cleaning, Residential	N
SWSV009	Airflow Adjustment, Residential	N
SWSV010	Economizer Controls, Commercial	Y
SWSV013	Duct Optimization, Residential	N
SWSV014	Lifecycle Refrigerant Management, Residential	N

Table 18: kWh Claims for Low-Cost Commercial HVAC and Refrigeration Related Measures

Measure ID	Measure Name	Total Net Therm	Total Net kWh	Total Net kW
SWCR005	Auto Closer for Refrigerated Storage Door	2,890.1	19,316,316.7	4,165.5
SWCR001	Anti-Sweat Heater Controls	(65,441.1)	7,780,965.0	599.9
SWCR015	Medium-Temperature Case Doors	589,474.4	6,429,937.3	852.8
SWCR004	ECM Retrofit for a Walk-in Cooler or Freezer	0.0	693,275.5	90.7
SWCR003	Fan Motor Retrofit for a Refrigerated Display Case	(26.0)	14,130.8	1.9
SWCR010	Bare Suction Line Insulation	0.0	2,575.5	0.5
SWSV005	Economizer Repair, Commercial	90.0	67,398.6	2.6
SWSV010	Economizer Controls, Commercial	0.5	54,145.7	0.0
SWSV002	Refrigerant Charge Adjustment, Commercial	(36.5)	46,800.8	39.7
SWSV004	Condenser Coil Cleaning, Commercial	(8.4)	9,907.7	9.2
SWSV003	Evaporator Coil Cleaning, Commercial	(3.7)	4,347.9	4.1
Total		**52,6939.2**	**34,419,801.5**	**5,766.9**

If a measure is not listed in Table 18, that means it had no savings claims for 2020 to 2023. All of the measures listed in Table 18 are add-on measures to refrigerated display cases or HVAC units. This means they would have to be implemented on top of an existing Lower-GWP refrigerated display case or packaged HVAC unit. CARB's GWP limits on refrigerated display cases only started in 2019 and CARB's limits on packaged HVAC systems don't start until 2025. Therefore, there is a very small pool of existing Lower-GWP equipment that the measures in Table 18 could be used on, so In, none of these measures were selected for further analysis in Section 6.

5.4 Food Desert Program

SoCalREN is also launching a Food Desert Energy Efficiency Equity Program (Food Desert Program) which is a new program and also does not have existing program data. However, SoCalREN did support a Healthy Stores Refrigeration Program (HSRP) which ran from late 2020 to early 2022 which provided free self-contained refrigerators to small, local businesses in communities that have limited access to affordable and fresh produce, also called "food desert" areas. The self-contained refrigerators are a measure in the new Food Desert program, so the available data from the HSRP program was analyzed. The HSRP included data from 2020 to 2022 from (2) public-facing reports. The reports give the total number of installed refrigerators and their model numbers. The

HSRP was not an EE program funded by the CPUC so it does not have claimed kWh, kWh, therm, or measure costs. However, the Study Team mapped the refrigeration make/model numbers to permutation sin measure package SWWCR018 to estimate theoretical kWh/kW/therm savings and measure costs, and Table 19 shows the results. All of the refrigerators installed in the HSRP are using Ultra-Low-GWP refrigerants. Self-Contained Refrigerators were selected for deeper analysis in Section 6.

Table 19: Healthy Stores Refrigeration Program Theoretical kWh, kW, Therm and Measure Costs

Measure ID	Units Installed	kWh Savings	kW Savings	Therm Savings	Measure Cost
SWCR018A	11	2,068.0	0.3	(6.3)	$38,408
SWCR018B	22	8,382.0	1.1	(25.5)	$76,185
SWCR018C	84	53,676.0	6.8	(163.0)	$446,505
SWCR018D	24	15,672.0	2.0	(47.8)	$174,743
Total	**141**	**79,798.0**	**10.2**	**(242.6)**	**$735,842**

6. Measure Analysis

Using the list of Lower-GWP solutions in Section 4 combined with the analysis of SoCalREN program data in Section 5, the following measures in Table 20 were selected for deeper analysis during a meeting with SoCalREN staff and representatives from their implementers.

Table 20. Lower-GWP Measures Selected for Deeper Analysis

Measure Name	Building Type	Associated MP(s)
Multifamily EHPWH CO_2	Multifamily – Common Area Multifamily – In-Unit	SWWH028 SWWH025
Multifamily EHPWH Lower-GWP[10]	Multifamily – Common Area Multifamily – In-Unit	SWWH028 SWWH025
Commercial EHPWH Lower-GWP[11]	Secondary Schools Small Office Assembly	SWWH027 SWWH028
Commercial Packaged HVAC Unit Lower-GWP	Secondary Schools Small Office Assembly	SWHC046 SWHC013
Reach-In Refrigerator or Freezer	Any	SWCR018

[10] This measure is for electric HPWHs that use a Lower-GWP refrigerant but do not use CO2.
[11] See Note 10

Once measures were selected, the team calculated changes to the following metrics for the Lower-GWP measures compared to the existing measures:

- kWh savings
- GHG savings
- Measure costs
- Refrigerant costs/benefits
- Total System Benefit (TSB)

In accordance with the SoCalREN territories, the analysis was conducted for Accelerated Replacement (AR) or Normal Replacement (NR) application types in California Climate Zones 6, 8, 9, 10, 13, 14, 15, and 16.

The analysis included:

- Mapping Lower-GWP technologies to existing measure package IDs based on size and efficiency requirements
- Calculating potential kwh savings impacts of Lower-GWP measures
- Collecting measure cost data of Lower-GWP technologies from online resources, distributor quotes and a CalNEXT study (55)
- Calculating GHG using the average marginal emissions from the Avoided Cost Calculator (ACC) for 2024
- Using the Refrigerant Avoided Cost Calculator (RACC) for deemed measures to estimate the avoided Lower-GWP refrigerant cost
- Running the previous data into the CEDARS Costs Effectiveness Tool (CET) to compute the Total System Benefits (TSB) for each Lower-GWP technology
- Comparing existing measure data to Lower-GWP measure data

6.1 Lower-GWP Measures Mapped to Measure Packages

Each Low-GWP technology was mapped to all Measure IDs it is applicable to, and this is shown in Table 21. This mapping led to the Lower-GWP and existing measure package data comparisons shown in the following sub-sections.

Table 21: Lower-GWP Measures Mapped to Existing Measure Package IDs

Lower-GWP Measure Description	Measure Package ID And Description
Reach-In Refrigerator or Freezer	SWHC018 Reach-in Refrigerator or Freezer, Commercial
Electric Heat Pump Water Heater	SWWH025 Heat Pump Water Heater, Residential, Fuel Substitution SWWH027 Heat Pump Water Heater, Commercial, Fuel Substitution SWWH028 Large Heat Pump Water Heater, Commercial and Multifamily, Fuel Substitution

Packaged HVAC Unit	SWHC013 Unitary Air-Cooled Air Conditioner, Over 65 kBtu/hr, Commercial SWHC046 Packaged Heat Pump Air Conditioner Commercial, Fuel Substitution

A detailed explanation of the methods used to calculate savings and measure costs for each technology type can be found in Sections below.

6.2 Lower-GWP Measure Refrigerant Costs and Benefits

The RACC is a tool used to calculate refrigerant leakage emissions and avoided costs of net refrigerant leakage emissions. The RACC was used to calculate the refrigerant costs and benefits of installing a Lower-GWP measure versus an existing measure (which uses High-GWP refrigerant). The Lower-GWP RACC values were used in the Lower-GWP CET runs.

6.3 Total System Benefit Analysis

The CET is a database calculation engine. The CET was used to run analysis on both the existing measures and Lower-GWP measures of the selected measure packages. The differences between the two measure types (existing and Lower-GWP) were the energy savings, measure cost, refrigerant benefits, and refrigerant cost. For this project, the CET was only used to calculate and analyze the Total System Benefit (TSB) of each Low-GWP measure. The existing measure and Low-GWP measure TSBs are included in the following sub-sections.

6.4 GHG Savings

The GHG savings were calculated using the following equation[12] where 0.39 is the average marginal emissions factor from the ACC for 2024

Equation 1: GHG Savings for Existing and Lower-GWP Measures

$$GHG\ Savings = \frac{kWh\ Savings}{1000} \times 0.39\ \left[\frac{Tonnes\ of\ CO2}{MWh}\right]$$

6.5 Reach-In Refrigerator or Freezer

SoCalREN currently has a list of approved reach-in refrigerators and freezers for the Food Desert Energy Efficiency Equity program. All of the approved refrigerators and freezers use R600a or R290a which are already Ultra-Low-GWP. Therefore, for this measure, the Study Team found all the ENERY STAR® certified refrigerators that do not use R600a or R290A (Non-Lower-GWP refrigerators and freezers) and calculated the refrigerant costs and benefits for the Non-Lower-GWP refrigerators. The SWCR018 CET files were modified to use the refrigerant costs and benefits for the Non-Lower-GWP refrigerators and freezers, and the TSBs were compared. The purpose of this exercise was to

[12] ACC 2022 Electric Model V1b, "Emissions" sheet, SP15 average Tonnes/MWh for 2024 was 0.39.

show SoCalREN the impacts to the Food Desert Program if refrigerators are approved for use in the Food Desert Program later that do not use R600a or R290a. Table 22 shows the non-Low-GWP refrigerator or freezers mapped to specific Measure Package IDs. The manufactures were anonymized for this report.

Table 22: Non-Low-GWP and Low-GWP refrigerator and freezer measures analyzed.

Equipment Type	Name	Refrigerant	Measure ID
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 1	R-449A	SWCR018E SWCR018N
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 2	R-448A	SWCR018E SWCR018G SWCR018N
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 3; Model A	R-134A	SWCR018G SWCR018N
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 3; Model B	R-450A	SWCR018A SWCR018B SWCR018E SWCR018N
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 4	R-513A	SWCR018A
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 5	R-450A	SWCR018A SWCR018B SWCR018E SWCR018N
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 6	R-290	SWCR018B SWCR018C SWCR018D SWCR018I SWCR018J SWCR018K SWCR018N SWCR018O
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 7; Model A	R-290	SWCR018B SWCR018C SWCR018D SWCR018I SWCR018J SWCR018K SWCR018N SWCR018O
Non-Lower-GWP Refrigerator or Freezer	Manufacturer 7; Model B	R-600a	SWCR018B

6.5.1 Calculations

6.5.1.1 Energy Penalty

The SWCR018 measure package calculates energy savings according to the ENERGY STAR® requirements based on daily energy consumption equations. Because the Non-Lower-GWP refrigerators met the requirements of the existing measures package it was assumed the kWh energy savings would not change between existing and Non-Lower-GWP refrigerators.

6.5.1.2 Measure Cost

For the measure cost, it was assumed the price of the Non-Lower-GWP refrigerators and freezers would be similar, regardless of the refrigerant since the measure package currently uses Lower-GWP refrigerant as its base. Thus, no further data collection or calculations were performed for the Non-Lower-GWP measure costs.

6.5.1.3 Refrigerant Cost and Benefit

The measure package SWCR018 currently uses R600 as the base (or pre-existing) refrigerant for its RACC calculations The RACC was run for the Non-Lower-GWP refrigerators assuming the base case refrigerant was R290A. The existing RACC for SWCR018 had $0 Refrigerant Cost and $0 Refrigerant Benefit. Table 23 below shows a summary of the Refrigerant Cost and Benefit for Low-GWP and Non-Low-GWP Refrigerators and Freezers.

Table 23: Existing (Lower-GWP) and Non-Lower-GWP Refrigerator and Freezer Refrigerant Costs & Benefits

Name	Refrigerant	Refrigerant Cost	Refrigerant Benefit
Manufacturer 1	R-449A	$46.13	$0.00
Manufacturer 2	R-448A	$45.79	$0.00
Manufacturer 3; Model A	R-134A	$47.25	$0.00
Manufacturer 4	R-513A	$20.73	$0.00
Manufacturer 3; Model B **Manufacturer 5**	R-450A	$19.79	$0.00
Manufacturer 6 **Manufacturer 7; Model A**	R-290A	$0.00	$0.00
Manufacturer 7; Model B	R-600A	$0.00	$0.07

6.5.2 Analysis and Conclusions

Table 24 below shows on average, the Non-Lower-GWP measures decreased in TSB by 12.6%. Since there was no change to the savings or cost, the TSB decrease was caused by the increase in refrigerant cost for the Non-Lower-GWP measures.

If SoCalREN approves a Reach-In Refrigerator or Freezer for use in the Food Desert program that does not use R600a or R290, it will decrease the overall program TSB. **It is recommended that SoCalREN consider what refrigerant a Reach-In Refrigerator or Freezer uses and the TSB impacts of that refrigerant before approving it for use in the Food Desert program.**

Table 24: Existing and Non-Low-GWP Refrigerator and Freezer Comparison

Measure ID	Existing Measure kWh Savings	Existing GHG Savings [Tonnes CO_2]	Existing Measure Cost	Existing Refrig. Cost	Existing TSB	Non-Low-GWP Refrig. Cost	Non-Low-GWP TSB	TSB Change
SWCR018A	185.8	0.07	$41.48	$0.00	$78.43	$20.26	$66.05	-16.1%
SWCR018B	375.8	0.15	$298.70	$0.00	$158.66	$19.79	$146.35	-8.0%
SWCR018E	316.9	0.12	$224.72	$0.00	$133.78	$37.24	$111.07	-17.4%
SWCR018G	363.8	0.14	$334.89	$0.00	$153.58	$32.79	$133.47	-13.4%
SWCR018N	612.4	0.24	$456.52	$0.00	$258.56	$35.75	$236.39	-8.8%
Average	**422.1**	**0.16**	**$308.32**	**$0.00**	**$178.21**	**$32.03**	**$158.50**	**-12.6%**

6.6 Electric Heat Pump Water Heaters (EHPWHs)

EHPWHs were selected for further analysis in the Multifamily program and the Public programs (SSP and MSP). As shown in Table 25, the three (3) measure packages for HPWHs are:

- SWWH025 Heat Pump Water Heater, Residential, Fuel Substitution
- SWWH027 Heat Pump Water Heater, Commercial, Fuel Substitution
- SWWH028 Large Heat Pump Water Heater, Commercial and Multifamily, Fuel Substitution

In Table 25 below, specific EHPWHs were mapped to specific measure IDs based on the building type and size of the water heater.

Table 25: EHPWHs mapped to Measure IDs

Name	Refrigerant	Size	Measure ID
Manufacturer 8; Model A	CO_2	43 gal	SWWH025AE SWWH027Z SWWH027AB
Manufacturer 8; Model B	CO_2	83 gal	SWWH025W SWWH027X SWWH028K
Manufacturer 8; Model C	CO_2	119 gal	SWWH028J SWWH028L SWWH028M SWWH028N
Manufacturer 9; Model A	CO_2	250 gal	SWWH028I SWWH028L SWWH028M SWWH028N
Manufacturer 9; Model B	CO_2	250 gal	SWWH028I SWWH028L SWWH028M SWWH028N
Manufacturer 10	CO_2	175 gal	SWWH028I SWWH028L SWWH028M SWWH028N
Manufacturer 11	R-513A	504 gal	SWWH028J SWWH028L SWWH028M SWWH028N

6.6.1 Calculations

6.6.1.1 Energy Penalty

EHPWHs have a kWh penalty because they substitute electricity for natural gas. In the CET, this electric penalty is combined with the natural gas savings to come up with an equivalent kWh reduction. In this study, the Study Team calculated the kWh penalty for the Lower-GWP EHPWHs. It was assumed that the natural gas savings would remain the same because the Lower-GWP EHPWHs are replacing the same natural gas-fired water heaters. Note that a Lower-GWP EHPWH kWh penalty that is less than an existing EHPWH kWh penalty means the Lower-GWP EHPWH saves more energy overall.

For example, under SWWH028I for a Multifamily building in Climate Zone 06, Manufacturer 10 has an existing EHPWH penalty of 708 kWh and a Lower-GWP measure penalty of 698.2 kWh, meaning the Lower-GWP EHPWH saves more energy overall.

The EHPWH savings were calculated using two methods. The first method was the DEER Water Heater Calculator (DWHC) (56) and the second method was an adjustment factor for modeled DHW energy use.

6.6.1.1.1 Deer Water Heater Calculator (DWHC)

The DWHC uses the following inputs to determine energy use of water heaters:

- Hourly hot water loads
- Ambient weather conditions
- Assumed heat losses
- DHW temperature set point
- DHW efficiency

The DWHC is used for SWWH025, SWWH027 and for the commercial building types in SWWH028. The multifamily building types in SWWH028 use modeled energy savings, which are explained in detail in Section 6.6.1.1.2 below. The Study Team added Lower-GWP EHPWHs to the DWHC to calculate the kWh use for each Lower-GWP EHPWH in the selected climate zones and commercial building types. The kWh energy use for the Lower-GWP EHPWH was different from the existing measure package because the efficiency, measured by coefficient of performance (COP), capacity, and storage tank size of the Lower-GWP EHPWHs was different than the EHPWHs already in the DHWC.

To calculate the kWh penalty, the DWHC calculates kWh usage for both the base case and measure case. Then, it subtracts the base case kWh usage from the measure case kWh usage to determine the kWh penalty (or savings). Since the Lower-GWP measures were already mapped to existing measure package offering IDs as seen in Table 25 above, the DWHC was used to determine the corresponding base case measures in order to calculate the final Lower-GWP EHPWH savings. For example, Manufacturer 10 is mapped to SWWH028I, SWWH028L, SWWH028M, and SWWH028N, which has the following technology IDs that can be mapped to both the DWHC and the measure package permutations in Table 26.

Table 26: Manufacturer 10 Mapping for DWHC Base Case and Measure Calculations

Measure ID and Offering ID	Base Case Technology ID	Existing Measure Technology ID	Lower-GWP Measure Technology ID	Building Type
SWWH028I	Boiler-Et-Central-Gas-gt150kBtuh-0.84Et	HP-COP-Central-3.00COP	LargeElecHPWH-Com-Man10-175gal-4.11COP	MFm
SWWH028L	Stor_TE-Gas-gt75kBtuh-0.80Et	Stor_COP-ElecHP-120gal-4.3COP	LargeElecHPWH-Com-Man10-175gal-4.11COP	Asm, ESe. OfS
SWWH028M	Inst_TE-Gas-lt200kBtuh-0.80Et	Stor_COP-ElecHP-120gal-4.3COP	LargeElecHPWH-Com-Man10-175gal-4.11COP	Asm, ESe. OfS
SWWH028N	Inst_TE-Gas-gte200kBtuh-0.80Et	Stor_COP-ElecHP-120gal-4.3COP	LargeElecHPWH-Com-Man10-175gal-4.11COP	Asm, ESe. OfS

Each base case technology ID was inputted into the DWHC and used to calculate the mapped Lower-GWP kWh savings.

6.6.1.1.2 Adjusted DHW Models

The multifamily building type in SWWH028 uses Energy Plus models to calculate energy savings instead of the DHWC. The Study Team expected the kWh penalty would change for the Lower-GWP EHPWHs in multifamily buildings, but the Study Team did not have access to the raw models used in SWWH028 because they were not available in the measure characterization in eTRM nor were they available on CEDARS. Therefore, the Study Team calculated a ratio of existing EHPWH to Lower-GWP EHPWH using the DWHC and applied it to the SWWH028 multifamily permutations. The ratio was calculated by averaging the known kWh ratios of all SWWH028 commercial permutations for each Lower-GWP EHPWH measure. This ratio was then applied to the existing multifamily permutations to calculate the Lower-GWP multifamily permutation, as seen in Equation 2.

Equation 2: Lower-GWP multifamily permutations kWh savings

$$Lower - GWP\ MFm\ kWh\ Savings = Average\ Savings\ Ratio \times Existing\ MFm\ kWh\ Savings$$

6.6.1.2 Measure Costs

Measure costs of the Lower-GWP EHPWHs were calculated using a combination of available manufacturer quotes and calculators, existing project data from the programs analyzed previously in Sectio, and averaging the equipment cost per kBtuh for the remaining Low-GWP measures. Manufacturer 8 has a sizing and cost calculator available for customers, but the team decided to use the program data previously analyzed in Section 4[13] since it included labor cost as well.

[13] Multifamily program data included installed costs for four (4) projects that installed CO_2 EHPWHs

Manufacturers 10 and 11 had manufacturer quotes that were used. Since there was no available cost data for Manufacturer 9, the average of all other manufacturers cost per kBtuh was used and applied to Manufacturer 9.

6.6.1.3 Refrigerant Cost and Benefit

The RACC was run for the Lower-GWP EHPWHs assuming the base case equipment uses natural gas. The RACC does not list any recommended refrigerant types for natural gas water heaters, however running the RACC with an R-134A or R-410A refrigerant base case does not affect the refrigerant cost and benefit results seen below in Table 27.

Table 27: Low-GWP HPWH RACC results per unit

Measure Name	Measure Description	Refrigerant Cost	Refrigerant Benefit
Manufacturer 8; Model A	CO_2 MFm EHPWH	$0.15	$0.00
Manufacturer 8; Model B	CO_2 MFm EHPWH	$0.15	$0.00
Manufacturer 8; Model A	CO_2 MFm EHPWH	$0.21	$0.00
Manufacturer 8; Model B	CO_2 MFm EHPWH	$0.21	$0.00
Manufacturer 9; Model A	CO_2 MFm EHPWH	$0.21	$0.00
Manufacturer 9; Model B	CO_2 MFm EHPWH	$0.21	$0.00
Manufacturer 10	CO_2 MFm EHPWH	$0.21	$0.00
Manufacturer 8; Model C	CO_2 MFm/Com Large EHPWH	$0.01	$0.00
Manufacturer 9; Model A	CO_2 MFm/Com Large EHPWH	$0.01	$0.00
Manufacturer 9; Model B	CO_2 MFm/Com Large EHPWH	$0.01	$0.00
Manufacturer 10	CO_2 MFm/Com Large EHPWH	$0.01	$0.00
Manufacturer 11	R-513A MFm/Com Large EHPWH	$7.84	$0.00

6.6.1.4 TSB

To determine TSB impacts, the CET for each measure was revised with the Lower-GWP kWh penalty, Refrigerant Cost, and Refrigerant Benefit.

6.6.2 Analysis and Conclusions

Table 28 shows the average kWh/GHG, refrigerant costs and measure costs for the existing and Lower-GWP EHPWHs. Table 29 show a summary of the kWh/GHG, refrigerant cost, measure cost, and TSB changes from the existing EHPWH to the Lower-GWP EHPWHs. In Table 28, a negative value for "kWh/GHG Change" means the kWh penalty decreased so it saves more energy.

Table 28: Lower-GWP EHPWH Results

Measure Offering ID	Measure Description	Avg Existing kWh Savings	Avg Existing GHG Savings [Tonnes CO2]	Avg Existing Total Cost	Average of Existing Refrigerant Cost	Average of Existing TSB	Average of Low-GWP Measure kWh Savings	Avg Low-GWP GHG Savings [Tonnes CO2]	Average of Low-GWP Measure Total Cost	Avg Low-GWP Refrigerant Costs	Average Low-GWP TSB
SWWH025AE	CO_2 MFm EHPWH	(980.5)	(0.4)	$3,960.33	$210.79	$1,271.43	(788.2)	(0.3)	$6,750.00	$0.15	$1,640.69
SWWH025W	CO_2 MFm EHPWH	(1,173.8)	(0.5)	$2,416.67	$210.79	$869.10	(803.5)	(0.3)	$6,750.00	$0.15	$1,385.20
SWWH027AB	CO_2 Com EHPWH	(9,454.2)	(3.7)	$2,555.28	$289.83	$3,697.94	(6,438.6)	(2.5)	$6,750.00	$0.21	$6,030.30
SWWH027X	CO_2 Com EHPWH	(11,516.7)	(4.5)	$4,034.35	$289.83	$9,872.66	(10,055.5)	(3.9)	$6,750.00	$0.21	$11,152.32
SWWH027Z	CO_2 Com EHPWH	(9,477.9)	(3.7)	$2,555.28	$289.83	$5,442.34	(6,438.6)	(2.5)	$6,750.00	$0.21	$7,790.80
SWWH028I	CO_2 MFm EHPWH	(676.8)	(0.3)	$184.35	$16.93	$168.21	(702.3)	(0.3)	$1,075.92	$0.01	$205.57
SWWH028J	CO_2 MFm EHPWH	(682.9)	(0.3)	$184.35	$16.93	$63.90	(670.7)	(0.3)	$1,242.42	$0.01	$126.80
SWWH028J	R-513A MFm EHPWH	(682.9)	(0.3)	$184.35	$16.93	$63.90	(839.0)	(0.3)	$728.26	$7.84	-$19.90
SWWH028K	CO_2 Com EHPWH	(220.9)	(0.1)	$158.05	$16.93	$68.58	(144.7)	(0.1)	$1,242.42	$0.01	$145.02
SWWH028L	CO_2 Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$120.96	(147.5)	(0.1)	$1,117.55	$0.01	$143.11
SWWH028L	R-513A Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$120.96	(176.9)	(0.1)	$728.26	$7.84	$115.38
SWWH028M	CO_2 Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$119.78	(147.5)	(0.1)	$1,117.55	$0.01	$141.90
SWWH028M	R-513A Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$119.78	(176.9)	(0.1)	$728.26	$7.84	$114.17
SWWH028N	CO2 Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$118.29	(147.5)	(0.1)	$1,117.55	$0.01	$140.35
SWWH028N	R-513A Com EHPWH	(143.6)	(0.1)	$185.90	$16.93	$118.29	(176.9)	(0.1)	$728.26	$7.84	$112.62
Grand Total		**(1,625.3)**	**(0.6)**	$680.83	$61.36	$1,021.92	**(1,271.0)**	**(0.5)**	$2,030.65	$1.27	$1,331.81

Table 29: Lower-GWP EHPWH Summary

Measure ID	Measure Description	kWh/GHG Change	Refrigerant Cost Change	Measure Cost Change	TSB Change
SWWH025AE	CO_2 MFm EHPWH	-19.6%	-99.9%	70.4%	29.2%
SWWH025W	CO_2 MFm EHPWH	-31.5%	-99.9%	179.3%	59.8%
SWWH027AB	CO_2 MFm EHPWH	-31.8%	-99.9%	164.2%	64.9%
SWWH027X	CO_2 MFm EHPWH	-12.8%	-99.9%	67.3%	13.3%
SWWH027Z	CO_2 MFm EHPWH	-32.0%	-99.9%	164.2%	43.5%
SWWH028I	CO_2 MFm EHPWH	3.8%	-99.9%	483.6%	23.6%
SWWH028J	CO_2 MFm EHPWH	-1.8%	-99.9%	573.9%	133.3%
SWWH028J	R-513A MFm EHPWH	22.9%	-53.7%	295.0%	-181.4%
SWWH028K	CO_2 Com EHPWH	-34.7%	-99.9%	686.1%	118.1%
SWWH028L	CO_2 Com EHPWH	2.4%	-99.9%	501.2%	20.4%
SWWH028L	R-513A Com EHPWH	22.9%	-53.7%	291.7%	-3.5%
SWWH028M	CO_2 Com EHPWH	2.4%	-99.9%	501.2%	20.7%
SWWH028M	R-513A Com EHPWH	22.9%	-53.7%	291.7%	-3.5%
SWWH028N	CO_2 Com EHPWH	2.4%	-99.9%	501.2%	21.0%
SWWH028N	R-513A Com EHPWH	22.9%	-53.7%	291.7%	-3.6%
Average		**-1.0%**	**-92.7%**	**413.8%**	**24.1%**

On average, Lower-GWP EHPWHs have a 1.0% decrease in kWh penalty (which is an increase in overall energy savings). However, this is very dependent upon the specific manufacturer. The range of kWh/GHG savings is from -34.7% (an overall kWh savings) to 22.9% (a higher kWh penalty). The average decrease in Refrigerant Cost is 92.7% but this is also dependent upon the specific manufacturer. The CO_2 EHPWHs have a 99.9% decrease in refrigerant cost and the R-513a EHPWHs have a decrease of 53.7%. The average TSB increased by 24.1% due to the decrease in kWh penalty and decrease in Refrigerant Cost. However, the TSB is lower for the EHPWHs that use R-513a because they use more electricity than the existing EHPWHs (i.e. they have a higher kWh penalty). The average measure cost for Lower-GWP EHPWHs increased by a whopping 418%.

The measure cost for Lower-GWP EHPWHs may be prohibitively expensive for some customers. However, the Multifamily program has seen installations of EHPWHs with CO_2 in 2023, which shows it is possible to persuade customers to use Lower-GWP EHPWHs with the right incentives**. It is recommended that SoCalREN consider increased incentives for Lower-GWP EHPWHs based on the increased Refrigerant Benefits in the short-term.**

In the long term, it is recommended that SoCalREN revise, or influence other Program Administrators to revise, SWWH025, SWWH027 and SWWH028 with Lower-GWP EHPWHs to take full advantage of the increased TSBs due to the lower kWh penalties. Additionally, none of the commercial building type Lower-GWP measures (under SWWH028) meet the efficiency requirements of the existing measure packages. This presents a gap in the existing Measure Package offerings and missed opportunities for programs to implement available Lower-GWP

equipment. For example, Manufacturer 10 has a rated COP of 4.11 and is mapped to SWWH028L by size. However, the measure package requirements state a rated COP of 4.30 for all commercial building types.

6.7 Packaged Heat Pump Air-Conditioning Units

Packaged heat pump air-conditioning (HP AC) units were selected for further study in the Public programs. During initial scanning and screening of Lower-GWP solutions, specification sheets could only be found online for a single HVAC manufacturer and only for units available in Europe. After a conversation with one of SoCalREN's implementers, specification sheets for two (2) other manufacturers' Lower-GWP HVAC units were sent over. These units were mapped to specific measure package IDS shown in Table 30 below.

Table 30: Lower-GWP HP AC Units Mapped to Measure IDs

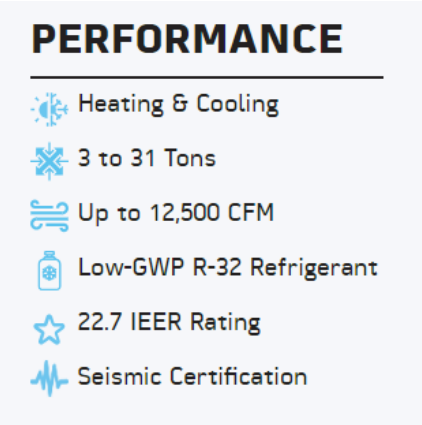
Name	Refrigerant	Measure ID
Manufacturer 12 Model A	R-454B	SWHC013N
Manufacturer 12; Model B	R-454B	SWHC013P
Manufacturer 12; Model C	R-454B	SWHC013Q
Manufacturer 12; Model D	R-454B	SWHC013R
Manufacturer 12; Model E	R-454B	SWHC013S
Manufacturer 13; Model A	R-454B	SWHC013S SWHC046L
Manufacturer 13; Model B	R-454B	SWHC046L
Manufacturer 13; Model C	R-454B	SWHC013S SWHC046L
Manufacturer 13; Model D	R-454B	SWHC046L
Manufacturer 13; Model E	R-454B	SWHC013S SWHC046L
Manufacturer 14	R-32	TBD

Manufacturer 12 was found to be available for the European market. Because of this, the specification sheets used were converted from EU values to US values.

Initial scanning and screening in Section 4 only garnered one (1) market-available Lower-GWP AC HP (Manufacturer 12). Later in the project, information on two (2) additional Lower-GWP AC HPs were given to the Study Team a SoCalREN implementer and mapped to existing Measure IDs. The first technology (Manufacturer 14) did not provide efficiency or capacity values for specific units but provided an overview for a class of units that will be offered by Manufacturer 14 charged with R-32. From the brochure, it appears these units will meet the existing measure package IDs, however,

because of the lack of size and efficiency data, the Manufacturer 14 units were not mapped to any measure IDs.

Figure 14: Class Performance Data for Manufacturer 14 R-32 units (57).



The other technology, Manufacturer 13, was mapped to the existing SWHC013 measure IDs as well as SWHC046, which is a fuel substitution version of SWHC013.

Note SWHC014 was not considered because the team did not find any available Lower-GWP equipment that met the size requirement (less than 65 kBtuh).

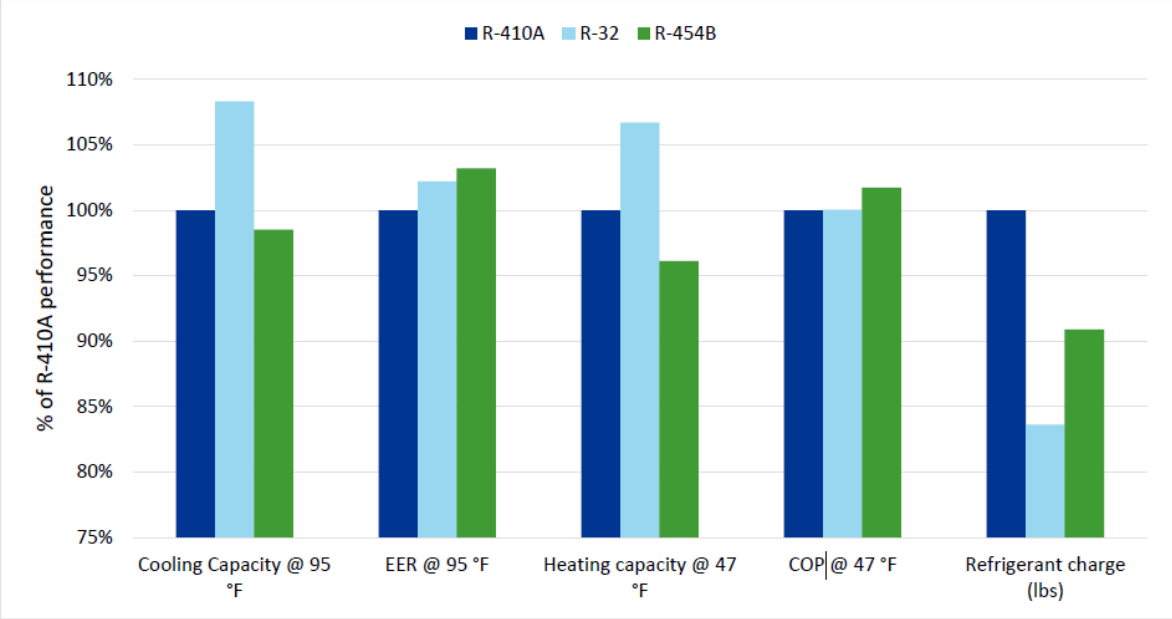
6.7.1 Calculations

6.7.1.1 Energy Savings

The existing packaged HP AC unit savings in measure packages SWHC013 and SWHC046 were calculated using Energy Plus modelling. Since the Lower-GWP measures meet the efficiency requirements of the existing measure IDs, it was assumed that the Lower-GWP measures have the same energy savings as the existing measures and no additional energy savings calculations were performed.

Although the Team did not calculate changes to kWh savings for the Lower-GWP HP AC units, it is worth noting here that there will probably be changes to kWh consumption in the Lower-GWP equipment. The refrigerant properties of A2Ls are different than R134a and R410a which will probably change the HVAC unit efficiency curves, part load curves, and capacity curves which are key inputs in HVAC modeling. Figure 16 below shows comparisons of refrigerant properties for R410a, R-32 and R-454b from the CPUC Study "*Forward-Looking Low-Global Warming Potential Refrigerant Transition Study*" (46).

Figure 15: Drop-in Performance Modeling of R-32 and R-454b (46)



The efficiency curves, part load curves and capacity curves are not publicly available data and must be provided by individual manufacturers. The scope of this study did not include gathering this data from manufacturers since that is a time-consuming process. However, if existing measure packages are updated with Lower-GWP units, it is recommended that this data be collected so the modelling can be revised with Lower-GWP refrigerants. **SoCalREN can commission a project like this or coordinate with the applicable Program Administrators to do so.**

6.7.1.2 Refrigerant Cost and Benefit

The RACC was run for the Lower-GWP HP AC units assuming the base measure was charged with R-410A. The existing SWHC013 does not include Refrigerant Cost and Benefit data. However, the SWHC046 measure package has an average Refrigerant Cost of $50.09 and an average Refrigerant Benefit of $0 for NR projects. See Table 31 for details.

Table 31: Lower-GWP HP AC RACC results per unit

Name	Refrigerant	Capacity	Refrigerant Cost	Refrigerant Benefit
Manufacturer 12 Model A	R-454B	< 135 kBtuh	$0.00	$459.19
Manufacturer 12; Model B	R-454B	>= 135 kBtuh	$0.00	$453.88
Manufacturer 12; Model C	R-454B	>= 135 kBtuh	$0.00	$453.88
Manufacturer 12; Model D	R-454B	>= 135 kBtuh	$0.00	$453.88
Manufacturer 12; Model E	R-454B	>= 135 kBtuh	$0.00	$453.88
Manufacturer 13	R-454B	>= 135 kBtuh	$0.00	$410.04
Manufacturer 14; Model A	R-32	< 135 kBtuh	$0.00	$400.00
Manufacturer 14; Model B	R-32	>= 135 kBtuh	$0.00	$395.38

6.7.1.3 Measure Cost and TSB

Because there was no cost data available, the Lower-GWP HP AC measure was assumed to be 20% more than the cost of the existing measure based on CalNEXT study "*Market Characterization of Ultra-Low GWP Space Conditioning Heat Pumps for Commercial Buildings Final Report*" (58). This estimate was applied to both the material and labor cost values in the existing measure package. As seen in Table # below, the total measure cost is the Incremental Measure Cost (IMC) because the measure application type (MAT) available for SWHC013 is Normal Replacement (NR). To be consistent, SWHC046 was also analyzed using IMC for NR measure cost.

6.7.2 Analysis and Conclusions

Table 32 shows the summary of kWh, incremental measure costs (IMC), refrigerant benefits, and TSBs for the existing and Lower-GWP HP AC Measures mapped to SWHC013. The existing measures in SWHC013 do not have refrigerant costs or benefits because the measure case HP AC units use the same refrigerant as the baseline HP AC units. The Lower-GWP HP AC units do have refrigerant benefits which has a profound impact on the TSB. For example, the units mapped to SWHC013N increased the average Refrigerant Benefit from $0 to $459.19 which increased the TSB from an average of $19.71 to $249.31. The overall average increase in TSB for Lower-GWP HPAC measures mapped to SWHC013 was 996%.

Table 33 shows the summary of kWh, IMC, refrigerant benefits, and TSBs for the existing and Lower-GAP HP AC measures mapped to SWHC046L. This is a fuel substitution measure, so the overall kWh savings is negative because it is really a kWh penalty. The refrigerant benefits are also $0 in this measure package because it assumes the new HP AC units use R-134a which is the baseline refrigerant in the RACC. The combination of $0 refrigerant benefit and negative kWh savings means some TSBs for specific building types and climate zones are negative. However, the overall average existing TSB is $153.59. The addition of the refrigerant benefits from the Lower-GWP measures increases the average TSB to $607.48 with is 296% increase.

The incremental measure costs (IMCs) for Lower-GWP HP AC measures are increased by 265% for those mapped to SWHC013 and 145% for those mapped to SWHC046.

Table 32: SWHC013 Lower-GWP HP AC unit data summary

Measure ID	kWh Savings	Average Existing IMC	Average Lower-GWP IMC	Existing Refrigerant Benefit	Lower-GWP Refrigerant Benefit	Avg Existing TSB	Avg Lower-GWP TSB	IMC Change	TSB Change
SWHC013N	36.3	$83.69	$434.03	$0.00	$459.19	$19.71	$249.31	419%	1,290%
SWHC013P	38.4	$90.95	$410.34	$0.00	$453.88	$20.69	$247.64	351%	1,217%
SWHC013Q	66.6	$122.38	$448.06	$0.00	$453.88	$36.12	$263.06	266%	696%
SWHC013R	36.2	$108.30	$378.32	$0.00	$453.88	$19.81	$246.75	249%	1,419%
SWHC013S	61.7	$131.88	$406.61	$0.00	$453.88	$33.75	$260.69	208%	836%
Average	**53.03**	**$116.61**	**$412.15**	**$0.00**	**$454.55**	**$28.92**	**$256.19**	**265%**	**996%**

Table 33: SWHC046 Lower-GWP HP AC Unit Data Summary

Measure ID	kWh Savings	Average Existing IMC	Average Lower-GWP IMC	Existing Refrigerant Benefit	Lower-GWP Refrigerant Benefit	Avg Existing TSB	Avg Lower-GWP TSB	IMC Change	TSB Change
SWHC046L	(166.39)	$193.47	$473.80	$ -	$403.80	$153.59	$607.48	145%	296%

In conclusion, the TSB increases for Lower-GWP HP AC units because the Refrigerant Benefits increase. Due to the current market availability, the cost of installing Lower-GWP HPAC equipment is expensive compared to existing HP AC equipment. However, with the impending regulations restricting High-GWP equipment installations starting in 2025, it is expected that costs for Lower-GWP equipment would decrease to stay competitive as more manufacturers start to produce Lower-GWP equipment.

It is recommended that SoCalREN consider increased incentives for Lower-GWP HP ACs based on the increased Refrigerant Benefits in the short-term.

In the long term, it is recommended that SoCalREN revise, or influence other Program Administrators to revise, SWWHC013 and SWHC046 with updated performance curves for units that use R454b and R-32. Performance data needs to be gathered from manufacturers, SoCalREN could commission or support a study to do this in order to update the aforementioned measure packages.

7. Conclusions & Recommendations

The following conclusions were made over the course of this study and recommendations are provided to SoCalREN.

7.1 Codes & Standards Recommendations

7.1.1 Summary

EPA first began regulating High-GWP refrigerants with SNAP Rule 20 in 2015 and the United States signed the Kigali Amendment in 2016. However, a court case in 2017 limited the EPA's ability to regulate refrigerant GWP. California had been relying on the EPA's rules to meet its own GWP reduction targets. Since the EPA's hands were tied , in 2018, California adopted a new **California Air Resources Board (CARB) HFC Regulation** (21) and passed **Senate Bill 1013 (SB1013)** (22) also known as the **California Cooling Act**. The HFC Regulation and SB1013 together are known as the **California Significant New Alternatives Program (CA SNAP)**. The CARB HFC regulation limits refrigerant GWP categorized by end-use, and its timelines are consistent with **the California Mechanical Code (CMC)**. Updates to the CARB HFC regulation were made in 2020. Concurrently, congress passed **American Innovation and Manufacturing (AIM) Act** in 2020 which gave the EPA authority to regulate refrigerant GWP. The EPA published a proposed rule in early 2023 with GWP limits and timelines by end-use. This final rule was adopted in late 2023. The **CARB HFC regulation** and the **EPA AIM Act "Final rule"** are not aligned in terms of GWP limits, timelines for compliance, and end-use definitions. In an email, CARB stated that there is no plan to align the CARB HFC with the EPA's AIM Act final rule. However, CARB noted that there is a report due by January 1, 2025 to the California senate to transition California to Ultra-Low-GWP which may align these two.

In the United States, state mechanical codes and state fire codes are usually adopted from a professional code-setting body. California adopted the 2021 **Uniform Mechanical Code (UMC)** as

its **California Mechanical Code (CMC)** and the 2021 **International Fire Code (IFC)** as its **California Fire Code (CFC)**. From there, it is the responsibility of the **Authority Having Jurisdiction (AHJ)** to enforce the mechanical and fire codes. There is an **AHJ** for each California county. Some cities within various counties have their own **AHJ**. The City of Los Angeles, for example, has its own **AHJ** even though Los Angeles County has an **AHJ**. In general, the local **AHJ**s enforce the **CMC** and the **CFC**. The **CMC** does not allow Lower-GWP refrigerants in **High-Probability Systems** because there is a chance leaking refrigerant can enter occupied spaces in these types of systems. Most, but not all, Lower-GWP refrigerants are classified as **A2L – slightly flammable**, or **A3 – highly flammable**. Most HVAC systems are **High-Probability** so, essentially, the **CMC** does not allow Lower-GWP refrigerants in most buildings. However, California senate bill AB209 circumvented the **CMC**. This bill states that an AHJ cannot prevent a refrigerant from being installed if it has been approved by the EPA. The EPA has approved many Lower-GWP refrigerants which means an **AHJ** is expected to allow Lower-GWP refrigerants because of the EPA approval even though the **CMC** does not permit them. This will create confusion in the market regarding which law or standard takes precedence and which interpretation is correct.

7.1.2 Recommendations

The Study Team recommends that SoCalREN train its implementers and contractors via webinars and fact sheets on the following aspects of Lower-GWP codes and standards

- EPA and CARB definitions of end-use
- EPA and CARB GWP limits
- EPA and CARB compliance dates
- CMC overview
- Allowable Lower-GWP refrigerants as per CMC
- AB209
- Allowable Lower-GWP refrigerants as per AB209

The Study Team also recommends SoCalREN begin a database to log any code compliance issues that arise in 2025 when Lower-GWP equipment is installed. This can be used to refine Lower-GWP training.

Lastly, the Study Team recommends that SoCalREN monitor developments with the 2025 CMC updates to determine if proposed changes will allow Lower-GWP refrigerants in High Probability Systems.

7.2 Low-GWP Market Recommendations

7.2.1 Summary

The Study Team scanned and screened for Lower-GWP technologies and interviewed five (5) SMEs about their knowledge of Lower-GWP refrigerants and equipment. The SME interviews showed the following things:

- Lower-GWP HVAC equipment may not be available for purchase until the second half of 2025 even though the EPA limits go into effect on January 1, 2025. Manufacturers may be planning to sell equipment with incumbent refrigerant into the end of 2025.
- Training on Lower-GWP refrigerants and equipment is still needed and was consistent with the findings from the CPUC Forward Looking Low-GWP study (46)
- Manufacturers and distributors could do a better job of assuring contractors about the quality and safety of Lower-GWP refrigerant which could be addressed during training on Lower-GWP refrigerants.
- Contractors do not directly interact with refrigerant reclaimers so gathering a bill of lading from the refrigerant reclaimer to prove R410a or R134a were properly disposed of could prove to be challenging.
- Some contractors see the possibility of making a value-proposition to their clients using Lower-GWP refrigerants. SoCalREN could incorporate sample calculations of GHG savings with Lower-GWP refrigerants in their trainings to help contractors make this proposition.

The Study Team provided a list of fourteen (14) Lower-GWP solutions and mapped them to existing measure packages where possible. All but two (2) of the Lower-GWP solutions map to at least one (1) measure package. These measure packages could be updated with Lower-GWP permutations, or new measure packages could be created.

During the scanning and screening process, the Study Team had difficulty finding specification sheets for HVAC equipment with Lower-GWP refrigerants. In some cases, the Study Team could find information about a new equipment line that would be using Lower-GWP refrigerant, but there was no publicly available information with specific capacities and efficiencies. This supported the SME interview finding that Lower-GWP HVAC equipment may not be available until the latter half of 2025.

7.2.2 Recommendations

The Study Team makes the following recommendations to SoCalREN regarding the Lower-GWP equipment market.

- Encourage participating contractors to seek Lower-GWP refrigerant training from equipment distributors or refrigerant suppliers.
- Provide contractors with tools to sell Lower-GWP equipment including the calculation of GHG benefits from Lower-GWP water heaters.
- Engage with the CPUC on tracking proper disposal of incumbent refrigerants. The CPUC provided some recommendations in its Forward Looking Low-GWP study (46), but gathering a bill of lading for the existing refrigerant may not be feasible.

7.3 Specific Lower-GWP Measures

The Study Team used a combination of SoCalREN's historical program data and CEDARS data to refine a list of the most actionable Lower-GWP technologies. The program data revealed that commercial refrigerators and freezers, domestic hot water heaters, and commercial AC units are among the top measures installed. The Study Team discussed the results of this analysis with

SoCalREN and SoCalREN implementer representatives and came up with the following list of Lower-GWP measures for which a deeper analysis was completed:

- Multifamily EHPWH – CO_2
- Multifamily EHPWH Lower-GWP
- Commercial EHPWH Lower-GWP
- Commercial Packaged HVAC Unit Lower-GWP
- Reach-In Refrigerator or Freezer

Each measure was mapped to existing measure packages. Then, the Study Team calculated kWh savings, GHG savings, refrigerant costs and benefits, and TSBs for each of the Lower-GWP measures and compared them to the existing measures from the measure packages.

7.3.1 Reach-In Refrigerators and Freezers

7.3.1.1 Summary

SoCalREN is launching a Food Desert program and all of the approved refrigerators and freezers in this program already use Lower-GWP equipment. So, the Study Team compared TSBs for Non-Lower-GWP refrigerators and freezers on ENERGY STAR to the existing Lower-GWP refrigerators and freezers. The analysis revealed that the TSB decreased for Non-Lower-GWP measures by an average of 12.6%. This is due to the increase in refrigerant costs for Non-Lower-GWP refrigerant.

7.3.1.2 Recommendations

The Study Team recommends that SoCalREN consider what refrigerant a reach-in refrigerator or freezer uses and the TSB impact before approving it for use in the Food Desert program.

7.3.2 Lower-GWP EHPWHs

7.3.2.1 Summary

The Lower-GWP EHPWHs were mapped to three (3) fuel substitution measure packages for commercial and multifamily building types. The Study Team calculated alternate kWh savings, GHG savings, and refrigerant costs for each technology and recalculated the TSBs. On average, the EHPWHs have a lower kWh penalty (meaning they save more energy), have lower refrigerant costs, and higher TSBs. However, this is dependent upon the manufacturer. The R-513a EHPWH uses more kWh and has a lower TSB than the existing EHPWHs.

The analysis results suggest that measure cost of Lower-GWP EHPWHs may be prohibitively expensive for some customers, but the SoCalREN Multifamily program has seen installation of CO_2 EHPWHs in 2023, which shows it is possible to persuade customers with the right incentives.

7.3.2.2 Recommendations

The Study Team recommends that SoCalREN consider increased incentives for Lower-GWP EHPWHs based on increased refrigerant benefit in the short term. In the long-term, The Study Team recommends that SoCalREN revise or influence revisions of measure packages SWWH025, SWWH027 and SWWH028 which include Lower-GWP EHPWHs to take full advantage of the kWh benefits from the Lower-GWP equipment. Measure package updates for SWWH028 should also

consider efficiency ratings of existing Lower-GWP EHPWHs. There is at least one Lower-GWP EHPWH manufacturer that does not meet the efficiency requirements of the existing measure package.

7.3.3 Lower-GWP HP AC Units

7.3.3.1 Summary

The Lower-GWP HP AC units were mapped to two (2) measure packages (one non-fuel substitution and one fuel substitution) in commercial buildings. The kWh and GHG savings did not change for the Lower-GWP units because the efficiency values of the Lower-GWP units fell within existing measure package permutations. However, the refrigerant benefits for the Lower-GWP units increased significantly. Due to the high increase in refrigerant benefit for Lower-GWP measures, the average TSB increased by 996% for SWHC013 and by 296% for SWHC046. Note that refrigerant benefits for both measure packages are $0 so a percentage increase in refrigerant benefits cannot be calculated because of the zero divisor. The cost cost of installing Lower-GWP equipment was estimated to be 20% more based on a recent CalNEXT study (55). However, the impending refrigerant GWP restrictions starting in 2025 are expected to reduce costs for Lower-GWP equipment as more manufacturers produce Lower-GWP equipment.

7.3.3.2 Recommendations

The Study Team recommends that SoCalREN consider increased incentives for Lower-GWP HP ACs based on the increased refrigerant benefits in the short-term. In the long term, the Study Team recommends that SoCalREN revise, or influence other Program Administrators to revise, SWWHC013 and SWHC046 with updated performance curves for units that use R454b and R-32. Performance data needs to be gathered from manufacturers, and SoCalREN could commission or support a study to gather this information in order to update the aforementioned measure packages.

8. Appendix I – State Codes & Standards

8.1 CMC Table 1102.3

Table 8.1: CMC Table 1102.3

REFRIGERANT	CHEMICAL FORMULA	CHEMICAL NAME1 (COMPOSITION FOR BLENDS)	SAFETY GROUP	OEL2 (ppm)	POUNDS PER 1000 CUBIC FEET OF SPACE
R-11	CCl3F	Trichlorofluoromethane	A1	C1000	0.39
R-12	CCl2F2	Dichlorodifluoromethane	A1	1000	5.6
R-12B1	CBrClF2	Bromochlorodifluoromethane	—	—	—
R-13	CClF3	Chlorotrifluoromethane	A1	1000	—
R-13B1	CBrF3	Bromotrifluoromethane	A1	1000	—
R-14	CF4	Tetrafluoromethane (carbon tetrafluoride)	A1	1000	25
R-21	CHCl2F	Dichlorofluoromethane	B1	—	—
R-22	CHClF2	Chlorodifluoromethane	A1	1000	13
R-23	CHF3	Trifluoromethane	A1	1000	7.3
R-30	CH2Cl2	Dichloromethane (methylene chloride)	B1	—	—
R-31	CH2ClF	Chlorofluoromethane	—	—	—
R-32	CH2F2	Difluoromethane (methylene fluoride)	A2L	1000	4.8
R-40	CH3Cl	Chloromethane (methyl chloride)	B2	—	—
R-41	CH3F	Fluoromethane (methyl fluoride)	—	—	—
R-50	CH4	Methane	A3	1000	—
R-113	CCl2FCClF2	1, 1, 2-trichloro-1, 2, 2 — trifluoroethane	A1	1000	1.2
R-114	CClF2CClF2	1, 2-dichloro-1, 1, 2, 2 tetrafluoroethane	A1	1000	8.7

R-115	CClF2CF3	Chloropentafluoroethane	A1	1000	47
R-116	CF3CF3	Hexafluoroethane	A1	1000	34
R-123	CHCl2CF3	2, 2-dichloro-1, 1, 1, - trifluoroethane	B1	50	3.5
R-124	CHClFCF3	2-chloro-1, 1, 1, 2 - tetrafluoroethane	A1	1000	3.5
R-125	CHF2CF3	Pentafluoroethane	A1	1000	23
R-134a	CH2FCF3	1, 1, 1, 2-tetrafluoroethane	A1	1000	13
R-141b	CH3CCl2F	1, 1-dichloro-1-fluoroethane	—	500	0.78
R-142b	CH3CClF2	1-chloro-1, 1-difluoroethane	A2	1000	5.1
R-143a	CH3CF3	1, 1, 1-trifluoroethane	A2L	1000	4.5
R-152a	CH3CHF2	1, 1-difluoroethane	A2	1000	2
R-170	CH3CH3	Ethane	A3	1000	0.54
R-E170	CH3OCH3	Methoxymethane (Dimethyl ether)	A3	1000	1
R-218	CF3CF2CF3	Octafluoropropane	A1	1000	43
R-227ea	CF3CHFCF3	1, 1, 1, 2, 3, 3, 3-heptafluoropropane	A1	1000	36
R-236fa	CF3CH2CF3	1, 1, 1, 3, 3, 3-hexafluoropropane	A1	1000	21
R-245fa	CHF2CH2CF3	1, 1, 1, 3, 3-pentafluoropropane	B1	300	12
R-290	CH3CH2CH3	Propane	A3	1000	0.56
R-C318	-(CF2)4-	Octafluorocyclobutane	A1	1000	41
R-400	zeotrope	R-12/114 (50.0/50.0)	A1	1000	10
R-400	zeotrope	R-12/114 (60.0/40.0)	A1	1000	11
R-401A	zeotrope	R-22/152a/124 (53.0/13.0/34.0)	A1	1000	6.6
R-401B	zeotrope	R-22/152a/124 (61.0/11.0/28.0)	A1	1000	7.2
R-401C	zeotrope	R-22/152a/124 (33.0/15.0/52.0)	A1	1000	5.2
R-402A	zeotrope	R-125/290/22 (60.0/2.0/38.0)	A1	1000	17
R-402B	zeotrope	R-125/290/22 (38.0/2.0/60.0)	A1	1000	15
R-403A	zeotrope	R-290/22/218 (5.0/75.0/20.0)	A2	1000	7.6
R-403B	zeotrope	R-290/22/218 (5.0/56.0/39.0)	A1	1000	18

R-404A	zeotrope	R-125/143a/134a (44.0/52.0/4.0)	A1	1000	31
R-405A	zeotrope	R-22/152a/142b/C318 (45.0/7.0/5.5/42.5)	—	1000	16
R-406A	zeotrope	R-22/600a/142b (55.0/4.0/41.0)	A2	1000	4.7
R-407A	zeotrope	R-32/125/134a (20.0/40.0/40.0)	A1	1000	19
R-407B	zeotrope	R-32/125/134a (10.0/70.0/20.0)	A1	1000	21
R-407C	zeotrope	R-32/125/134a (23.0/25.0/52.0)	A1	1000	18
R-407D	zeotrope	R-32/125/134a (15.0/15.0/70.0)	A1	1000	16
R-407E	zeotrope	R-32/125/134a (25.0/15.0/60.0)	A1	1000	17
R-407F	zeotrope	R-32/125/134a (30.0/30.0/40.0)	A1	1000	20
R-407G	zeotrope	R-32/125/134a (2.5/2.5/95.0)	A1	1000	13
R-407H	zeotrope	R-32/125/134a (32.5/15.0/52.5)	A1	1000	19
R-407I	zeotrope	R-32/125/124a (19.5/8.5/72.0)	A1	1000	16
R-408A	zeotrope	R-125/143a/22 (7.0/46.0/47.0)	A1	1000	21
R-409A	zeotrope	R-22/124/142b (60.0/25.0/15.0)	A1	1000	7.1
R-409B	zeotrope	R-22/124/142b (65.0/25.0/10.0)	A1	1000	7.3
R-410A	zeotrope	R-32/125 (50.0/50.0)	A1	1000	26
R-410B	zeotrope	R-32/125 (45.0/55.0)	A1	—	27
R-411A6	zeotrope	R-1270/22/152a (1.5/87.5/11.0)	A2	990	2.9
R-411B6	zeotrope	R-1270/22/152a (3.0/94.0/3.0)	A2	980	2.8
R-412A	zeotrope	R-22/218/142b (70.0/5.0/25.0)	A2	1000	5.1
R-413A	zeotrope	R-218/134a/600a (9.0/88.0/3.0)	A2	1000	5.8
R-414A	zeotrope	R-22/124/600a/142b (51.0/28.5/4.0/16.5)	A1	1000	6.4
R-414B	zeotrope	R-22/124/600a/142b (50.0/39.0/1.5/9.5)	A1	1000	6
R-415A	zeotrope	R-22/152a (82.0/18.0)	A2	1000	2.9
R-415B	zeotrope	R-22/152a (25.0/75.0)	A2	1000	2.1
R-416A6	zeotrope	R-134a/124/600 (59.0/39.5/1.5)	A1	1000	3.9
R-417A6	zeotrope	R-125/134a/600 (46.6/50.0/3.4)	A1	1000	3.5

R-417B	zeotrope	R-125/134a/600 (79.0/18.3/2.7)	A1	1000	4.3
R-417C	zeotrope	R-125/134a/600 (19.5/78.8/1.7)	A1	1000	5.4
R-418A	zeotrope	R-290/22/152a (1.5/96.0/2.5)	A2	1000	4.8
R-419A	zeotrope	R-125/134a/E170 (77.0/19.0/4.0)	A2	1000	4.2
R-419B	zeotrope	R-125/134a/E170 (48.5/48.0/3.5)	A2	1000	4.6
R-420A	zeotrope	R-134a/142b (88.0/12.0)	A1	1000	12
R-421A	zeotrope	R-125/134a (58.0/42.0)	A1	1000	17
R-421B	zeotrope	R-125/134a (85.0/15.0)	A1	1000	21
R-422A	zeotrope	R-125/134a/600a (85.1/11.5/3.4)	A1	1000	18
R-422B	zeotrope	R-125/134a/600a (55.0/42.0/3.0)	A1	1000	16
R-422C	zeotrope	R-125/134a/600a (82.0/15.0/3.0)	A1	1000	18
R-422D	zeotrope	R-125/134a/600a (65.1/31.5/3.4)	A1	1000	16
R-422E	zeotrope	R-125/134a/600a (58.0/39.3/2.7)	A1	1000	16
R-423A	zeotrope	R-134a/227ea (52.5/47.5)	A1	1000	19
R-424A6	zeotrope	R-125/134a/600a/600/601a (50.5/47.0/0.9/1.0/0.6)	A1	970	6.2

8.2 Flammable Refrigerant Limitations

Section 1103.3 does not allow A3 or B3 refrigerants with the following exceptions (36)
  - The refrigerant was approved by the AHJ
  - Laboratories with more than 100 square feet of space per person
  - Industrial occupancies
  - Listed self-contained systems containing <0.33 lbs of A3 refrigerant installed in accordance with the listing and manufacturer's instructions
- Section 1104.5 of the CMC allows a maximum of 1100 pounds of A2, B2, A3, and B3 (other than A2L and B2L) refrigerants in a building regardless of the probability or occupancy group. (36)
- Section 1104.6 does not allow A2, A2L, A3, B1, B2L, B2, or B3 refrigerants to be used in High-Probability systems for human comfort with the following exceptions (36):
  - Refrigerant in Listed equipment with a factory -sealed refrigerating system containing no more than 2.2 lbs of refrigerant installed in accordance with the listing and manufacturer's instructions
  - Refrigerant in Listed equipment with a factory-sealed refrigerating system containing no more than 4.4 lbs of A2L refrigerant installed in accordance with the listing and manufacturer's instructions.
- Section 1104.8 does not allow a change in the type of refrigerant used in a system without notifying the AHJ, the user of the equipment, and observance of safety requirements (36). This means that an A2L refrigerant cannot be used as a drop-in replacement of an A1 refrigerant unless the AHJ and the user are notified.

The exception in Section 1103.3 which states "Listed self-contained systems containing <0.33 lbs of A3 refrigerant installed in accordance with the listing and manufacturer's instructions" are allowed applies to room/wall/window air conditioning equipment, packaged terminal air conditioning units (PTACs), packaged terminal heat pumps (PTHPs), portable air conditioning equipment. This exception is most probably the reason CARB set the prohibition date for these units at 1/1/23.

8.3 Machinery Room

When certain conditions are found, refrigeration systems must be housed in a refrigeration machinery room. These conditions are summarized below (36):

- Quantity: the total quantity of refrigerant exceeds the amount in Table 1102.3
- Equipment: Direct and indirect-fired absorption equipment is used
- A1 System: There is an A1 system with total compressor horsepower of 100+ kW
- Refrigerant type: the system contains any refrigerant besides an A1 refrigerant

Refrigeration Machinery Rooms have certain requirements for:

- Access
- Openings

- Detectors & Alarms
- Normal Ventilation
- Emergency Ventilation
- Special Requirements

The CMC includes different requirements for Emergency Ventilation and Special Requirements based on the type of refrigerant. These Emergency Ventilation airflow requirements can be found in Sections 1106.2.5.1 and 1106.2.5.2 of the CMC. The Special Requirements for systems with A2L, A2, A3, B1, B2L, B2, and B3 refrigerants can be found in sections 1107.1.7, 1107.1.7.2, 1107.1.7.3, 1107.1.8, 1107.1.9. The interested reader may review those sections for further information.

8.4 Other Refrigeration Requirements

The CMC includes additional requirements for refrigeration systems which include the following:

- Refrigeration Machinery Room Equipment and Controls
- Refrigeration Piping, Containers, and Valves
- Valves
- Pressure-Limiting Devices
- Pressure-Relief Devices
- Overpressure Protection
- Special Discharge Requirements
- Labeling and Identification
- Testing of Refrigeration Equipment
- Refrigerant-Containing Pressure Vessels
- Maintenance and Operation

The CMC includes different requirements for Emergency Shut-off (1108.3), Pressure Limiting Devices (1111.1), Discharging Location Interior to Building (1112.11.1), Discharging Location Exterior to Building (1112.11.2), Special Discharge Requirements (1114.1). The interested reader may review those sections for further information.

8.5 California Fire Code

The current version of the California Fire Code is the 2022 California Fire Code (CFC). The CFC adopted the International Fire Code. Chapter 6 Section 608 of the CFC covers mechanical refrigeration systems.

Table 33 below gives a summary of the CFC requirements that differ between A1 and other refrigerants. **Please note, the CFC requirements are summarized in this table and not all exceptions are discussed because the purpose of this table is to provide an overview. Persons looking for more details should directly read the listed CFC sections.**

Table 2: CFC Code Summary of Differences between A1 and All Other Refrigerants

CFC Section	Topic	Requirement	A1 Trigger	All Other Refrigerant Trigger
608.6	Access	Access to refrigerant circuit must be provided for fire department	Refrigerant circuit containing 220+ lbs	Refrigerant Circuit containing 30+ lbs
608.7	Testing	Refrigeration equipment subject to periodic testing and records of testing must be maintained. Tests must be conducted by qualified persons		
608.8	Emergency Signs	Refrigeration units must be provided with emergency signs, charts and labels		
608.9.1	Refrigerant Detection	A detector must be provided at a location where refrigerant from a leak is expected to accumulate. The System must initiate audible and visible alarms inside and outside of each entrance to the refrigerating machinery room and transmit a signal to an approved location when: • The TLV-TWA values in the CMC • 25% of the LFL	Required for all A1 refrigerants	Required for all other refrigerants (Exception: Ammonia must abide by IIAR 2)
608.10	Remote Controls	Remote controls of mechanical equipment and appliances located in machinery room must be provided	Not required	Required for flammable refrigerants
608.11	Emergency Pressure Control	Permanently installed refrigeration systems must be provided with emergency pressure control system	Not required	Required for systems with 6.6+ lbs of flammable, toxic, or highly toxic refrigerants
608.12	Storage, Use and Handling	Flammable and combustible materials may not be stored in machinery rooms	Refrigerant circuit containing 220+ lbs	Refrigerant Circuit containing 30+ lbs
608.13.1 – 608.13.4	Discharge and Termination of Pressure Relief and	Various requirements in Sections 608.13.1 – 608.13.4 depending on flammability and toxicity of refrigerant	Not required	See Sections 608.13.1 – 608.13.4

	Purge Systems			
608.14	Mechanical Ventilation Exhaust	Exhaust from mechanical ventilation systems serving refrigeration machinery rooms capable of exceeding 25% of Lower Flammability Limit or 50% of IDLH must have approved treatment systems to reduce discharge concentrations to those values or lower	Not required	Required for systems with flammable, toxic, or highly toxic refrigerants (Except A2L refrigerants must meet section 608.18)
608.17	Electrical Equipment	Machinery rooms must conform to Class I, Division 2 hazardous location classification requirements of California Electrical Code	Not required	Groups A2, A3, B2, and B3 refrigerants. (Exceptions: 1. Ammonia that is ventilation according to CMC 1101.2, Exception 1. 2. A2L refrigerants vented according to CFC 608.18)
608.18	Special Requirements for A2L Refrigerant Machinery Rooms	Machinery rooms with refrigerant systems containing A2L refrigerant that don't comply with 608.17, must comply with 608.18.1 – 608.18.2	Not required	A2L refrigerants
608.18.1	Ventilation System Activation	Ventilation must be activated by refrigerant detection system and must be in accordance with 608.9 and: • Detectors must activate at or below refrigerant concentration of 25% of LFL • Upon activation, detection system must activate emergency ventilation system • Detection signaling and control circuits must be supervised		

608.18.2	Emergency Ventilation System	Emergency ventilation system must be provided at minimum exhaust rate in ASHRAE 15 or Table 608.18.2. Shut down of emergency ventilation must be manual		

8.6 Local Codes & Standards

Local codes & standards are either the state codes & standards (CMC or CFC) or they are codes enacted by the AHJ. It would be too time consuming to determine if each AHJ has its own codes or uses the CMC and CFC because there are over ninety (90) AHJs in SoCalREN territory. The Study Team reviewed the following Local Codes in Table 34. The local codes are largely the same as the state codes.

Table 3: Los Angeles County and City of Los Angeles Mechanical and Fire Code Summary

Local Code	Adopts State Code?	Amendments to CMC Affecting Refrigerants
Los Angeles County Mechanical Code (Title 29) **(59)**	Yes. Adopts 2022 CMC with some amendments.	Adds that the method of discharge for systems containing other than A1 refrigerants must comply with Title 32 and Title 20 of Los Angeles County Code (59).
Los Angeles County Fire Code	Yes. Adopts 2022 CFC and the following chapters of the 2021 International Fire Code • 1-7 • 9-10 • 12 • 20-37 • 39-40 • 50-51 • 53-56 • 59-67 • 80	None
City of Los Angeles Mechanical Code	Yes. Adopts portions of the 2022 CMC.	None
City of Los Angeles Fire Code	No. Adopts 2019 California Fire Code and 2018 International Fire Code.	None

9. Appendix II – Interview Responses

Lower-GWP Responses: Interviewee #1

12) General Information

a. **What is your main area of work? HVAC, Water heating, refrigeration or other?**
   - Water heater installations in residential and commercial, water heater maintenance, plumbing

b. **What size/type of equipment do you or your company work with?**
   - 40,-50 gallon water heaters in residential
   - 65-80 gallons in commercial

c. **What is your role at your company?**
   - Owner of water heater contracting company
   - Company doesn't do design work
   - Company is not trained/certified to handle refrigerants

13) What types of refrigerants does your company work with?
   - No refrigerant work is done or needed since systems come pre-charged, any refrigerant needs would be sent to C2s (which is a specialty contractor), although none have been used

14) Does your company install any equipment that uses Low-GWP refrigerants (A2L or A3 refrigerants).

a. **If yes, what are the positives and negatives of working with this equipment for you and the customer?** N/A

b. **If no, why not?**
   - Did not know of any Lower-GWP EWHPH until recently, but is open to working with them if introduced
   - Expressed interest in working with other EHPWH manufacturers when asked about working with others

15) What percentage of your customers have inquired about Low-GWP refrigerants or Low-GWP equipment?
   - 0%

16) What barriers and opportunities do you see for Low-GWP equipment in the near and long-term future?
   - No barriers besides being trained/knowledgeable about low-GWP projects
   - HPWHs have been an easy sale with incentives available
   - SoCalREN can put together a manufacturer-distributor list to connect with contractors
   - Contractors are always looking for opportunities to be specialists for certain systems

17) Do you know of any refrigerant reclaim locations in your service area? N/A

18) Are you aware of refrigerant reclaim requirements? N/A

19) Have you or your technicians received any training on Low-GWP refrigerants or equipment?

- Have not received training on Lower-GWP systems, but would be interested in receiving training from manufacturers/distributors of Lower-GWP systems
- There is not enough training in the market for installing (and maintaining) Lower-GWP systems
- Many plumbers don't want to deal with HPWH systems because of the training involved (that right now they have to find themselves)
- Training should be on troubleshooting/installing actual units with different components and programming
- Training comes through distributor reps who send trainers to installation offices for live training sessions with demo unit as well as for project/site-walkthrough to provide design requirements based on building site
- Training is the best way to get plumbers on-board with new technologies

20) **Do you know what types of buildings and equipment can use A2L or A3 refrigerants in California?** N/A
21) **Is there any other information you want to add about Low-GWP refrigerants?**
    - For EWHPWHs, it is important to know if the distributor provides the design work for their systems
    - Customers complain that EHPWH are louder
    - HPWH may require full panel upgrade at an extra cost but can be covered with incentives
    - This SME uses TECH Clean CA for incentives
    - Have not run issues with higher utility rates or cold room temperatures

Lower-GWP Responses: Interviewee #2

1) **General Information**
    a. **What is your main area of work? HVAC, Water heating, refrigeration or other?**
        - HVAC & Refrigeration – commercial (defined by this contractor as 5+ tons)
    b. **What size/type of equipment do you or your company work with?**
        - 5 + tons
    c. **What is your role at your company?**
        - President
2) **What types of refrigerants does your company work with?**
    - All types of A1 refrigerants, no A2L or A3, No ammonia
3) **Does your company install any equipment that uses Low-GWP refrigerants (A2L or A3 refrigerants).** No
    a. **If yes, what are the positives and negatives of working with this equipment for you and the customer?** N/A
    b. **If no, why not?**
        - Can't get this equipment through the current supply chain. Their business model is based on service and replacement – customers expect a new unit within a week from them not within a year. Their business doesn't do plan spec or new construction where

long lead times can be tolerated. They get called when an AC unit is down. They do some work with planned replacements – but even then customer can't wait long for a new HVAC unit. Planned replacements are on an annual basis – in December 2024 this contracotr will tell customer what needs to be replaced, and give options with pricing. Building owners will go with whatever is cheaper.

4) **What percentage of your customers have inquired about Low-GWP refrigerants or Low-GWP equipment?**
   - 0% - 1 customer out of 500
5) **What barriers and opportunities do you see for Low-GWP equipment in the near and long-term future?**

   Barriers –
   - #1: Additional refrigerant leak sensors required for A2L
   - #2: Integrating Low-GWP equipment with existing fire-life safety systems: there is another trade installing duct smoke sensors. It is already an issue with one trade blaming another for why something is not operating right and could get worse with the ones required for A2L systems. There needs to be better integration between units and fire life safety systems for A2L refrigerants
   - #3: Manufactures have to comply with the GWP requirements, but contractor is concerned that equipment quality will suffer.
   - #4: Concerned if they be able to supply Lower-GWP equipment within reasonable time period? During COVID, it took forever to get replacement parts.

   Opportunities –
   - #1: There is a lot of value in the new Lower-GWP refrigerant, it is a good thing. There is an opportunity to market and sell it and differentiate yourself from other contractors. This contractor could propose to a customer to sell an A1 system for $12k or an A2L for $15k. the $15k would capture more revenue and contractor could make a case for why it is a better option.
6) **Do you know of any refrigerant reclaim locations in your service area?**
   - Yes, their service techs are required to recover, reclaim and submit refrigerant. They generally use refrigeration supply distributor which has 15-20 branches. This is an additional service refrigeration supplier provides to get the contractor's business. Every technician on staff has EPA 608 universal cards.
7) **Are you aware of refrigerant reclaim requirements?**
   - Yes, every technician has EPA 608 universal cards
8) **Have you or your technicians received any training on Low-GWP refrigerants or equipment?**
   - Yes – all of techs have been trained multiple times over the past two years. Contractor is getting training from distributors. Some distributors will come to shop the contractor's shop and some you have to go to their location. Where the training happens doesn't matter so much, but if it's at the distributor, the distributor will provide food/coffee.
9) **Do you know what types of buildings and equipment can use A2L or A3 refrigerants in California?**
   - This contractor believes it is all of them except medical facilities from OSHPD HCAI.

10) Is there any other information you want to add about Low-GWP refrigerants?

- Even though manufactures/distributors say that Lower-GWP units are available, if this contractor asked for a Lower-GWP unit from a distributor or manufacturer, the date it would ship would be well over 1 year. Customers cannot wait that long for a unit, so it's as if the unit does not exist.
- Manufacturers of commercial-sized systems may continue selling equipment that doesn't meet the EPA GWP limits until 1/1/2026 as long as it was manufactured before 1/1/25. The contractor believes that the manufacturers are producing as much equipment that doesn't meet the EPA requirements before 1/1/25 so they can continue to sell that equipment for an additional year in 2025.
- The contractor provided an anecdote that they just replaced a chiller at a customer site and had a discussion of whether it would be better to install a new R410a chiller or an R454b chiller because of the EPA and CARB requirements. However, when getting a quote for the R454b chiller, the lead time for shipment was over 1 year meaning that chiller was not a viable option.
- Technicians are already trained on A2L refrigerants and they have been receiving training for a few years now. They have gauges that are compatible with the flammable refrigerant.
- You can buy Low-GWP refrigerant from a refrigerant supplier, but you cannot buy new equipment made for that refrigerant.

Lower-GWP Responses: Interviewee #3

1) General Information

a. What is your main area of work? HVAC, Water heating, refrigeration or other?

- 55% residential, 35% commercial HVAC. Commercial RTU or split system up to 25 ton.

b. What size/type of equipment do you or your company work with?

- Roughly up to 25 ton equipment

c. What is your role at your company?

- General Manager

2) What types of refrigerants does your company work with?

- R410a, R134a (but not much), also R-22. No A2L refrigerants right now.

3) **Does your company install any equipment that uses Low-GWP refrigerants (A2L or A3 refrigerants).**

- Not currently. Don't do anything with R-32.

a. If yes, what are the positives and negatives of working with this equipment for you and the customer? N/A

b. If no, why not?

- A2L units not going to be available for residential until May 2025.
- Some contractors have drawn back from the A2Ls because of the flammability
- The R-32 residential is coming out next May
- Everyone is using R410a until 2025

- One manufacturer that they use is going to use R-32
- Another manufacturer that they use is going to use R454b even in residential units.

4) **What percentage of your customers have inquired about Low-GWP refrigerants or Low-GWP equipment?**
   - Not many, maybe 10%. A lot of people who ask about Low-GWP are all about the latest and greatest so they will ask if they need a Low-GWP system.
5) **What barriers and opportunities do you see for Low-GWP equipment in the near and long-term future?**

   Opportunities:
   - None really. This is the 4th refrigerant phase-out in the last 40 years. This SME was involved when R-22 was phased out.

   Barriers:
   - Nobody has seen the refrigerants in the field so they don't know how it will act or how it will cool.
   - There is concern if there is a gas package unit with a refrigerant leak. Contractors concerned about what happens if the gas furnace is burning gas while there is a leak – will the refrigerant light on fire? Manufactures have not provided information about this leak/fire potential.
   - Manufacturers are selling R410a units until forced by the government to sell the Low-GWP units. No manufacturer has offered training on Lower-GWP equipment to this SME's knowledge. Nobody will have time in the summer of 2024 to participate in training so training on Lower-GWP equipment might be offered in October 2024. Also, if the training is given now, but contractors don't end up installing it until 2025. The SME is concerned everyone will forget what was said during the training in fall 2024 and have to do the training again. He thinks manufacturers or distributors will do training around October 2024.
6) **Do you know of any refrigerant reclaim locations in your service area?**
   - Yes. The SME listed (3) which are all HVAC or refrigerant distributors. He noted that anywhere that sells HVAC systems will reclaim them.
7) **Are you aware of refrigerant reclaim requirements?**
   - Yes, via EPA training.
8) **Have you or your technicians received any training on Low-GWP refrigerants or equipment?**
   - No
9) **Do you know what types of buildings and equipment can use A2L or A3 refrigerants in California?**
   - The SME thinks it is going to be required by all of them (commercial and residential) and he knows that from basic industry knowledge. This is the 3rd refrigerant change so he knows it will get phased out in all buildings.
10) **Is there any other information you want to add about Low-GWP refrigerants?**
    - This SME thinks manufacturer should be required to give contractors a unit and test it. He is concerned about how it would work in an actual home.

- When selling a new HVAC unit, his company will usually buy a system and do some trial and error testing with it so they know it is a good unit to put in someone's home. They probably buy an A2L unit in Q1 2025 to test in a heating and cooling season. He thinks about 30% of contractors will do this kind of extra testing themselves to make sure the units are installed properly, and the rest will say "we have to put these units in anyway so why bother testing them ourselves."
- This SME thinks the market will start to see a slow transition to Low-GWP units in May 2025. MFG will sell every R410a system they have first. This SME will try to sell R410a units until end of 2025. They probably will stock up on units in April 2025 so they can continue to sell R410a equipment through the end of 2025.

In this interview, the Team asked what this contractor does with refrigerant in an existing unit that was removed from a home. Below are the responses:

- If the compressor is still good, they puump the refrigerant down into the condenser unit and give it to a metal scrap guy that comes to break the unit down for the metal. The scrap guy will recover the refrigerant and take it somewhere to be reclaimed.
- If the compressor is bad, they will recover the refrigerant themselves and take it to whoever is the closest that will take it (usually a refrigerant or HVAC distributor).
- There is no paper work required to be signed or submitted to state that the refrigerant was recovered properly. The EPA training has a 100-question test that has the requirements for reclaiming, recovering, storing refrigerant properly. In the EPA training they tell you that you must properly recover the refrigerant or it is a $25,000 fine.

When asked directly about payment for R410a, this SME indicated they do not get much money for R410a right now from distributors, but will probably get more money in the future as it is phased out.

Lower-GWP Responses: Interviewee #4

1) **General Information**
   a. **What is your main area of work? HVAC, Water heating, refrigeration or other?**
      - Building automation department, controls/monitoring buildings, HVAC mechanics, remote building monitoring; HVAC systems background
   b. **What size/type of equipment do you or your company work with?**
      - This SME does not work for a contracting firm, but he has experience with built up systems for a state county, large chillers, and some packaged units
   c. **What is your role at your company?**
      - Supervisor for HVAC department for a County in California
2) **What types of refrigerants does your company work with?**
      - The county he works with uses R12, R22, R134a, R123 and R410a in their HVAC systems

3) **Does your company install any equipment that uses Low-GWP refrigerants (A2L or A3 refrigerants).**
   a. **If yes, what are the positives and negatives of working with this equipment for you and the customer? N/A**
   b. **If no, why not? N/A**
      - His county doesn't sell anything, but they do have some Ammonia in large systems/chillers
4) **What percentage of your customers have inquired about Low-GWP refrigerants or Low-GWP equipment?** N/A
5) **What barriers and opportunities do you see for Low-GWP equipment in the near and long-term future?**
   Barriers:
      - Certain refrigerants can be problematic when in use
      - SME is concerned about how well the Lower-GWP refrigerants operate. He is concerned that they do not operate at the same system pressures which could lead to problems and equipment replacement.
      - SME is concerned and wary of any Lower-GWP refrigerant that is marketed as a drop-in replacement. This SME was involved in the R-22 phase-out
6) **Do you know of any refrigerant reclaim locations in your service area?**
      - This SME indicated that a refrigerant distributor will handle refrigerant disposal/reclaim. The county would bring refrigerant in cylinder for drop-off if it was 5-20 lbs. Otherwise it would be part of a larger scope of work
      - This SME thinks that refrigerant vendors charge a refrigerant reclamation fee
7) **Are you aware of refrigerant reclaim requirements?**
      - Yes, a universal EPA card is required for mechanics/technicians and are well-versed in refrigerant handling, card is required for buying refrigerant
8) **Have you or your technicians received any training on Low-GWP refrigerants or equipment?**
      - No, this SME has not heard of any training opportunities from manufacturers; refrigerant vendors would provide low-GWP refrigerant training
9) **Do you know what types of buildings and equipment can use A2L or A3 refrigerants in California?**
      - No
10) **Is there any other information you want to add about Low-GWP refrigerants?**
      - Success is based on operational pressures that work with existing equipment

10. References

1. **CPUC.** Attachment A. *California Energy Efficiency Coordinating Committee.* [Online] https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/energy-efficiency/rolling-portfolio-program-guidance/caeecc_final-revision_attachment-a_clean.pdf.

2. **SB-1206 Hydrofluorocarbon gases: sale or distribution. *Aalifornia Legislative Information*. [Online] 2022. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB1206.**

3. CPUC. CPUC Forward-Looking Low-GWP Refrigerant Transition Impacts - Final Work Plan. *California Energy Efficiency Energy Contracts*. [Online] 2023. https://pda.energydataweb.com/#!/documents/2797/view.

4. EPA. Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons Under the American Innovation and Manufacturing Act of 2020. *Federal Register*. [Online] 2020. https://www.federalregister.gov/documents/2023/10/24/2023-22529/phasedown-of-hydrofluorocarbons-restrictions-on-the-use-of-certain-hydrofluorocarbons-under-the#p-209.

5. —. Substitutes in Residential and Light Commercial Air Conditioning and Heat Pumps. *epa.gov*. [Online] https://www.epa.gov/snap/substitutes-residential-and-light-commercial-air-conditioning-and-heat-pumps.

6. —. Understanding Global Warming Potentials. *EPA.gov*. [Online] https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

7. UC Berkeley. Greenhouse effect. *Understanding Global Change*. [Online] https://ugc.berkeley.edu/background-content/greenhouse-effect/.

8. EPA. International Treaties and Cooperation about the Protection of the Stratospheric Ozone Layer. *EPA.gov*. [Online] https://www.epa.gov/ozone-layer-protection/international-treaties-and-cooperation-about-protection-stratospheric-ozone.

9. —. Addressing Ozone Layer Depletion. *EPA.gov*. [Online] https://www.epa.gov/ozone-layer-protection/addressing-ozone-layer-depletion.

10. Martin Wolf, Adam Meier, Bridget Nyland, Sejong Youn, Debra Stump, and Wendy Jacobs. Institutions and governments can slow climate change by regulating and reducing halocarbon refrigerant use. *sciencepolicyreview.org*. [Online] 2020. https://sciencepolicyreview.org/2020/08/institutions-and-governments-can-slow-climate-change-by-regulating-and-reducing-halocarbon-refrigerant-use/.

11. EPA. Final Rule - Protection of Stratospheric Ozone: Change of Listing Status for Certain Substitutes under the Significant New Alternatives Policy Program. *epa.gov*. [Online] 2023.

12. —. Final Rule 21 - Protection fo Straospheric Ozone: Signiciant New Alternatives Policy Program New and Changed Listings. *epa.gov.* [Online] December 1, 2016. https://www.epa.gov/sites/default/files/2016-12/documents/snap_action_scr2_factsheet.pdf.

13. —. Final Rule 23 - Protection of Stratospheric Ozone: New Listings for the Significant New Alternatives Policy Program. *epa.gov.* [Online] April 23, 2021. https://www.epa.gov/sites/default/files/2021-04/documents/fact_sheet_snap_final_rule_23_final_4-23-21_508.pdf.

14. —. Final Rule 25 - Protection of Stratospheric Ozone: Listing of Substitutes under the Significant New Alternatives Policy Program in Refrigeration, Air Conditioning, and Fire Suppression. *epa.gov.* [Online] April 2023. https://www.epa.gov/system/files/documents/2023-04/SNAP%20Final%20Rule%2025%20Factsheet_Final_4-3-2023_508_2.pdf.

15. —. Fact Sheet: Final Rule 26 - Listing of Substitutes under the Significant New Alternatives Policy Program in Commercial and Industrial Refrigeration. *epa.gov.* [Online] May 2024. https://www.epa.gov/system/files/documents/2024-05/snap-final-rule-26-factsheet.pdf.

16. Building Safety Journal. EPA Phasedown of Hydrofluorocarbon Refrigerants: Where Do We Stand? [Online] 2024. [Cited: August 8, 2024.] https://www.iccsafe.org/building-safety-journal/bsj-technical/epa-phasedown-of-hydrofluorocarbon-hfc-refrigerants-where-do-we-stand/.

17. Title 42 - The Public Health and Welfare, Chapter 85 - Air pollution Prevention and Control, Subchapter VII - American Innovation and Manufacturing. *uscode.house.gov.* [Online]

18. EPA. Final Rule - Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act of 2020. *epa.gov.* [Online] 2023. https://www.epa.gov/system/files/documents/2023-10/technology-transitions-final-rule-fact-sheet-2023.pdf.

19. CARB. California Significant New Alternatives Policy (SNAP): About. *arb.ca.gov.* [Online]

20. SB-1383 Short-lived climate pollutatns: methane emissions: dairy and livestock: organic waste: landfills. *leginto.legislature.ca.gov.* [Online] 2016. https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383.

21. California Code of Regulations, Title 17: Public Health, Division 3: Air Resources, Chapter 1: Air Resources Board, Subchapter10: Climate Change, Article 4: Regulations to Achieve Greenhouse Gas Emissions Reductions, Subarticle 5: Prohibitions on Use of C.

22. SB-1013 Fluorinated refrigerants. *leginfo.legistalture.ca.gov.* [Online] 2018. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1013.

23. CARB. California Significant New Alternatives Policy. [Online] 2024. [Cited: February 8, 2024.] https://ww2.arb.ca.gov/our-work/programs/california-significant-new-alternatives-policy-

snap/about#:~:text=In%202020%2C%20CARB%20amended%20the,are%20technologically%20and%20commercially%20feasible..

24. UL. Update on Code Requirements for Mechanical Refrigeration Systems. *ul.com*. [Online] 2022. https://www.ul.com/news/update-code-requirements-mechanical-refrigeration-systems.

25. AHRI. AHRI Flammable Refrigerants Research Initiative. *ahrinet.org*. [Online] https://www.ahrinet.org/analytics/research/ahri-flammable-refrigerants-research-initiative.

26. ASHRAE. Standard 15-2022 (packaged w/Standard 34-2022) -- Safety Standard for Refrigeration Systems and Designation and Safety Classification of Refrigerants. *accuristech.com*. [Online] 2022. https://store.accuristech.com/standards/ashrae-15-2022-packaged-w-standard-34-2022?product_id=2504061#:~:text=The%202022%20edition%20is%20the,and%20mitigation%20actions%20and%20more.

27. UL. *Low GWP Refrigerants for Commercial Refrigeration*. 2019.

28. —. Important New Requirements for Use of Low-GWP Refrigerants. *ul.com*. [Online] 2024. https://www.ul.com/news/important-new-requirements-use-low-gwp-refrigerants.

29. —. Updated Requirements for Refrigerant Detection Systems. *ul.com*. [Online] https://www.ul.com/insights/updated-requirements-refrigerant-detection-systems.

30. Intertek. UL 60335-2-40 Testing and Certification. *intertek.com*. [Online] https://www.intertek.com/hvacr/60335-2-40/#:~:text=UL%2060335%2D2%2D40%20outlines,compliance%20with%20the%20safety%20requirements.

31. —. UL 60335-2-40 Frequently Asked Questions. *intertek-cdn.s3.amazonaws.com*. [Online] https://intertek-cdn.s3.amazonaws.com/www-intertek-com/dms-legacy/Intertek-UL-60335-2-40-FAQ.pdf.

32. —. Understanding UL 60335-2-89 for Commercial Refrigeration Equipment. *iaeimagazine.org*. [Online] June 30, 2023. https://iaeimagazine.org/columns/certification-insights/understanding-ul-60335-2-89-for-commercial-refrigeration-equipment/.

33. Danfoss. IEC 60335-2-89 flammable refrigerant limit change. *danfoss.com*. [Online] https://www.danfoss.com/en/about-danfoss/our-businesses/cooling/refrigerants-and-energy-efficiency/refrigerant-faq-iec/#:~:text=What%20are%20the%20new%20charge,from%20150g%20to%201.2kg.

34. AHRI. AHRI Low-GWP Alternative Refrigerants Evaluation Program. *ahrinet.org*. [Online] https://www.ahrinet.org/analytics/research/ahri-low-gwp-alternative-refrigerants-evaluation-program.

35. Los Angeles City Mechanical Code 2022. *up.codes*. [Online] 2022. https://up.codes/viewer/los_angeles/ca-mechanical-code-2022/chapter/new_1/administration#new_1.

36. California Mechanical Code 2022, Chapter 11 Refrigeration. *up.codes*. [Online] 2022. https://up.codes/viewer/california/ca-mechanical-code-2022/chapter/11/refrigeration#1102.2.

37. Resource Compliance. IIAR 2-2021: Ammonia Machinery Room Ventilation Requirements. *resourcecompliance.com*. [Online] June 28, 2022. https://resourcecompliance.com/2022/06/28/iiar-2-2021-ammonia-machinery-room-ventilation-requirements/.

38. —. Access to Refrigeration Systems. *resourcecompliance.com*. [Online] February 6, 2024. https://resourcecompliance.com/2024/02/06/access-to-refrigeration-systems-2/.

39. CARB. High-GWP Refrigerants. *arb.ca.gov*. [Online] https://ww2.arb.ca.gov/resources/documents/high-gwp-refrigerants.

40. ASHRAE. Update on New Refrigerants Designations and Safety Classifications. *ashrae.org*. [Online] November 2022. https://www.ashrae.org/file%20library/technical%20resources/bookstore/factsheet_ashrae_english_november2022.pdf.

41. Daikin. ASHRAE Standards 15 and 34 - Considerations for VRV/VRF Systems. *daikinac.com*. [Online] May 2013. https://www.daikinac.com/content/assets/DOC/White-papers-/TAVRVUSE13-05C-ASHRAE-Standard-15-Article-May-2013.pdf.

42. Trane. Engineers Newsletter: A2L Refrigerants and ASHRAE Standard 15. *trane.com*. [Online] August 2023. https://www.trane.com/content/dam/Trane/Commercial/global/learning-center/engineers-newsletters/ADM-APN088-EN.pdf.

43. —. Engineers Newletter: Refrigerant System Equipment Room Design. *trane.com*. [Online] 1992. https://www.trane.com/content/dam/Trane/Commercial/global/products-systems/education-training/engineers-newsletters/standards-codes/enews-21_2_01011992.pdf.

44. MEP Academy. How HVAC Split System Air Conditioners Work. *mepacademy.com*. [Online] October 20, 2022. https://mepacademy.com/how-hvac-split-system-air-conditioners-work/.

45. California Building Code 2022 (Vol 1 & 2): Chapter 3 Occupancy Classificaion and Use. *up.codes*. [Online] 2022. https://up.codes/viewer/california/ca-building-code-2022/chapter/3/occupancy-classification-and-use#3.

46. CPUC. Forward-Looking Low-GWP Warming Potential Refrigerant Transition Study. [Online] June 28, 2024. https://pda.energydataweb.com/api/view/3997/CPUC%20Forward-Looking%20Low-GWP%20Refrigerant%20Transition%20Study.pdf.

47. ENERGY STAR(R). Commercial Refrigerators and Freezers. *energystar.gov*. [Online] https://www.energystar.gov/productfinder/download/certified-commercial-refrigerators-and-freezers/.

48. —. ENERGY STAR(R) Certified Refrigerators. [Online] https://www.energystar.gov/productfinder/download/certified-residential-refrigerators/.

49. Copeland. CO2 Refrigeration on the Rise. *e360hub.copeland.com*. [Online] February 18, 2022. https://e360hub.copeland.com/prepare-for-the-widespread-adoption-of-co-by-learning-from-emersons-experts-and-exploring-our-breadth-of-co-resources/co-refrigeration-on-the-rise.

50. OSHA. Process Safety Management. *osha.gov*. [Online] https://www.osha.gov/process-safety-management/sbrefa.

51. R744 Co, Cooling Marketplace. Raley's Unorthodox Ammonida/R744 System. *r744.com*. [Online] 2020. https://r744.com/raleys-unorthodox-ammonia-r744-refrigeration-system/.

52. Climalife. R1234ze. *climalife.co.uk*. [Online] https://www.climalife.co.uk/r1234ze#:~:text=Ultra%20low%20GWP%20(7)%2C,in%20supermarkets%20and%20commercial%20buildings..

53. Environmental Investigation Agency. Search, Reuse, and Destroy: How States Can Take the Lead on a 100 Billion Ton Climate Problem. [Online] 2019. https://eia.org/report/20190214-search-reuse-destroy/.

54. EPA. EPA-Certified Refrigerant Reclaimers. *epa.gov*. [Online] https://www.epa.gov/section608/epa-certified-refrigerant-reclaimers.

55. CalNEXT. Market Characterization of Ultra-Low GWP Space Conditioning Heat Pumps for Commercial Buildings. *calnext.com*. [Online] December 18, 2023. https://calnext.com/wp-content/uploads/2023/12/ET23SWE0028_Market-Characterization-of-Ultra-Low-GWP-Space-Conditioning-Heat-Pumps-for-Commercial-Buildings_Final-Report.pdf.

56. DEER. DEER Water Heater Calculator. *cedars.sound.com*. [Online] August 29, 2022. https://cedars.sound-data.com/deer-resources/tools/water-heaters/file/2919/download.

57. Daikin. Advanced Technologies Propel Performance and Savings. *Daikin Applied*. [Online] 2024. https://www.daikinapplied.com/products/rooftop-systems/rebel.

58. Ben Seeley, Marian Goebes, Dan Simpson, Yolanda Beesemyer. Market Characterization of Ultra-Low GWP Space Conditioning Heat Pumps for Commercial Buildings Final Report. *CalNEXT*. [Online] 2023. https://calnext.com/wp-content/uploads/2023/12/ET23SWE0028_Market-Characterization-of-Ultra-Low-GWP-Space-Conditioning-Heat-Pumps-for-Commercial-Buildings_Final-Report.pdf.

59. Title 29 - Mechanical Code. *library.municode.com*. [Online] August 2, 2024. https://library.municode.com/ca/los_angeles_county/codes/code_of_ordinances?nodeId=TIT29MECO.

60. California Mechanical Code 2022, Chapter 11 Refrigeration. *up.codes*. [Online] 2022. https://up.codes/viewer/california/ca-mechanical-code-2022/chapter/11/refrigeration#1104.2.