Southern California Edison

Market Study of Low-GWP Refrigerants in C&I Applications

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This report summarizes the key findings and recommendations TRC's Market Study of Low Global Warming Potential (GWP) Refrigerants in Commercial and Industrial (C&I) Applications conducted for Southern California Edison (SCE). The objective of this project was to **explore the market barriers and opportunities for low and ultra-low global warming potential (GWP) refrigerants and understand the implications for Southern California Edison's (SCE's) commercial and industrial (C&I) offerings**. The purpose of this report is to inform near-term planning and identify technologies for measure package development, program development, or further research.

Recent regulations from the California Air Resources Board (CARB) and the Environmental Protection Agency (EPA) are mandating the transition away from legacy high-GWP refrigerants (DNV, 2024). While this transition aligns with long-term emissions reduction goals, adoption faces meaningful barriers related to higher first cost, contractor readiness, building code and related codes, and uncertainty regarding regulatory enforcement, particularly in existing facilities. There is opportunity for SCE to incentivize the market to move toward ultra-low-GWP refrigerants, which have an even lower climate impact than the low-GWP refrigerants required by regulations. Many of the ultra-low-GWP refrigerants require more safety precautions, causing both market and code barriers to their adoption. Though barriers exist, they may be navigable for certain applications.

To conduct the study, the research team:

- Reviewed 16 existing market studies of low and ultra-low-GWP refrigerants in C&I end uses.
- Reviewed existing and upcoming measure packages for equipment that use refrigerants.
- Reviewed national and state codes and standards for refrigerant regulations and restrictions.
- Interviewed 9 staff from two investor-owned utilities (IOUs), two staff from CARB, and 6 subject matter experts.

Results

Low and ultra-low-GWP refrigerants are becoming available in some products on the market but face challenges to adoption. Standard GWP refrigerants (<700 GWP) are more common on the market today. Key findings indicate that refrigerant choice is rarely a primary driver in customer decision-making; instead, first cost, performance, operating conditions, and compliance requirements dominate equipment selection decisions.

Ultra-low-GWP measure packages are feasible to develop within the current tools, but measure package developers may need to expend additional effort to acquire supplemental ultra-low-GWP equipment cost and performance data and define the eligibility requirements for most equipment types. Program administrators may face uncertainty around baseline definitions given new regulations and the absence of clear top-down signals to promote low-GWP options within deemed measure structures.

However, there are some sectors that are primed to adopt ultra-low-GWP refrigerant alternatives, with several promising technologies for measure packages and regulations already causing users to consider alternative refrigerants:

- Standalone food refrigeration units are available in ultra-low-GWP refrigerant options, but equipment turnover in this sector is driven by equipment burnout.

- The service and domestic hot water sector has promising ultra-low-GWP refrigerant options but lacks regulatory drivers to facilitate the refrigerant transition.

Other equipment also has promise to shift to low or ultra-low-GWP refrigerants but needs additional research and field demonstrations to address technical, safety, and cost barriers. In particular, TRC identified ultra-low-GWP technologies for walk-in coolers and freezers and light and large commercial heating, ventilation, and air conditioning (HVAC). But innovation is needed for HVAC technology to overcome efficiency and cost barriers for CO_2, and code barriers for propane.

Conclusions

Despite current barriers, IOUs have near-term levers that they can use to accelerate the refrigerant transition. Based on the study findings, the research team identified several opportunities to encourage the adoption of lower GWP refrigerants, including the following:

- Deemed Measure Opportunities
  - An ultra-low-GWP kicker measure package for high-impact market segments.
    - Propane reach-in refrigerators and freezers
    - CO_2 heat pump water heaters
- Pilots and Custom Offerings
  - Pilot demonstration of propane walk-in coolers and freezers
  - Collaborate with CARB on a custom measure pathway for CO_2 supermarket refrigeration systems to support CARB's F-gas Reduction Incentive Program (FRIP)
  - A2L[1] safety fact sheets for contractors
- Collaboration and research needs:
  - How to incentivize refrigerant recovery and leak repairs
  - HVAC technologies: How to reduce cost barriers for CO_2 and code barriers for propane
  - Engage California Public Utilities Commission (CPUC), CARB, and the IOUs on new baseline and measure cases, costs to consumers, and enforcement approaches would significantly improve the feasibility of low-GWP measure packages.
  - There is opportunity for SCE to be involved in advancing new codes and technologies:
    - Engage with ASHRAE Standing Special Project Committee 15, Technical Committee 10.1, and Technical Committee 9.1 on CARB-funded propane safety code research, particularly for HVAC technologies.
    - Stay informed with the recommendations from CARB's SB 1206 natural refrigerant transition report (expected July 2026) to look for IOU opportunities to accelerate the market towards natural (a type of ultra-low GWP) refrigerants.
    - Monitor ongoing ultra-low-GWP field demonstrations and engage with energy efficiency stakeholders to ensure results can be used for measure package development.

Deliverable format

An Excel workbook ("Market Study of Low-GWP Refrigerants") accompanies this report and provides detailed data and references. Refer to the workbook in tandem with this report to easily find

[1] A2L refrigerants are non-toxic, lower flammability, and lower burning velocity

information of interest. The workbook content includes high level summaries, analyses, lists of resources, and reference materials.

1 Introduction

1.1 Purpose of Project

The overall goal of this project is to **explore the market barriers and opportunities for low and ultra-low global warming potential (GWP) refrigerants and understand the implications for Southern California Edison's (SCE's) commercial and industrial (C&I) offerings**.

The specific research objectives include:

1. Identifying changes to assumptions for deemed measures.
2. Understanding customer drivers and barriers to support program delivery.
3. Reviewing statewide and national codes for low-GWP refrigerants for C&I technologies.
4. Identifying source information for potential new offerings.
5. Summarizing the findings from the project in a final report.

The project's methodology included:

1. Identifying assumptions in current measure packages (MPs) for C&I technologies.
2. Reviewing recent studies of low and ultra-low-GWP C&I technologies to compare the latest market research with the assumptions in measure packages, to identify customer drivers and barriers to low and ultra-low-GWP refrigerants, and to identify measure opportunities.
3. Reviewing the latest codes and standards and other policies related to low-GWP refrigerants affecting C&I technologies.
4. Conducting 3 interviews with 9 investor-owned utility (IOU) staff, 1 interview with 2 California Air Resources Board (CARB) staff, and discussions with 6 subject matter experts.

This report is accompanied by a workbook titled "Market Study of Low-GWP Refrigerants" that contains additional information and resources gathered during this study; see Appendix B: Workbook Contents for a description of the content in the workbook.

1.2 Definitions and Refrigerant Classifications

To maintain consistency in our discussions, we will use the following definitions for refrigerant categories in this report. In Table 1 we defined these using California's SB 1206 regulation that governs refrigerant GWP limits; for standard GWP refrigerants, we adopt the EPA's limit of 700 because it is more stringent than SB 1206's limit of 750.

Table 1: Refrigerant GWP Categories Used in this Report

GWP	GWP Class	Source
<10	Ultra-Low-GWP	**SB1206**
10<X≤150	Low-GWP	**SB1206**
150<X≤700	Standard GWP	**EPA**

GWP	GWP Class	Source
>700	High GWP	**SB1206**

ASHRAE classifies refrigerant safety based on flammability level and toxicity level. **Error! Reference source not found.** shows the ASHRAE safety classifications. The "L" subclass indicates that they are of lower burning velocity (<10 cm/sec) compared to A2 or B2 subclasses, so they are less flammable. As detailed in Appendix D: Refrigerant Resources: Refrigerant Drivers and Barriers, most of the high GWP refrigerants are A1, while most of the standard GWP refrigerants are A2L, and some of the ultra-low-GWP refrigerants are A3 or B2L. A major challenge in the market has been shifting to lower GWP refrigerants while ensuring safety.

Figure 1: ASHRAE Refrigerant Safety Classifications (*UNEP/ASHRAE Refrigerant Fact Sheet #1—Update on New Refrigerants Designations and Safety Classifications*, 2022)

SAFETY GROUP

Increasing Flammability →

Higher Flammability	A3	B3
Lower Flammability	A2 A2L*	B2 B2L*
No Flame Propagation	A1	B1
	Lower Toxicity	Higher Toxicity

Increasing Toxicity →

Another distinction when discussing refrigerants is whether the refrigerant is synthetic or natural. Most synthetic refrigerants contain per- and polyfluoroalkyl substances (PFAS), which are already prohibited in some countries and states. PFAS are a group of human-made 'forever chemicals" that do not break down in the environment and pose serious health risks to humans (Verzeletti, 2025). California restricts PFAS in consumer products such as textiles, cosmetics, and food packaging; California may restrict PFAS in refrigerants in the future, so it is important to be aware of which refrigerants contain PFAS. In this report, we also refer to natural refrigerants – these are refrigerants that occur naturally and are not produced synthetically. Common natural refrigerants are CO_2 (R-744), propane (R-290), isobutane (R-600a), and ammonia (R-717). Natural refrigerants do not contain PFAS. PFAS is found in some synthetic refrigerants, but not all synthetic refrigerants contain PFAS.

2 Key Findings and Recommendations

This section summarizes key findings and opportunities related to the refrigerant transition identified throughout this study. Later sections of the report outline these strategies in greater detail. These **recommendations are listed in order of urgency**, where the most urgent are first.

2.1 Deemed Measure Recommendations

Finding: The California Public Utilities Commission (CPUC) is selective with proposed measure packages, and the success of a measure package depends on program implementer demand (Interview with SCE)**.** The calculation of refrigerant GWP benefits is feasible within the current structure of the Refrigerant Avoided Cost Calculator (RACC), but data collection and eligibility will require additional work (Interview with SCE). Measure developers should ensure that a high-demand market segment will use the proposed measure package to promote adoption of the intended technology.

Strategy: Ultra-Low-GWP refrigerant supplemental incentives: Offer a supplemental incentive to leapfrog from hydrofluorocarbons (HFCs) directly to carbon dioxide (CO_2) or propane (R-290) systems. Combining ultra-low-GWP kicker incentives with other energy efficiency incentives will make it easier for customers to invest in projects. To leverage the refrigerant valuation capability already built into the RACC tool, measure packages must allow the user to claim the portion of the total system benefit (TSB) from the difference in refrigerant GWP between the baseline and measure case (*Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance*, 2024). The RACC calculates the value of refrigerant avoided cost by determining the lifecycle refrigerant emissions and costs, including the end-of-life refrigerant leakage, using CARB-provided emission estimates (*Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance*, 2024). These deemed measures would be new offerings that do not need to abide by the DEER update cycle – they would go live once they're approved by the CPUC.

Focus on one key market segment for low-GWP incentives to show proof of concept. IOUs should have discussions with program implementers to determine the market segment with the greatest potential demand and design a measure pathway for that customer segment.

Idea 1: Measure package kicker for propane reach-in refrigerators and freezers. Standalone commercial refrigeration unit retrofit programs could be a good fit to incentivize change before regulations mandate it (*California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses*, n.d.). For example, ultra-low-GWP retail food refrigerator and freezer technology is readily available (*Product Finder — ENERGY STAR Certified Refrigerators and Freezers*, n.d.). Still, many small businesses keep legacy refrigerant systems to delay the cost of system replacement, even those who inherit older equipment when starting a new business (CADMUS, 2024). This market segment could benefit greatly from the accelerated replacement of existing standalone systems and higher incentive rates for ultra-low-GWP systems and is an area for high-impact investment. Small businesses in disadvantaged communities (DACs) could benefit greatly from incentives and resources to upgrade to ultra-low-GWP refrigerants. (Sources: (CADMUS, 2024); Interviews with SCE and PG&E, 2026; Interviews with TRC SMEs, 2026)

Idea 2: Measure package kicker for CO_2 heat pump water heaters. Customers are still installing gas water heaters because of the high upfront and high operating costs of heat pump water heaters in areas where gas is cheaper than electricity (Powers, 2025; Valmiki et al., 2025). On top of that,

CO_2 units generally cost more because they are more expensive to manufacture to account for higher operating pressures and temperatures (Powers, 2025; Valmiki et al., 2025). To encourage the market towards CO_2 heat pump water heater (HPWH), a kicker incentive would help lower the high first cost for consumers. The 2028 Database of Energy Efficient Resources (DEER) Scoping Memo was recently released, proposing a Net-to-Gross ratio (NTG) of 1 for CO_2, allowing users to claim more savings from CO_2 systems and making a measure for this equipment more appealing (Energy Efficiency Branch, CPUC, 2026b). The current measure case refrigerant in the RACC is R-134a, which has a GWP of 1430, compared to CO_2's GWP of 1 (*Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance*, 2024). R-134a can be a reasonable baseline for an add-on measure, given that 590 of 740 products in the ENERGY STAR HPWH database use R-134a, compared to 95 products that use CO_2 (ENERGY STAR, 2026).

Section 3.2.3 contains COP and refrigerant charge data for CO_2 HPWHs over 100 gallons, and uniform energy factor (UEF) data for HPWHs in the ENERGY STAR database.

2.2 Pilots and Custom Offerings Recommendations

Finding: The Food Refrigeration Investment Program (FRIP) can provide a maximum of $750,000 per project for a supermarket conversion, whereas projects can cost several million dollars and require the store to shut down for weeks to months at a time. This leads to many potential candidates ultimately abandoning their projects (Source: Interview with CARB). According to CARB's Refrigerant Management Program, 75% of refrigeration systems are in food retail facilities, 12% are in industrial process facilities, and 8% are in cold storage and other refrigeration facilities (*RMP: Distributors, Wholesalers & Reclaimers | California Air Resources Board*, n.d.). To date, CARB has awarded $7M across 29 projects to reduce 220,000 Metric Tons of CO_2; this is an average of roughly $240,000 per project (CARB, n.d.-b). Of these 29 projects, 20 of them use R-744. The FRIP projects cost $32 per Metric Ton of CO_2 reduced, on average; for retail food, this average is $48 per $MTCO_2$ reduced, compared to $70 per $MTCO_2$ for industrial and $16 per $MTCO_2$ for cold storage (CARB, n.d.-b).

Strategy: Collaborate with CARB on the development of a custom measure pathway for large grocery store conversions to CO_2 refrigeration systems. During our interview with CARB, they expressed interest in helping IOUs develop streamlined programs that can supplement FRIP funding, as funding remains a large barrier to natural refrigerant transition projects for large grocery stores. This may require a CPUC decision stating that a claim on the refrigerant avoided cost can be approved independent of the energy savings; without a decision such as this, a new measure pathway will need the ability to document energy savings from the project which may or may not be feasible, depending on the conversion. Furthermore, the ability to claim refrigerant savings over the existing refrigerant in the system, rather than a lower GHG standard refrigerant would support deeper savings and higher incentives.

CARB recommends incentivizing the grocery store systems with greater than 50 pounds of refrigerant to have the most impactful investment. There are about 6,000 facilities in California with 25-30,000 systems that have greater than 50 pounds of refrigerant, according to CARB. Often, these systems are being repaired rather than replaced, which keeps high-GWP refrigerants in use. Transitioning them to CO_2 would have a substantial impact and GHG emissions reductions. (Interview with CARB, 2026).

Finding: The recent EPA Technology Transfer Rule Reconsideration leaves a regulatory incentive gap for supermarket systems, remote condensing units, and cold storage warehouses with less than 50 pounds of refrigerant to transition to ultra-low-GWP

refrigerants (*Phasedown of Hydrofluorocarbons*, 2025). **Walk-in coolers and freezers have high market potential in DACs**, according to a March 2026 CalNEXT report (Wiseman et al., 2026). New walk-in cooler and freezer technologies can work within the 150-gram charge limit for A3s and provide sufficient cooling, which presents an opportunity to go beyond regulations and install ultra-low-GWP propane technology. These systems are not eligible for CARB FRIP funding because their refrigerant charges are less than 50 pounds. There are an estimated 337,000 buildings in California that have at least one walk-in cooler and freezer, with many of these operated by small, independent retailers in disadvantaged communities (Wiseman et al., 2026). “Affordable and reliable refrigeration is essential for food security for the more than 2.6 million Californians living in low-income, low-access areas.” (Wiseman et al., 2026).

Strategy: New pilot program or field demonstration for propane walk-in coolers and freezers. Supporting the adoption of cost-effective packaged propane systems in these communities can help achieve both emissions goals and food security goals. The March 2026 CalNEXT report by Wiseman et al. provides details on these systems, including avoided cost benefits from reducing refrigerant leaks and unit refrigerant costs related to changes in refrigerant type and volume, which can be used to help design deemed measures. However, it also identifies technical issues that are a barrier to the mass deployment of these systems. Through discussions with the authors of that study and with CARB, TRC has determined that further field demonstrations of this equipment are required but they are a strong candidate for future measure packages. TRC recommends a pilot program or field demonstration of this equipment, with targeted incentives for small and medium food retail businesses. Developing and running this type of program to determine the Net Metered Energy Consumption (NMEC) would ensure that there are actionable findings for measure package developers to create future measures for these products.

Finding: Despite the availability of training resources on the safe use of A2Ls, many contractors do not make use of them and engage in unsafe practices such as not using spark resistant equipment or not following proper recharging protocol (Forth et al., 2026)**.** For the safe adoption of A2Ls, contractors need to purchase the necessary spark-resistant equipment and get the proper safety certification. Reducing friction for contractors to learn about and perform safety practices directly lowers the price the end customer sees (KGG Consulting, 2025).

Strategy: Provide fact sheets or education programs for installers of A2L refrigerants. There are opportunities for regional energy networks (RENs) or utilities to educate contractors about costs, codes, and safety standards for these new products. TRC recommends encouraging contractors to use the resources provided by industry organizations and equipment manufacturers to learn about the safe use of these refrigerants – See Appendix C: 8.3 Training Resources for Refrigerant Safety.

2.3 Collaboration Recommendations and Research Needs

Finding: Only a small percentage of refrigerants are recovered at the end of their useful life (Scheehle et al., 2026)**.** CARB’s GWP limits do not restrict the use of R-410A in HPWHs and Industrial Process Refrigeration now or in the future and have allowed various types of HVAC equipment to be sold with R-410A within the past three to four years (*California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses*, n.d.). Starting in 2030, CARB will require manufacturers to stop selling virgin R-410A; and users who have a newly installed R-410A will need to use recycled refrigerant for any maintenance. However, there is an insufficient amount of recovered refrigerant to meet the projected demand (Slater et al., 2026). To create a recycled R-410A refrigerant market, contractors need to recover it from retiring units so that reclaimers can process it to be used again.

For non-residential facilities, CARB requires that any person performing installation, maintenance, service, repair, or disposal of stationary appliances that could release standard or high GWP refrigerant must make a recovery attempt (RMP: Distributors, Wholesalers & Reclaimers | California Air Resources Board, n.d.). However, many refrigerants are not recovered at the end of the equipment's useful life, according to reports from contractors (Scheehle et al., 2026).

Strategy: Research is needed on how to incentivize refrigerant recovery, tracking, and leak repair. To prevent the ventilation of refrigerants directly into the atmosphere, TRC recommends further research on methods to ensure that CARB's Refrigerant Management Program (RMP) is followed to properly capture and dispose of refrigerants when the equipment is retired. Currently, the CPUC does not allow customers to claim benefits for recapturing refrigerant from non-residential systems because recovery is required by the RMP, yet there is evidence that RMP is not followed (Forth et al., 2026). Giving contractors a financial benefit for recapturing refrigerant would offset the opportunity cost of time spent recovering refrigerant and could move the needle on RMP adoption (CADMUS, 2024); Interview with Pacific Gas & Electric (PG&E)), 2026). Other ideas to study for recovery incentives include:

- **How to boost reclaim market** until market forces takeover
- How reclaimed payment can **offset opportunity costs,** whether it should be pre-paid
- Whether connecting contractors to reclaim facilities would increase recovery
- Whether RMP adoption could be increased through training or requiring reclaiming to get contractor license
- Whether refrigerant recovery should be written into MPs as an eligibility requirement to ensure that they are captured

Additionally, CARB requires any amount of refrigerant leak to be repaired within 14 days of detection. Leak inspections are required for non-residential systems using standard or high GWP refrigerants either annually for small systems (50-200 pounds refrigerant), quarterly for medium systems (200-2,000 pounds refrigerant), or monthly for large systems (2,000+ pounds refrigerant) (*RMP: Distributors, Wholesalers & Reclaimers* | *California Air Resources Board*, n.d.). TRC recommends supporting MPs such as the proposed "Lifecycle Refrigerant Management, Commercial", which proactively fixes leaks and documents leak causes, energy and greenhouse gas (GHG) impacts, and repair costs. A pilot leak repair program could make use of this measure package incentive, and data collected during a pilot would inform tools and calculations – this was recently proposed as a key element to phase out natural gas measures in a CPUC Proposal (Energy Efficiency Branch, CPUC, 2025).

Finding: To drive heating, ventilation, and air conditioning (HVAC) towards ultra-low-GWP options, innovation is needed for lowering manufacturing costs (CO_2) and reducing code barriers (propane). CARB requires HVAC equipment to use refrigerant with GWP less than 750 (*California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses*, n.d.). Despite a historical barrier of increased costs from A2Ls, this has not affected the proliferation of A2L products – over 91% of products used < 750 GWP A2L refrigerants as of Q4 2025 (Heating Air Conditioning & Refrigeration Distributors International, 2025). Given the high market penetration of these products, there is no further need beyond these regulations to incentivize customers to switch to equipment with < 750 GWP refrigerants. Additional research and development are needed to drive HVAC refrigerants towards ultra-low-GWP alternatives. Current ultra-low-GWP options either face cost barriers (for CO_2) or code barriers (for propane) in the United States, despite their proliferation in Europe and Asia (KGG Consulting, 2025; Scheehle et al., 2026; Stewart et al., 2023).

Strategy: Engage CPUC and CARB to create alignment on regulations and enforcement. Based on IOU interviews**,** there is confusion among program administrators about how CARB will enforce regulations and concerns about the ability to offer incentives to promote a switch to low-GWP refrigerants if the law requires it, such as for new retail food refrigeration equipment (Interviews with SCE and PG&E, 2026). Aligning with CPUC and CARB on using regulations to establish the new baseline and measure cases and how to leverage funds to support the push of these new refrigerants would create a top-down motivation for low-GWP MPs, where the bottom-up efforts have failed. Additionally, CARB intends to enforce GWP limits in existing facilities with more than 50 pounds of refrigerant using the annual reporting that the Refrigerant Management Plan (RMP) requires (Interview with CARB, 2026). Guidance from CARB on future regulations and their enforcement would inform MP developers when creating an ultra-low-GWP kicker for measure packages. CARB is planning to release a natural refrigerant transition plan in July of 2026 (Interview with CARB, 2026). TRC recommends reviewing this report to determine if it answers these questions and following up with CARB for any clarification.

- **Create a consensus on the costs for customers.** There is uncertainty among measure developers whether low-GWP equipment will increase first and operating costs for customers even after incentives, and whether the upcoming regulations will make rebates and MPs obsolete for low-GWP equipment (Interviews with SCE and PG&E, 2026). Regulators, measure developers, and program implementers need to collaborate on what the costs will be for end users to design programs with higher uptake.
- **Be involved in the development of A3 codes**. ASHRAE is conducting CARB-funded research on propane safety to develop the next generation of propane standards that would allow propane in more applications for HVAC (Scheehle et al., 2026). ASHRAE estimates this research project to be completed by the end of 2027 (Interview with CARB, 2026).
- **Keep an eye out for SB 1206 refrigerant transition report.** CARB anticipates publishing a natural refrigerant transition report with recommendations for incentives in July 2026 (Interview with CARB, 2026).
- **The 2028 Database of Energy Efficient Resources (DEER) Scoping Memo** was recently released, proposing a Net-to-Gross ratio (NTG) of 1 for CO_2, allowing users to claim more savings from CO_2 systems and making a measure for this equipment more appealing (Energy Efficiency Branch, CPUC, 2026b). Incorporating all other ultra-low-GWP refrigerants into this proposal would give a greater financial benefit to measures using these refrigerants.

Strategy: Ongoing monitoring of field demonstrations. As low-GWP technologies are field tested, the deemed measures team should follow the results of these studies to identify viable technologies for deemed measure packages. TRC recommends monitoring these and engaging energy efficiency stakeholders so that they have the data needed for measure package developers. TRC identified a few upcoming projects that could be of interest to SCE:

- **Field Assessment of R-454C Compared to R-404A / CO_2 Supermarket Systems | Energy Transition Coordinating Council (ETCC)** – Active project assessing R-454C, R-404A, and R-744 (CO_2) performance in supermarket systems.
- **CARB FRIP – A3 Monobloc Heat Pump Risk Assessment** – Active project, awarded to Air-Conditioning, Heating, and Refrigeration Technology Institute at the end of 2025.

- **CARB FRIP Solicitation – Commercial and Industrial Refrigeration** – Now Accepting Applications through 3/31/26.
- **CARB is creating a field demonstration program for walk-in coolers and freezers using propane and remote condensing units using CO_2** (Interview with CARB, 2026). These could be good candidates for future deemed measures. Involvement by SCE in this program would help ensure that the outputs are actionable for measure package developers.

3 Key Deemed Measure Cases of Interest

Specific cases emerged throughout the study that are either opportunities for deemed measures where the regulations are most relaxed or cases where regulations are too stringent. This section investigates those further to evaluate the feasibility of measure packages containing this equipment. TRC investigated key opportunities to expand deemed measure package offerings where low-GWP technology can reach beyond regulatory goals or take advantage of mechanical code changes. This included:

1. **Standalone food refrigeration using propane or isobutane**: The 2025 California Mechanical Code sets A3 refrigerant charge limits at 300 or 500 grams for open- or closed-door standalone food refrigeration, allowing for propane and isobutane to be used in larger refrigerators and freezers (*2025 California Mechanical Code Title 24, Part 4*, 2025). Because there is ultra-low-GWP equipment available on the market, there is opportunity for additional GHG savings beyond the CARB and EPA low-GWP (< 150) refrigerant requirements.
2. **Heat pump water heaters using CO_2**: Another opportunity lies in the CO_2 heat pump water heater market, which has been field tested in California and shown up to a 61% reduction in total grid system cost at the tradeoff of an 88% energy cost increase for the customer (Valmiki et al., 2025). An incentive for these systems could help mitigate this barrier and improve adoption rates. The 2028 DEER Scoping Memo was recently released, proposing a Net-to-Gross ratio (NTG) of 1 for CO_2, allowing users to claim more savings from the program (Energy Efficiency Branch, CPUC, 2026b). This further demonstrates the potential of a CO_2-based measure package, given that a typical NTG is around 0.6.
3. **HVAC using ultra-low-GWP refrigerants**: The 2025 California Mechanical Code allows A2L refrigerants to be used in HVAC applications, which led to a surge of R-32 (GWP = 675) and R-454B (GWP = 466) units on the market in 2025 (*2025 California Mechanical Code Title 24, Part 4*, 2025; KGG Consulting, 2025). These refrigerants meet the GWP limits for HVAC set by CARB and EPA but there is opportunity for additional GHG savings from using ultra-low-GWP refrigerants.

At the end of each of the following subsections there are summaries of TRC's recommendations for SCE that include a stoplight figure next to them to indicate the technology's readiness for deemed measure package development. Green means the technology is ready to go, yellow means that further research is needed, and red means that it should not be pursued.

3.1 Commercial Refrigeration

There are two classes of commercial refrigeration equipment: a full refrigeration system for grocery stores, and small stand-alone equipment, such as reach-in refrigerators. Modernizing equipment can unlock non-refrigerant benefits that save energy and offer flexibility (e.g., new features, efficiency, operating improvements) (Faramarzi et al., 2024).

3.1.1 CARB and EPA GWP regulations

Standalone refrigeration units

The EPA GWP limit for new refrigeration standalone units was set at < 150 GWP as of 2025 (US EPA, 2022). CARB regulates refrigeration equipment for retail food refrigeration based on the amount of refrigerant; new equipment containing more than 50 pounds of refrigerant must have a GWP < 150 (*California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses*, n.d.). CARB does not have a GWP limit for standalone refrigeration units with less than 50 pounds of refrigerant – equipment of this size falls under the EPA GWP limit of < 150 GWP.

Large refrigeration systems (over 50 pounds refrigerant)

The CARB GWP limits for cold storage warehouses, supermarkets, and retail food remote condensing units apply to new systems with more than 50 pounds of refrigerant, and the limit is set at 150 GWP. The EPA limits for these end uses was 150 GWP or 300 GWP, depending on the amount of refrigerant (less than or greater than 200 pounds) or the high temperature side of the cascade system. On May 26, 2026, the EPA released a final rule reconsideration regarding the GWP limits for cold storage warehouses, supermarkets, and retail food remote condensing units (*Phasedown of Hydrofluorocarbons*, 2025). It sets the current GWP limits for remote condensing units and supermarkets to 1,400 and for cold storage warehouses to 700, and it pushes back the GWP limits of 150 and 300 to 2032, as shown in Table 2. Because the CARB GWP limits for these end uses only apply to cases in which there are 50 pounds of refrigerant or more, the EPA final rule reconsideration leaves the cases where there are less than 50 pounds of refrigerant without a regulatory incentive to transition to low- or ultra-low-GWP refrigerants. This opens the door for financial incentives to encourage the transition to ultra-low-GWP refrigerants for cold storage warehouses, supermarket systems, and remote condensing units.

Table 2. CARB and EPA GWP limits for large refrigeration systems

	CARB	EPA (2026)	EPA (2032)
Supermarkets	150 (>50 lb. refrigerant)	1,400 (all systems)	150 (>200 lb. refrigerant) 300 (<200 lb. refrigerant)
Cold storage warehouses	150 (>50 lb. refrigerant)	700 (all systems)	150 (>200 lb. refrigerant) 300 (<200 lb. refrigerant)
Remote condensing units	150 (>50 lb. refrigerant)	1,400 (all systems)	150 (>200 lb. refrigerant) 300 (<200 lb. refrigerant)

As of 2026, CARB requires companies owning or operating greater than 20 retail food facilities in California to meet a company-wide GWP limit. This limit is the average GWP for all of their refrigeration equipment containing more than 50 pounds of refrigerant. By December 31st, 2026, the company-wide weighted average must be less than 2,500 GWP, or they must demonstrate a 25% or greater reduction in GHG below 2019 levels. In 2030, this GWP limit lowers to 1,400 (or 55% reduction in GHG below 2019 levels). CARB will require companies owning or operating fewer than 20 retail food facilities in California to meet this same 1,400 GWP limit by Jan 1, 2030.

There is an opportunity here to go beyond the regulatory requirements and incentivize a shift to ultra-low-GWP equipment before the January 2030 deadline hits. An incentive for businesses to meet the GWP limits before the deadline may help avoid inventory issues, such as those that happened during Q3 2025 when the HVAC market transition to A2Ls (KGG Consulting, 2025).

3.1.2 Relevant code requirements

New retail food refrigeration products are available with ultra-low-GWP refrigerants: propane (R-290) is sold in smaller standalone systems and CO_2 (R-744) in large refrigeration systems, in addition to incumbent high GWP refrigerants (TRC, 2021).

Large refrigeration systems (over 50 pounds refrigerant)

Because CO_2 is in the A1 safety class, it does not face significant difficulties for code compliance. Because of the higher pressure and temperature of these systems, refrigerant lines must be fully replaced to handle the operating conditions (TRC, 2021).

Standalone refrigeration units

Propane being an A3 refrigerant means that it faces more complicated code requirements. Unlike other refrigerants whose charge limits are relative to the size of the occupied space, the mechanical code limits propane by the total charge amount (*2025 California Mechanical Code Title 24, Part 4*, 2025). Propane appliances must be factory sealed. The most relevant regulations and standards for propane are the EPA Significant New Use Policy (SNAP), ASHRAE 15-2022, and UL 60335-2-89. Both SNAP and ASHRAE 15-2022 mention UL 60335-2-89 as the guideline for refrigerant charge limits in retail food appliances (ASHRAE, 2022; Significant New Alternatives Policy, 2014). Underwriters Laboratories (UL) updated UL 60335-2-89 in 2021 to allow for higher propane charges in commercial self-contained, plug-in displays based on open or closed design (Underwriters Laboratories, 2025). Open-door appliances have a charge limit of 500 grams, and closed-door appliances have a charge limit of 300 grams. UL 60335-2-89 still limits most other self-contained systems to 150 grams. Other codes refer to this standard as well:

- California Fire Code aligns with UL-60335-2-89 on charge limits for propane and requires a machinery room for exceeding high probability system limits (*2025 California Fire Code Title 24, Part 9*, 2025).
- National Fire Code requires areas using propane to be designated as a Class 1 Division 1 or 2 hazardous location and defers to ASHRAE 15 guidance (*GSA Fire Code 2024 Based on the International Fire Code 2024 (IFC 2024)*, 2024).

For most standalone refrigeration units, the limits are 300 g (closed-door) and 500 g (open-door), which is generally a sufficient charge for these types of systems.

For applications that do not use these appliances and that require more than 150 grams, the equipment must be in a machinery room with the proper safety precautions or be located outdoors. It is important to note that even following these guidelines, approval from the authority having jurisdiction may still be necessary. Section 1103.3 of the 2025 California Mechanical Code states that “Group A3 and B3 refrigerants shall not be used except where approved by the Authority Having Jurisdiction” except in listed self-contained systems, industrial occupancies, and laboratories with more than 100 square feet (*2025 California Mechanical Code Title 24, Part 4*, 2025).

3.1.3 Market barriers and opportunities

Standalone refrigeration units

Small food retailers can benefit from small propane refrigeration units. In an interview, CARB agreed that a supplemental incentive for propane standalone refrigeration units would work well particularly for small businesses – as demonstrated in the CDFA's Healthy Refrigeration Program. Propane is a cheaper option for small and medium businesses and contractors can install them without needing additional training, since these systems are self-contained (Forth et al., 2026). An accelerated replacement (AR) incentive for propane self-contained systems would be very impactful for small businesses (Interview with CARB). Many small and medium businesses tend to miss out on incentives because they are not aware of them (Scheehle et al., 2026).

In addition to GHG savings, the newer ultra-low-GWP equipment may offer operating energy savings: The National Renewable Energy Laboratory studied propane display cases and showed that they use 62% less energy than R-134A display cases (Bulk et al., 2022).

The main technical barrier for these units is the propane charge limit. UL-60335-2-89 increased the charge limit from 150 grams to 500 grams for open door appliances and 300 grams for closed door appliances. This new charge limit allows for a larger storage capacity up to around 75 cubic feet in some cases (Product Finder — ENERGY STAR Certified Refrigerators and Freezers, n.d.).

Propane display cases are common for smaller systems (such as those using < 150 grams of refrigerant) (*Product Finder — ENERGY STAR Certified Refrigerators and Freezers*, n.d.), but there are opportunities for the market to adopt propane in larger equipment capacities and in stores that have not had the capital cost to upgrade their smaller equipment. According to ENERGY STAR, there are 154 propane refrigerators and freezers that have a volume greater than 50 cubic feet, along with over 1,600 more units of smaller volumes, showing that there is equipment available to meet a fairly high cooling need (Product Finder — ENERGY STAR Certified Refrigerators and Freezers, n.d.).

Large refrigeration systems (over 50 pounds refrigerant)

New facilities and existing facilities have different incentives regarding full refrigeration systems. New facilities are primarily installing low-GWP refrigeration systems, typically using CO_2 in commercial systems and ammonia in industrial systems (TRC, 2021). These facilities must already pay an upfront cost to install equipment, therefore the newer low-GWP equipment is a better investment because of additional features that come along with the updated refrigerant. It is easier to install ultra-low-GWP systems in newly constructed stores, because the installation is not limited by existing equipment or the need to shut down the store (Scheehle et al., 2026).

There are ultra-low-GWP products on the market that can improve system efficiency and reduce GHG emissions. The main barrier to these systems stems from the retrofit itself. Existing facilities are very reluctant to replace existing refrigeration systems because refrigerant transition projects can cost up to half of the store's capital expenditure budget, according to a representative from Save Mart (Scheehle et al., 2026). Existing systems need to shut down, which reduces retail capacity and adds to the cost of the retrofit. For grocery store system conversion projects, they may need to close the store for weeks or months, which adds to costs via avoided revenue - this can be untenable, even with F-gas Reduction Incentive Program (FRIP) funding (Interview with CARB, 2026). FRIP is the CARB incentive program that was created to promote the adoption of low-GWP refrigerants; the first round targeted grocery stores and supermarkets and the second round addresses ultra-low-GWP in a variety of C&I sectors in addition to supermarkets (CARB, n.d.-a). If the whole system works on a certain refrigerant, the owner will not want to change out the refrigerant until they replace the whole system (TRC, 2021). Most existing facilities are planning to retrofit to R-448A (1,387 GWP) and R-449A (1,397 GWP), both of which are A1 refrigerants that can be drop-in replacements to existing systems, avoiding the need for long shutdowns (TRC, 2021). Some facilities are exploring options including systems using R-454A (239 GWP), R-454C (148 GWP), and/or R-455A (146 GWP) (TRC, 2021). These last three refrigerants have similar characteristics to their HFC counterparts regarding performance. It has been uncommon to retrofit an existing store with a full CO_2 refrigeration system or micro-distributed low-GWP systems (TRC, 2021). For the full refrigeration system retrofit to CO_2, existing facilities must also pay the additional cost of removing existing refrigerant lines to put in new lines that can handle the operating conditions of CO_2.

Small businesses and large retailers face different barriers and opportunities due to their sizes. Many of these food service facilities' ownership turns over quickly; if the business is not corporate, then the owner likely does not have spare funds to spend on a high first cost (Scheehle et al., 2026). Accelerated replacement of equipment faces persistent first cost barriers, because the owner is paying the extra cost of the new equipment rather than the marginal cost of one equipment type vs the other (Interviews with SCE and PG&E, 2026). In food service, burnout or major facility upgrades drive equipment turnover.

According to our interview with CARB, many of their potential grocery store system conversion projects have fallen through due to a lack of funding, even with FRIP support. There is a need in the market for supplemental incentives to the FRIP program that would motivate stores to move forward with grocery store system conversions. These would be targeted incentives for large grocery retailers that have existing systems that they need to convert to CO_2. **Additional support from the IOUs would help these projects move forward; a more standardized pathway for custom measures for grocery store system conversions would lower barriers for adoption (Interview with CARB, 2026).** Current custom pathways for energy efficiency programs have lengthy timelines and uncertainty about final approved values (Reynolds et al., 2024). To perform these projects, customers need high confidence in the final approved incentives and a commitment to short approval times to distribute funds (Reynolds et al., 2024).

CARB recommends incentivizing the grocery store systems with greater than 50 pounds of refrigerant to have the most impactful investment. There are about 6,000 facilities in California with 25-30,000 systems that have greater than 50 pounds of refrigerant, according to CARB. Often, owners repair these systems rather than replace them, which keeps high GWP refrigerants in use (Interview with CARB, 2026). Transitioning them to CO_2 would have a substantial impact and GHG emissions reductions.

3.1.4 Performance of Proposed Measure Technologies

Standalone refrigeration units

During our study, we identified two types of standalone refrigeration units with potential opportunities for the SCE deemed measures team. These are reach-in refrigerators and freezers and walk-in coolers and freezers. Both technologies can use propane refrigerant within the current charge limits. In this section, we analyze the availability and performance of these equipment types.

Reach-in refrigerators and freezers

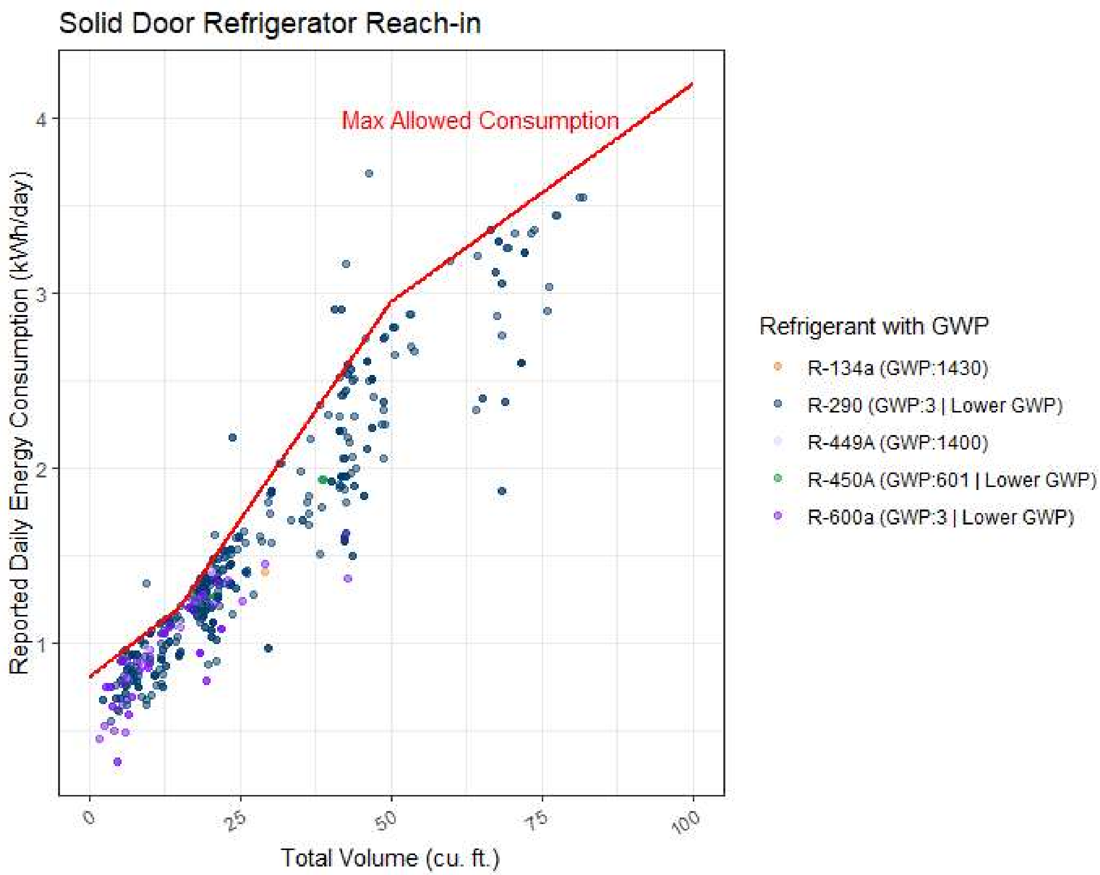
TRC compared the California Foodservice Instant Rebates list to the ENERGY STAR certified commercial refrigerators and freezers to determine whether products qualified for rebates use R-290 already (*California Foodservice Instant Rebates – With the California Foodservice Instant Rebates Program, Customers Can Get Valuable Instant Rebates on Qualifying Energy-Efficient Equipment for Their Businesses.*, n.d.; *Product Finder — ENERGY STAR Certified Refrigerators and Freezers*, n.d.). Table 3 shows the counts of these products by refrigerant type. However, there were 781 qualified refrigerators and 546 qualified freezers that were not in the ENERGY STAR database and therefore we did not find refrigerant data for these.

ENERGY STAR breaks their product data further down into solid door and transparent door appliances. The solid door reach-in refrigerator is the only product in this database that has other refrigerant options besides R-290 and R-600a (both ultra-low-GWP). This product has alternatives that use R-450A (GWP = 601), R-449A (GWP = 1400), and R-134a (GWP = 1430).

Table 3. Counts of commercial refrigerators and freezers in the California Foodservice Instant Rebates list and the ENERGY STAR certified product list by refrigerant type.

	R-290	R-600a	R-450A	R-449A	R-134a	Refrigerant Unspecified
CA Instant Rebate Qualified refrigerators	155	42	14	1	1	781
CA Instant Rebate Qualified freezers	112	3				546
ENERGY STAR refrigerators	602	85	14	6	1	
ENERGY STAR freezers	260	2				

Figure 2. ENERGY STAR efficiency for solid door reach-in refrigerators, overlaid with the maximum allowed consumption in the existing measure package specification.



In smaller capacity refrigerators, the R-290 and R-600a systems are slightly more efficient on average compared to the other refrigerant alternatives, as seen in **Error! Reference source not found.**. These refrigerants also have a higher total system benefit because they have a much lower GWP compared to the alternatives.

TRC could not identify a product database that contained refrigerant charge data; to meet this need, we reviewed a sample of product specification sheets. Based on 6 specifications, a typical refrigerant charge for reach-in refrigerators using propane is between 59 to 150 grams, as shown in Table 4. It is unclear whether there is a direct correlation between volume and charge, therefore TRC recommends further research into this subject.

Table 4. Refrigerant Charges for a Sample of Solid Door Reach-in Refrigerators

Model name	R-290 charge	Volume (cubic feet)	Efficiency (kWh/day)
Beverage-Air HRP1HC	3.8 oz. (110 g)	21.2	1.4
Avantco Z1-R-HC	2.1 oz. (59 g)	21.3	1.5

Avantco Z2-R-GHC	3.9 oz. (111 g)	43.6	3.2
Avantco A-49R-HC	4.6 oz. (130 g)	46.7	2.2
Traulsen G30010	4.5 oz. (128 g)	69.3	
Beverage-Air HR3HC-1S	5.3 oz. (150 g)	71.5	2.6

Walk-in coolers and freezers

Measure description: Packaged propane systems are self-contained units integrating the compressor, evaporator, and condenser components. They are designed for through-the-wall or ceiling installation in walk-in coolers and freezers (WICFs), do not require refrigerant piping, and have charge sizes under 150 grams (Wiseman et al., 2026). As discussed above, the limit of the refrigerant charge for propane is 150 grams for all appliances other than reach-ins. They work for small-to-medium-sized restaurants, grocery stores, and convenience stores. They are modular and suitable for retrofits and space-constrained environments.

Energy Performance: Propane WICFs are a promising application because they can operate under the charge limit and operate much more efficiently. The recently published CalNEXT final report identified propane WICFs as a measure package opportunity (Wiseman et al., 2026). Recent analysis of propane WICFs showed an average energy reduction of 54% for medium temperature systems and 38% for low temperature systems compared to baseline HFC condensing units, and 99% lower refrigerant-related emissions (Wiseman et al., 2026). The study found that this could save $1,400 and $700 annually per unit for medium and low temperature systems, respectively, with an additional $100 per unit annual savings from refrigerant costs.

Barriers: Based on conversations with CARB, some technical issues have thus far prevented mass-market adoption. For instance, these units currently have the compressor mounted on top of the unit, which restricts their use to applications with enough ceiling clearance. Development of a wall-mounted unit would open the market to more diverse retrofit applications. Additionally, the field performance of these units in the two demonstration cases from Wiseman et al. was reported to be lower than the manufacturer's specifications, which could indicate unforeseen performance, installation, or commissioning issues. It is typical for equipment to perform worse in the field than in the specifications, but it was beyond the scope of this project to determine whether this underperformance was worse than is typical. Because these products are so new to the market, it will take more field testing to address these issues.

Issues facing WICFs (Wiseman et al., 2026):

- System size limitations due to 150g propane charge cap.
- Technician training and availability – requires EPA 608 certification for propane.
- Space constraints: current units have ceiling-mounted compressors, which are restricted by the room ceiling height. The certification of wall-mounted designs would unlock retrofit opportunities.
- Waste heat ejected into the room – when installed in unconditioned or tightly packaged kitchens, the waste heat from these indoor-mounted units can be unviable.
- Supply chain and equipment availability – most units are currently manufactured in Europe

and are available in the United States, but availability could be subjected to global macroeconomic events.

- Propane misinformation and flammability concerns – misconceptions about the safety of propane contribute to contractor and end-user hesitation.
- End user knowledge – small business owners are unaware of propane options and overloaded by refrigerant regulations.
- Limited awareness of systems and lack of incentive programs – existing incentive programs focus on larger systems, which exclude small businesses
- CARB FRIP is only used for systems over 50 pounds of refrigerant, excluding small businesses with low-charge systems.

3.1.5 Recommendations for SCE

These deemed measures would be new offerings that do not need to abide by the DEER update cycle – they would go live once they're approved by the CPUC.

Measure Package Supplemental Incentive: Reach-in refrigerator or freezer (SWCR018) - accelerated replacement (AR): kicker for propane and isobutane

Measure Opportunity: Almost all of the products analyzed in Section **Error! Reference source not found.** met the maximum allowed consumption for the IOUs' current measure package, as shown in Figure 2. Our analysis in Section 3.1.4 showed that a majority of the units listed on ENERGY STAR use R-290 or R-600a, therefore a measure would need to encourage the accelerated replacement of existing units. A supplemental accelerated replacement incentive could drive consumers towards the ultra-low-GWP alternatives.

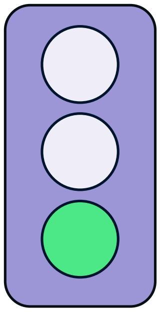
Since there is already a measure package (SWCR018) that allows end users to claim rebates for these equipment types, a kicker incentive would need to allow users to claim the TSB from the propane or isobutane refrigerant using the RACC. This capability is built into RACC functionality, so the measure developers would need to design the measure package to let the user claim the TSB for propane or isobutane. The RACC calculates the TSB of refrigerant avoided cost by determining the lifecycle refrigerant emissions and costs, including the end-of-life refrigerant leakage, using CARB-provided emission estimates (*Refrigerant Avoided Cost Calculator and Fuel-Sub Calculator Technical Guidance*, 2024).

To do this, the refrigerant charge information is needed for the typical equipment. See Section **Error! Reference source not found.** for charge data.

If existing equipment is still operating, users can claim the existing condition for accelerated replacement and use a dual baseline to calculate savings. Note that accelerated replacement measures require a preponderance of evidence to be eligible for the incentive.

Recommendation: TRC recommends that SCE invest in the development of a supplemental accelerated replacement measure package for propane or isobutane reach-in refrigerators and freezers (Table 5).

Table 5. Propane Reach-in Refrigerator and Freezers Measure Details



Measure Opportunity	Reach-in refrigerator or freezer
Required GWP limit	GWP < 150 (per EPA; CARB has no limit)
Potential measure	Supplemental accelerated replacement incentive to existing measure SWCR018 for using propane or isobutane (GWP = 3)
Codes limiting use	EPA SNAP, ASHRAE 15-2022, and UL 60335-2-89 have charge limit of < 300 g (closed-door) or < 500 g (open-door), which is usually enough for equipment < 75 ft^3.
Equipment availability	ENERGY STAR product finder shows hundreds of propane or isobutane refrigerators and freezers available
Efficiency impact	Similar or better performance than low GWP
Primary market barrier	Cost of retrofit and knowledge of incentives

Pilot Demonstration: Walk-in coolers and freezers using propane

Measure Opportunity: A measure package does not currently exist for whole refrigeration systems for walk-in coolers and freezers. However, there is an existing measure for electronically commutated motor retrofits for a Walk-in Cooler or Freezer (SWCR004). A retrofit option for switching to a propane compressor may be an option but is likely to be difficult to combine with the existing measure due to additional safety measures required for A3 refrigerants. Developing a new measure package would require collecting baseline and measure efficiency and cost data for this equipment, as well as new construction and replacement installation costs. Measure developers could use a pilot demonstration to study the efficiency and energy performance of these systems, and they can gather costs from contractor interviews, regional equipment suppliers, and wholesale restaurant supply stores.

Despite the code restrictions that limit the size of these systems, there is an opportunity to leverage this technology for a key market segment in small businesses. There are an estimated 139,000+ food service and retail establishments operating an estimated 200,000 condensing units (Wiseman et al., 2026). These small businesses are likely not subject to CARB regulations that impose GWP limits on refrigeration equipment containing 50 pounds of refrigerant or more. Therefore, there is little incentive for them to update their systems until they break down and need replacement.

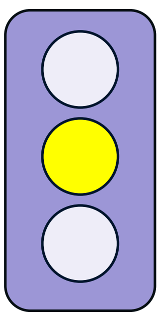
An estimated 16,000 condensing units are sold in California annually; analysis by Wiseman et al., 2026 shows that a 5% market penetration of existing annual sales would yield 950 megawatt-hours (MWh) in energy savings and 450 metric tons of avoided carbon emissions from 240 units. If expanded to retrofits and early replacement opportunities, the market potential increases dramatically.

A measure package incentive targeting this market specifically could go a long way towards helping small businesses stay up to date, reduce their carbon footprint, and reduce their overall energy consumption.

Recommendation: TRC recommends that SCE invest in the research and development of these products using pilot demonstrations and revisit it in the future for measure development. Details are available in Table 6. Additionally, SCE can maintain a qualified product list of UL-listed packaged propane systems, including system specifications and performance data. CARB is creating a pilot and demonstration program for propane WICFs – there could be potential for SCE to leverage or contribute to this program.

Once this technology is ready for the measure development stage, TRC recommends revisiting Wiseman et al., 2026 because it outlines how to create a measure package and an IOU program for this product. The writers of Wiseman et al. are not currently developing a new measure package for this product because further field demonstrations are needed to address the issues outlined in Section 3.1.4, according to a conversation with the authors.

Table 6: Walk in Coolers and Freezers Using Propane Measure Details



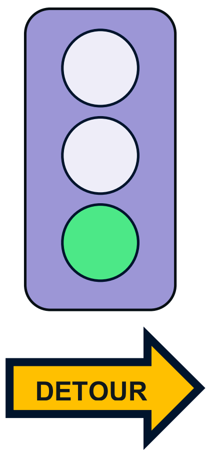
Measure Opportunity	Walk-in coolers and freezers using propane
Required GWP limit	< 150 (per EPA; CARB has no limit)
Potential measure	Invest in field demonstrations to lead to future measure development
Codes limiting use	EPA SNAP, ASHRAE 15-2022, and UL 60335-2-89 have charge limit of < 150 g.
Equipment availability	Product is available in the U.S. through manufacturers, distributor, and restaurant supply stores.
Efficiency impact	Recent analysis of propane WICFs showed an average energy reduction of 54% for medium temperature systems and 38% for low temperature systems compared to baseline HFC condensing units, and 99% lower refrigerant-related emissions (Wiseman et al., 2026).
Primary market barrier	Space constraints, technician training, and end-user knowledge of systems

Custom Measure Pathway: Large refrigeration system (>50 pounds refrigerant) conversion to CO_2

Measure Opportunity: During our interview with CARB, they expressed interest in helping IOUs develop streamlined programs that can supplement FRIP funding, as funding remains a large barrier to natural refrigerant transition projects for large grocery stores. CARB recommends incentivizing the grocery store systems with greater than 50 pounds of refrigerant to have the most impactful investment. There are about 6,000 facilities in California with 25-30,000 systems that have greater than 50 pounds of refrigerant, according to CARB. Often, these systems are being repaired rather than replaced, which keeps high-GWP refrigerants in use. Transitioning them to CO_2 would have a substantial impact and GHG emissions reductions. A case study in Sacramento showed 27% energy savings and 23% energy cost savings when operating a CO_2 supermarket refrigeration system; however, this system equipment and installation cost 24% higher than an HFC baseline (NARSC, 2025).

Recommendation: TRC recommends working with CARB to develop a custom measure pathway for CO_2 supermarket system conversions to supplement the FRIP program funding (Table 7).

Table 7: CO_2 Supermarket System Conversions to CO_2 Measure Details



Measure Opportunity	Supermarket system conversion to CO_2
Required GWP limit	< 150 GWP (per CARB; EPA limit is 1,400)
Potential measure	Custom measure pathway for large grocery stores to convert existing refrigeration systems entirely to CO_2 refrigerant; this would supplement FRIP funding
Codes limiting use	None; must meet safety requirements for higher system pressure and efficiency requirements in Title 24 Part 6
Equipment availability	Custom equipment; readily available
Efficiency impact	Case studies show 27% energy savings over baseline (NARSC, 2025)
Primary market barrier	Initial cost of the system (Interview with CARB; NASRC, 2025; Scheele et al., 2026)

3.2 Service & Domestic Hot Water

3.2.1 Relevant regulations and code requirements

Regulations: There are no existing regulations that specifically require service & domestic hot water equipment to transition to lower GWP refrigerants. The refrigerant manufacturing regulations from SB 1206 will impact the service & domestic hot water market, which prohibit the sale of virgin bulk HFC refrigerants in California based on GWP: in 2025, the refrigerant GWP limit for refrigerant manufacturing was set to 2,200, and it will decrease to 1,500 in 2030 and 750 in 2033 (SB 1206, 2022). HPWHs typically use R-134a (GWP= 1430), R-32 (GWP = 675), and R-513A (GWP = 630) (ENERGY STAR, 2026). Eventually, the heat pump water heater market will need to adapt to lower GWP limits if they have not transitioned to lower GWPs already. **There is an opportunity to transition to <750 GWP refrigerants earlier than regulations require and to transition to ultra-low-GWP refrigerants.**

Code requirements: There have been ultra-low-GWP alternatives (CO_2, R-1234yf, R-1234ze) already available on the market that allow users to transition to more environmentally friendly alternatives, according to the ENERGY STAR product guide (ENERGY STAR, 2026). As mentioned before, CO_2 is an A1 refrigerant and does not face code-compliance issues. R-1234yf contains PFAS and may be subject to a PFAS ban in the future, although California does not restrict PFAS in refrigerants currently.

3.2.2 Market barriers and opportunities

Barriers: CO_2 systems are more prevalent than other emerging refrigerants and have been on the market for a long time; the biggest barrier to these units is that the first cost is too high (Opinion Dynamics, 2025). Customers generally prioritize first cost and operating cost relative to other considerations, such as sustainability. Customers are reluctant to voluntarily replace their gas systems with HPWHs – they tend to raise both upfront and operating costs relative to gas systems (Opinion Dynamics, 2025). CO_2 HPWH are more costly in actual installations relative to an equivalent code-efficient gas system baseline (Valmiki et al., 2025).

Other Lower GWP Options: Beyond CO_2, propane is also low cost, flexible, internationally used, and ultra-low-GWP. The main barrier to propane HPWH adoption is United States (US) regulatory constraints on charge limits and authority having jurisdiction (AHJ) discretion. Propane HPWHs have not been scaled commercially in the US yet, however low charge systems are being researched as a less expensive alternative (Nawaz, 2024).

Beyond natural refrigerants, some synthetic standard GWP refrigerants are being explored as drop-in replacements for R-134A or R-410A in heat pump water heaters, such as R-456A (GWP = 687) or R-485A (GWP = 143) (however, R-485A is not yet in the California Mechanical Code) (Kim et al., 2024). Because they are still in the research and development phase, not much is known about their field performance. TRC was unable to identify whether these refrigerants contain PFAS.

3.2.3 Performance of Proposed Measure Technology

Energy Performance (Commercial COP rating, >100 gallons): The existing measure case specifications (SWWH027, SWWH028, SWWH031) for commercial heat pump water heaters greater than 100 gallons require at least a 4.3 COP, or 3.0 COP for any multifamily system.

A recent report showed that CO_2 HPWHs are the most efficient compared to those using R-410A, R-134a, and R-513A refrigerants (Feng et al., 2025). However, heat pump water heaters often do not perform as well in the field as their rated conditions suggest and can lead to raised costs relative to gas for multifamily buildings: a CalNEXT study demonstrated two CO_2 central heat pump water heaters in multifamily buildings and found they increased energy cost by 88% and 135% compared to the gas system baseline (Valmiki et al., 2025). The cost of electricity is more expensive than the cost of gas on a Btu basis, which contributes to the increase in energy cost when electrifying. Both performed less efficiently than the rated performance with a system COP of 2.9 (reduced swing tank setpoint) and 2.3 (swing tank set too high) compared to the rated COP of 3.2. However, they produced 86% and 83% GHG emissions reduction and 61% and 51% reduction in total grid system cost.

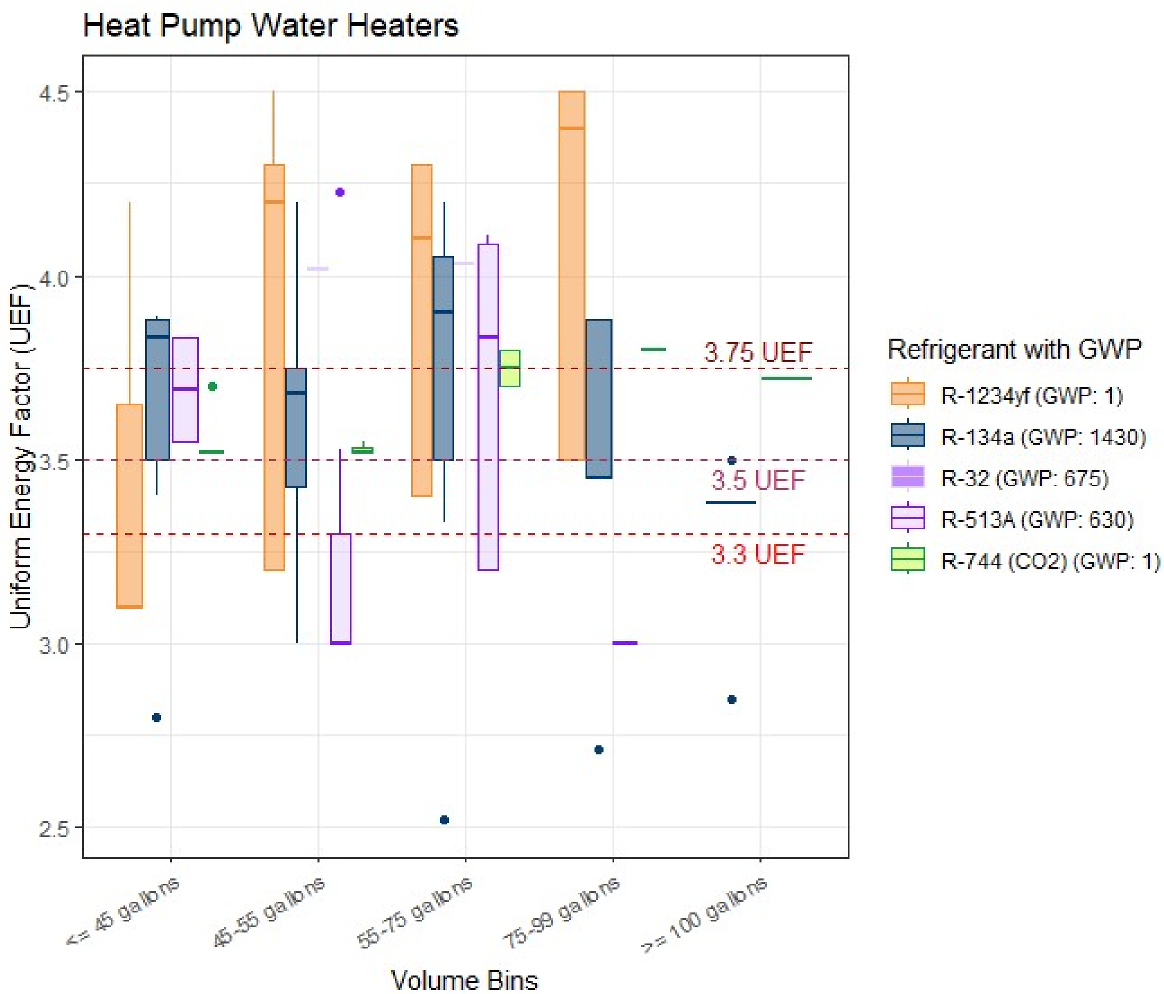
TRC researched available products on the market that use CO_2 as their refrigerant and can service a storage capacity of at least 100 gallons. Table 8 shows their COP data. Many of the heat pumps have separate primary storage tanks, therefore TRC did not include storage capacity here. Some of the products currently on the market can meet the current measure package specifications, so an incremental add-on measure could work for them. However, others are below the current specification of 4.30, demonstrating that there may be a need to lower the efficiency standard to accommodate the lower efficiency of these products and to promote participation. Another option could be to add a new efficiency tier where these products can participate. If the simulations or calculation methodology for the measure package is granular enough, consider having a separate tier for these types of systems to account for the different energy savings and refrigerant savings from the RACC.

Table 8. CO_2 Heat Pump Water Heater COP data

Brand	Model	Refrigerant Charge	COP	Testing Method	Link to source
ECO2	SANCO2	25.4 oz	5.5 / 4.2 / 2.8 at 80 / 47 / 17 F	Method unspecified	**SANCO2**
Harvest Thermal	Uses SANCO2	25.4 oz	5.5 / 4.2 / 2.8 at 80 / 47 / 17 F; Also provides performance curves (see link)	Method unspecified	**Harvest Thermal** performance curves
Lync by Watts	Aegis A	44 / 55 / 66 lbs.	3.5 / 3.6 / 3.8	Method unspecified	**Aegis A**
Mitsubishi	Heat2O	14 lbs. 5 oz	4.11	AHRI rating	**Heat2O**
Intellihot	iE1	3.96 lbs.	Up to 4.9 COP (without Heating Elements)	Method unspecified	**iE1**
Transom	SIMCO2E	25 lbs.	4.00	AHRI 1300 standard, DOE test point of 70F inlet and 120F outlet at 80.6F air temperature	**SIMCO2E**

Energy Performance (UEF rating, <100 gallons): The existing measure case specifications (SWWH027 and SWWH031) for heat pump water heaters with less than 100 gallons of storage require an efficiency of 3.30, 3.50, or 3.75 UEF for different tiers of storage capacity. Based on ENERGY STAR data, there are CO_2 products that would meet these measure case specifications across all sizes of storage capacity. Based on existing products, the CO_2 equipment would fall under the 3.5 or 3.75 UEF tiers, as seen in Figure 3.

Figure 3: ENERGY STAR data for electric heat pump water heaters by refrigerant type and capacity.



The refrigerant charge data for the A.O. Smith or GE Appliances heat pump water heaters is not readily available online. Measure developers would need to request this information directly from the manufacturer in future studies. Table 9 shows the SANCO$_2$ brand from ECO$_2$ Systems, which has charge information in specification sheets online.

Table 9. Refrigerant Charge and Efficiency of SANCO$_2$ Heat Pump Water Heaters

Model Name	R-744 Charge	Storage Volume	UEF
Heat Pump Unit with 119-gallon tank	25.4 oz. (720 g)	110 gallons	3.72

Model Name	R-744 Charge	Storage Volume	UEF
Heat Pump Unit with Heater (Cold Climate) with a 119-gallon tank	25.4 oz. (720 g)	110 gallons	3.72
Heat Pump Unit with 83-gallon tank	25.4 oz. (720 g)	83 gallons	3.80
Heat Pump Unit with Heater (Cold Climate) with an 83-gallon tank	25.4 oz. (720 g)	83 gallons	3.80
Heat Pump Unit with 43-gallon tank	25.4 oz. (720 g)	43 gallons	3.66
Heat Pump Unit with Heater (Cold Climate) with 43-gallon tank	25.4 oz. (720 g)	43 gallons	3.66

Table 9 shows that the efficiency of the SANCO$_2$ heat pump water heaters varies with the storage tank size. The heat pump units themselves are the same across all products, hence the consistent refrigerant charge. For commercial systems, ECO$_2$ Systems offers storage tanks from 119 gallons to 505 gallons.

Product Availability: There are nine brands owned by two manufacturers listed in the ENERGY STAR database that make CO_2 heat pump water heaters less than 100 gallons; the two manufacturers are A.O. Smith and ECO$_2$. Through our search, TRC was able to identify five manufacturers that make CO_2 heat pump water heaters with storage over 100 gallons: ECO2, Lync by Watts, Mitsubishi, Intellihot, and Transom. While some manufacturers specified the COP testing method on their specification sheet, others did not. Therefore, additional research is needed to determine the COP range of these products.

AO Smith makes residential water heaters that use CO_2 refrigerant, but they do not appear to have a commercial-scale product (>100 gallons) that uses CO_2 refrigerant. AO Smith-manufactured heat pumps with >100 gallons of storage on CEC-approved product list (branded AO Smith, State, and Lochinvar) use R-134a or R-513a. Rheem-manufactured units are also using R-134a (includes Ruud and Raypak brands), and these are also on the CEC-approved product list.

Baseline Refrigerant: The RACC currently lists R-134a and R-410A as common refrigerants for heat pump water heaters. Starting in 2030, CARB will prohibit the sale of R-410A (GWP = 2088), so manufacturers have begun transitioning to lower GWP refrigerants in their products (*SB 1206*, 2022). The only high-GWP HPWH refrigerant listed in the ENERGY STAR database is R-134a (GWP = 1430). It is still prevalent, with 590 products using R-134a out of 740 products listed on the ENERGY STAR database of heat pump water heaters. For context, there are 95 products using CO_2 listed in this database.

Barriers: Despite the benefits of lower GWP emissions and lower grid system cost, the high first cost and high operating costs (where electricity rates are higher than gas rates) remain a barrier to adoption (Opinion Dynamics, 2025; Powers, 2025). The refrigeration cycle for CO_2 required it to operate at high temperatures and pressures, which requires robust equipment design to ensure safe operation (J. Wang et al., 2021) – there have been no documented safety issues from operating a CO_2 HPWH. A recent CalNEXT report found that "program and utility rates should be designed to reward building owners for the energy efficiency impacts that are being realized with central heat pump water heater systems", referring to the high TSB at the higher cost to the consumer (Valmiki et al., 2025).

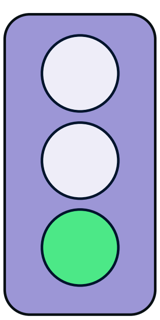
3.2.4 Recommendations for SCE

Measure Package Supplemental Incentive: Heat Pump Water Heaters (SWWH027, SWWH028, and SWWH031) kicker for CO_2 refrigerants

Measure Opportunity: The RACC currently uses R-134a as the measure case refrigerant. For a CO_2 measure add-on, R-134a is still a reasonable baseline assumption to calculate the TSB from the avoided emissions reductions using CO_2 as the refrigerant. The 2028 DEER Scoping Memo was recently released, proposing a Net-to-Gross ratio (NTG) of 1 for CO_2, which would allow users to claim more savings from the measure (Energy Efficiency Branch, CPUC, 2026b). This kicker incentive can be used in existing and upcoming HPWH programs to encourage the use of the CO_2 refrigerant. CO_2 HPWHs are very expensive and regulations do not set GWP limits for these equipment types (*California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses*, n.d.; ENERGY STAR, 2026; US EPA, 2022). Providing a supplemental incentive would help to value the TSB savings for using CO_2 refrigerant compared to the R-134a baseline equipment and increase the incentive by reducing the incremental cost.

Recommendation: TRC recommends that a supplemental incentive for CO_2 refrigerants be added to the existing HPWH measure packages (SWWH027, SWWH028, and SWWH031) that would encourage users to adopt the CO_2 version of these products compared to the other refrigerant alternatives, shown in Table 10. This incentive would help overcome the barriers of the higher first cost for these systems and the higher operating costs where electricity rates are higher than gas rates.

Table 10: CO_2 Heat Pump Water Heater Measure Details



Measure Opportunity	CO_2 Heat Pump Water Heaters
Required GWP limit	None
Potential measure	Supplemental incentive to existing measure SWWH027, SWWH028, and SWWH031 for using CO_2 refrigerant
Codes limiting use	None; must meet safety requirements for higher system pressure
Equipment availability	5 manufacturers identified for >100-gallon systems, 2 manufacturers (9 brands) identified for <100-gallon systems

Measure Opportunity	CO_2 Heat Pump Water Heaters
Efficiency impact	Similar or better performance than other HPWHs; increased energy cost compared to gas baseline
Primary market barrier	Initial and operating costs of the system (Valmiki et al., 2025)

3.3 HVAC

3.3.1 CARB and EPA GWP regulations

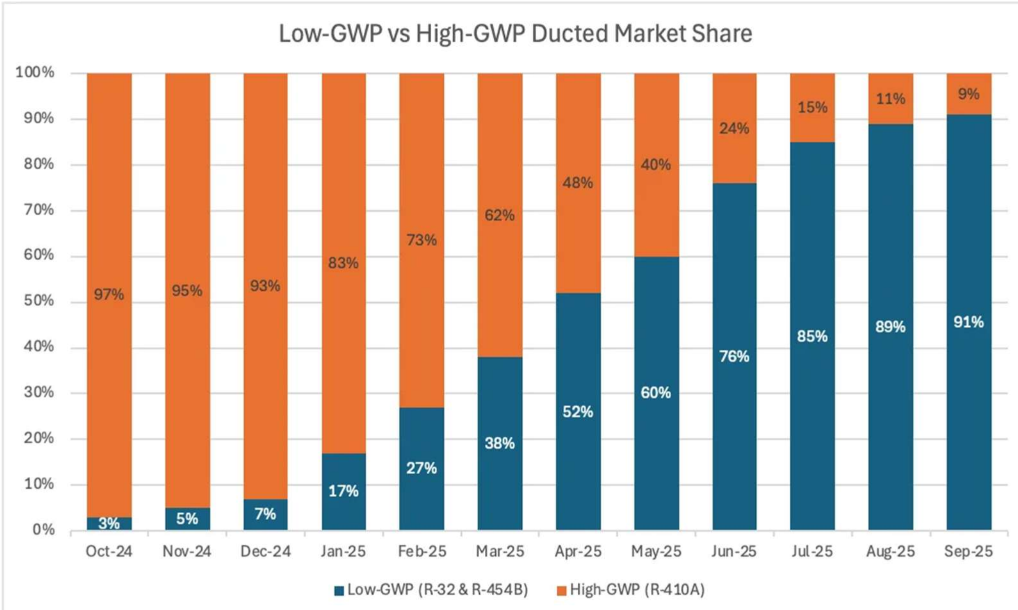
CARB GWP limits for air-conditioning equipment are set to < 750 GWP; as of Jan 1, 2026, this applies to all of the following air-conditioning equipment: chillers used for air-conditioning, Variable Refrigerant Flow (VRF) systems, room/wall/window air-conditioning equipment, PTACs, PTHPs, portable air-conditioning equipment, and residential dehumidifiers (new), and other air-conditioning (new) equipment, residential and non-residential (California Code of Regulations Title 17. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols, Propellants, and Foam End-Uses, n.d.).

The EPA GWP limit for stationary residential and light commercial air conditioning and heat pumps is set to < 700 GWP (American Innovation and Manufacturing Act of 2020, 2020). The recent final rule consideration allows the sale of products in this subsector above this limit, manufactured or imported before January 1, 2025, without an end date (*Phasedown of Hydrofluorocarbons*, 2025). The EPA GWP limit is set to < 700 GWP for chillers used for comfort cooling, VRF systems, data centers, computer room air conditioning, and information technology equipment cooling.

3.3.2 Relevant code requirements

A2L Refrigerants: The 2025 mechanical code approved A2L refrigerants for use in high probability spaces (*2025 California Mechanical Code Title 24, Part 4*, 2025). Figure 4 shows how they have already highly penetrated the market – 91% of HVAC sales at the end of 2025 were using A2L refrigerant (Heating Air Conditioning & Refrigeration Distributors International, 2025). The mechanical and fire codes require additional safety measures to install these in existing buildings that currently use A1 refrigerants.

Figure 4. Residential and Light Commercial HVAC Equipment Sales from Oct 2024 – Sept 2025 (Heating Air Conditioning & Refrigeration Distributors International, 2025)



Building and mechanical codes reference several ASHRAE and UL codes and standards that inform safe use of refrigerants in buildings[2]. The California Building Standards Commission updated the California Mechanical Code in 2025 to allow the use of A2L refrigerants in high-probability systems, defined as those in which refrigerant leakage is highly likely to enter an occupied space. It includes light commercial heat pump or AC or VRF (VRF system; direct expansion split system; packaged rooftop unit (RTU); packaged terminal air conditioner (PTAC); water source heat pump) (*2025 California Mechanical Code Title 24, Part 4*, 2025).This code update opens the door for the use of many standard and low-GWP refrigerants in new applications such as HVAC and water heating. Manufacturers and contractors are already familiar with the safe use of A1 and A2L refrigerants because these have been available on the US market for longer than A3s, such as propane.

These systems need to comply with safety requirements, but regulations no longer prohibit their installation. Regulations for HVAC end uses setting GWP limits at 700 (EPA) or 750 (CARB) are either currently in place or effective Jan. 1, 2027. In response, the market has adopted R-32, R-454B, and R-513a to comply with these limits. These are standard GWP refrigerants that satisfy current and upcoming GWP limits, so there is no regulatory motivation to transition to lower GWP refrigerants.

Ultra-low-GWP Refrigerants: TRC investigated key cases in which the existing codes and standards in the United States are restricting the growth of ultra-low-GWP equipment. The two most promising ultra-low-GWP natural refrigerants for HVAC end uses are propane and CO_2. Because CO_2 is an A1 refrigerant, it does not face code barriers to implementation. However, CO_2 equipment may struggle to meet efficiency requirements. For heating operation, Title 24 Part 6 requires liquid source heat pumps and heat recovery chillers with a capacity greater than 600 tons refrigeration to meet a COP of at least 2.97 when providing 140°F hot water and up to 4.93 COP when providing

[2] The building code and the mechanical code are the ultimate guidelines that projects must follow, but the AHJ has the final say over what business can install. Depending on AHJ approval, demonstration cases may break the code requirements. For example, the AHJ can decide to approve systems with higher refrigerant charges for propane regardless of legislative approvals.

105°F hot water (California Energy Commission, 2025). The efficiency requirement is slightly lower for air source heat pumps: for refrigeration greater than 150 tons, the equipment must meet 1.483 COP at 140°F hot water and 2.029 COP at 105°F hot water (California Energy Commission, 2025). For cooling operation, Title 24 Part 6 has requirements for full load and part load operation. Assuming full load operation, large air source heat pumps (>150 tons) must meet 5.595 energy efficiency ratio (EER), and liquid source heat pumps with a capacity greater than 600 tons of refrigeration must use less than 0.5895 EER (California Code of Regulations, Title 24, Part 6, Section 110.2, Table 110.2B-K). Based on discussions with TRC engineers in the process of acquiring a large heat pump, CO_2 heat pumps may have trouble meeting these requirements in the field. Demonstrations from manufacturers have shown that other ultra-low-GWP refrigerants such as propane, ammonia, and R-123ze, are more promising for meeting efficiency requirements. Because this project is ongoing, manufacturer performance data is not yet available to share.

Propane faces more code barriers because of its A3 safety class. Specifically, UL Standards are the driving force for charge limits on propane and other A3 refrigerants. ASHRAE refrigerant standards and EPA policies refer to UL as the guideline for refrigerant charge limits (ASHRAE, 2022; Significant New Alternatives Policy, 2014). Residential and light commercial air conditioning and heat pumps (self-contained) can use propane if they meet UL 484, and the charge size of propane must not exceed 1,000 grams of propane. For portable air conditioners, the charge size must not exceed 300 grams of propane. Section 7.2 provides more detail on propane-specific regulations.

ASHRAE is conducting CARB-funded research into propane safety to develop the next generation of propane standards that would allow propane in more applications for HVAC (Scheehle et al., 2026, Interview with CARB). CARB expects this research project to be completed in late 2027 (Interview with CARB).

3.3.3 Market barriers and opportunities

TRC explored two key HVAC market segments that are closer to adopting ultra-low-GWP alternatives: light commercial and large commercial heat pumps. This section focuses on ultra-low-GWP edge cases that might present opportunities for programs or measure packages in the future if there is innovation on the codes and standards front and/or the technology cost.

Refrigerant Barriers

Codes and standards limit propane systems, whereas the cost – particularly to meet efficiency requirements - limits the growth of CO_2 systems. Currently, CO_2 HVAC systems are mainly adopted in large central plants where strategies can be employed to make the system more efficient and economical, particularly heat recovery and thermal energy storage (Scheehle et al., 2026). Heat recovery is necessary for CO_2 systems to meet efficiency requirements and have a positive return on investment (Z. Wang et al., 2021). Because there are more heat sources and sinks to draw from in a central plant, CO_2 becomes a more logical option in these end uses. Combining heat pumps with thermal energy storage is another way to address the cost barrier (Z. Wang et al., 2021). Central plants can meet peak loads with pre-generated energy by leveraging storage, which allows them to downsize equipment and lower the initial cost of the system. Improving the energy efficiency of the end uses (i.e. building) can reduce peak loads, which further allows downsizing the equipment. Smaller capacity systems may also be viable by leveraging heat recovery or thermal energy storage.

TRC has identified propane as a key refrigerant for large commercial HVAC to explore opportunities and limitations more in depth, as it is very efficient yet very flammable and the safety requirements are less familiar to practitioners.

Currently, propane is not viable in most light commercial HVAC applications due to charge limits. However, the building code does allow propane in larger amounts, such as for large commercial HVAC systems, if it is in a machine room or outdoors and follows specific safety standards. For most other HVAC end uses, the code requirements make propane an unviable refrigerant.

Light HVAC Market

Although there were supply shortages of R-454B during the summer of 2025 that spooked many industry players, manufacturers resolved these shortages within 9 months and no longer impact the manufacture and distribution of these systems, according to a representative of HARDI[3]. As of Q4 2025, an estimated 91% of HVAC sales were equipment using these standard GWP A2L refrigerants (Heating Air Conditioning & Refrigeration Distributors International, 2025).

Manufacturers just transitioned to R-32 and R-454B, but these are likely to be transitional refrigerants until systems with low-GWP (<150) replace them (KGG Consulting, 2025). Manufacturers will likely need to design systems that use even lower GWP refrigerants at some point soon, either to meet consumer demand for more sustainable options or to meet any changing regulations for GWP limits or PFAS prohibitions.

Further research and development are needed to bring down the costs of manufacturing CO_2 light commercial HVAC systems before they can be widely adopted. Light commercial air conditioning and heat pumps (self-contained) can use propane if they meet UL 484 and the charge size must not exceed 1,000 grams of propane. For portable air conditioners, the charge size must not exceed 300 grams of propane. As long as the required capacity can be met by these charge sizes, this can be a viable alternative. For context, the average charge size for R-454B and R-32 in small commercial (<65 kBtu/hr) packaged AC is 1.14 lbs. per ton, and split AC is 1.75 lbs. per ton (TRC, 2025). Studies show that a propane charge of 30 g/kW (0.23226 lbs. per ton) is attainable in heat pumps through charge optimization (Bani Issa et al., 2025).

Midsize HVAC (RTU) Market

The “middle of the road” commercial buildings that are typically served by rooftop units (RTUs) have standard GWP refrigerant options using R-32 and R-454B that have high market penetration (91-95%) and meet current GWP regulation requirements (Heating Air Conditioning & Refrigeration Distributors International, 2025). Therefore, it is difficult for natural refrigerants to compete with the products on price because they are either harder to manufacture, face code barriers, and/or are more complicated to install.

The mid-range capacity systems using RTUs do not have a natural transition to natural refrigerants. Packaged RTUs are high-probability, meaning that A3 refrigerants (such as propane) cannot be used (Scheehle et al., 2026). Even with future code changes, authorities are unlikely to allow A3s in RTUs because a leak from these systems would release directly into occupied space. There are not as many indirect HVAC systems (i.e. monobloc) in the US compared to Europe, which has hydronic monoblocs that are much easier to transition to natural refrigerants (Stewart et al., 2023; Interview with TRC HVAC SME). Manufacturers have saturated the mid-range capacity market with products that offer a low cost for high efficiency. Units using CO_2 refrigerant cannot compete on price with the existing products on the market. Unless regulations require it, it will be difficult for natural refrigerant systems to compete with incumbents on cost.

Large HVAC Market

Sustainability-conscious businesses are considering CO_2, propane, and ammonia for large commercial HVAC equipment because of their ultra-low-GWP and non-PFAS status (Scheehle et al., 2026). However, CO_2 faces efficiency issues because it requires high operating temperatures and pressures, and propane and ammonia face limitations from the mechanical code because of their safety classes.

For central plants, drivers for equipment selection decisions include the operating parameters required to meet the hot and chilled water demand (Interview with TRC SME). Existing systems may operate at certain temperatures and pressures that the new equipment would need to be able to meet. This may automatically rule out certain low-GWP equipment in the near term; manufacturers are continually developing low-GWP alternatives but may not be able to meet the full range of operating conditions yet because of refrigerant properties (Hughes et al., 2024). Competition among manufacturers for low-GWP market share will drive innovation for finding low-GWP replacements for existing equipment (KGG Consulting, 2025).

Financial incentives and regulations also drive equipment replacement for customers (KGG Consulting, 2025). Refrigerant GWP is typically not a key consideration for choosing equipment. Other benefits motivate customers, such as performance or meeting operating requirements (Interview with SCE, Interview with CARB). An incentive to reduce the cost and provide supporting documentation about the added benefits could make a difference to customers decision making.

CO_2 heat pumps are more expensive to engineer than other heat pumps because of the high pressure, making them better suited for larger applications like supermarkets, cold storage, or data centers.

CO_2 heat pumps may overcome cost barriers by serving as a heat recovery chiller to provide simultaneous heating and cooling, provided the system efficiency is accounted for (J. Wang et al., 2021). Because there are large heat losses from the high operating temperature required by CO_2, capturing this heat for useful water heating can improve the system efficiency. Title 24 Part 6 requires COP compliance only at one of four standard rating conditions (Low, Medium, High, or Boost) (California Energy Commission, 2025). Liquid source simultaneous heating and cooling requires a system COP of 5 for High heating conditions, 6.98 for Medium, and 8.9 for Low. Compliance with cooling-only performance is still required. As mentioned in Section 3.3.2, **CO_2 equipment is likely to have difficulty meeting the cooling-only COP requirements;** however, if the code allows for an exception for CO_2 systems, requiring only the system COP to be accounted for if the system only operates in simultaneous heating and cooling mode, this equipment may be viable.

HVAC units using greater than 150 grams of propane require a machinery room or must be located outdoors because of its A3 safety class (*2025 California Mechanical Code Title 24, Part 4*, 2025). Ammonia is subject to similar limitations to propane because of its B2L safety class. To meet the required capacity of large HVAC systems, **propane and ammonia equipment must be in a machinery room or outside if allowed by AHJ** (*2025 California Mechanical Code Title 24, Part 4*, 2025). Demonstration projects in North America have installed these types of systems, but they are not prevalent (*Sustainable District Heating & Cooling*, n.d.).

Innovation in the Industry

During a San Francisco Climate Week panel, TRC heard from Stet Sanborn from Smith Group and ASHRAE[3]. Mr. Sanborn works on electrification and decarbonization of large HVAC systems and pushes forward refrigerant codes and standards at ASHRAE. According to Mr. Sanborn, his firm encourages its clients to skip the transition step to standard GWP refrigerants and move straight to ultra-low-GWP refrigerants, since the technology exists and has been tested. They use CO_2 and ammonia for their large HVAC projects, leveraging thermal energy storage, heat recovery, and efficiency to make them financially viable.

Similarly, manufacturers have used thermal energy storage to introduce CO_2 HVAC systems to the residential market. Harvest Thermal is the first CO_2 HVAC residential system on the market and has installed 500 systems in California this year (Scheehle et al., 2026). It provides heating and domestic hot water by using thermal energy storage and optionally provides cooling with an additional DX heat pump or an economizer/night cooling add-on to the air handling unit (Harvest Thermal, n.d.). This helps to avoid high time-of-use costs and provide demand flexibility. However, the cost of CO_2 heat pumps requires that Harvest Thermal prices these systems as a premium product and therefore the company relies on rebates and incentives and a lease-to-own pay structure to promote adoption. According to a panel with Harvest Thermal at San Francisco Climate Week, they are doing research and development to reduce cost and become cost competitive without rebates and incentives[3]. They are also doing research on propane systems to be able to deploy them when codes and standards allow it. They believe that propane will be a cheaper system because the operating conditions are easier to achieve than CO_2, but California fire codes limit the maximum charge amount.

3.3.4 Availability of Ultra-Low-GWP Technology

Light Commercial HVAC

Ultra-low-GWP alternatives are not common in light commercial HVAC applications. TRC identified Harvest Thermal as the first potential candidate in the US for CO_2 HVAC in light commercial applications, although they manufactured these systems for residential use. There are CO_2 heat pumps for room air conditioning on the market in the UK (e.g. Clade, Megawave). These CO_2 units would have a higher relative cost than standard GWP units.

Midsize Commercial HVAC

TRC did not identify any viable ultra-low-GWP alternatives to RTUs. R-32 and R-454B refrigerants serve this market, which meet both CARB and EPA GWP regulations.

Large Commercial HVAC

- Many existing chillers and heat pumps use **R-513A** (GWP = 630) or **R-454B** (GWP = 466) to meet the EPA and CARB GWP limits.
- **Propane** is more prominent in Europe (AERMEC, Clade), but some US manufacturers sell propane units (Swegon, Frick) or can design custom systems (Budzar). In the US, not enough is known about propane leaks, despite existing codes that provide safety considerations around these systems.

[3] “California Leads the Way on Natural Refrigerants, HVACR Innovation & Market Transformation” on April 21, 2026 (Scheele et al, 2026)

- **Ammonia** is better suited for locations that are unpopulated, such as rural areas. The risks of an ammonia leak in a populated area are too high to tolerate. Ammonia chillers are offered by several manufacturers in the US (GEA, Frick, Evapco, Mayekawa) and Europe (Sabroe).
- **CO_2** chillers and heat recovery chillers are also available from some manufacturers on the US market; however, they can operate less efficiently due to the transcritical cycle and higher pressures at which they must operate. CO_2 may be found in smaller capacity chillers (Carnot, Flow) or custom systems (Vitalis).
- **Manufacturers are increasingly offering ultra-low-GWP synthetics** (1233zd, 1234ze, 1234yf) in centrifugal chillers by major manufacturers in the US (Smardt, York, Budzar) and in Europe (Daikin, Carrier).

Propane and ammonia are available for some product types on the market, but part of the barriers to adopting these are the fear of safety issues.

3.3.5 Recommendations for SCE

EPA requires these equipment types to use refrigerants with GWP less than 700, and CARB requires these equipment types to use refrigerants with GWP less than 750. Given that there is high market penetration of low-GWP A2L refrigerants as of Q1 2026, there is no need to incentivize customers to switch to equipment with these refrigerants. **An opportunity exists for additional research incentives to drive refrigerants towards ultra-low-GWP alternatives.** Details of the potential measure are shown in Table 11.

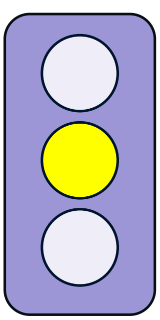
Further research is needed to create a deemed measure case for ultra-low-GWP HVAC:

- For example, a measure package that combines a CO_2 heat pump with TES tank

Research Needed: Light Commercial Heat Pumps using Ultra-Low-GWP natural refrigerants CO_2 and Propane (SWHC014 for unitary or SWHC046 for packaged)

Current ultra-low-GWP options either face cost barriers (for CO_2) or code barriers (for propane) in the United States, despite their proliferation in Europe and Asia (KGG Consulting, 2025; Scheehle et al., 2026; Stewart et al., 2023) (Table 11).

Table 11: Light Commercial Heat Pumps using CO_2 or Propane Measure Details



Measure Opportunity	Light Commercial Heat Pumps using CO_2 or Propane
Required GWP limit	< 700 (per EPA): < 750 (per CARB)
Potential measure	Further research is needed to address cost or code barriers: applicable measures are SWHC014 and SWHC046
Codes limiting use	CO_2: None Propane: EPA SNAP, ASHRAE 15-2022 limit charge: light commercial air conditioning and heat pumps (self-contained) must meet UL 484 and charge size must not exceed 1,000 grams;

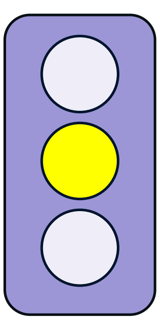
Measure Opportunity	Light Commercial Heat Pumps using CO_2 or Propane
	for portable air conditioners, the charge size must not exceed 300 grams
Equipment availability	CO_2: Uncommon, unless paired with water heating Propane: Common on EU market, but not viable in the US
Efficiency impact	Further research and field demonstrations are needed to evaluate the performance
Primary market barrier	CO_2: Cost of manufacturing Propane: Codes limiting charge amount

Research Needed: Large Commercial HVAC using Ultra-Low-GWP natural refrigerants CO_2, Propane, and Ammonia (SWHC005 water cooled chiller, SWHC052/020 air cooled chiller)

There are many new chillers on the market that can use refrigerants with a GWP less than 150 (i.e. R-454C) and some that have a GWP less than 10 (R-1234yf, R-1234ze, CO_2, ammonia, and propane). There is an opportunity for an incentive for chillers that use lower than required GWP.

Because the propane systems are newer to the US market, there are not many field demonstrations of these products in the US. Despite the efficiency challenges faced by CO_2 systems, there is potential for designers to overcome them using efficiency strategies (e.g., heat recovery, thermal storage), and designers like Smith Group have shown these systems are possible in CA. Therefore, we recommend further research and field demonstration of large commercial HVAC using natural refrigerants. Details of the opportunity are available in Table 12.

Table 12: Large Commercial Heat Pumps using CO_2, Propane, or Ammonia Measure Details



Measure Opportunity	Large Commercial Heat Pumps using CO_2, Propane, or Ammonia
Required GWP limit	< 700 (per EPA): < 750 (per CARB)
Potential measure	Further research is needed to overcome cost barriers and safety perceptions. May be better suited to custom measure pathways.
Codes limiting use	CO_2 is not limited by Mechanical or Fire Codes, but may struggle with efficiency requirements Propane and ammonia systems must be located in machinery rooms or outdoors and meet safety requirements in California Mechanical Code and Fire Code
Equipment availability	Equipment is available, but may need to be custom built for the US market; 13

Measure Opportunity	Large Commercial Heat Pumps using CO_2, Propane, or Ammonia
	manufacturers identified
Efficiency impact	Further field demonstrations are needed to evaluate performance, but initial case studies show similar performance to other HPs
Primary market barrier	Product awareness, cost barriers, code barriers

4 Measure Package Drivers and Barriers

4.1 2026 DEER Resolution

The 2026 DEER resolution Attachment A requires that effective Program Year 2028, refrigerant-related fields be added to the eTRM permutations to enable tracking the refrigerant effects of energy efficiency measures that contain refrigerants. The new fields are net lifecycle refrigerant leakage emissions (mt CO_2e), refrigerant type for measure, standard practice, and existing equipment cases, end-use specific energy consumption fields for measure, standard practice, and existing equipment (Energy Efficiency Branch, CPUC, 2026a).

Effective Program Year 2024-2026, mid-cycle new offerings added to existing measure packages or mid-cycle updates to existing measure packages that add, change, or remove refrigerant must use the RACC-FSC v3.0/3.1. The RACC-FSC v3.0/3.1 "shall be used to calculate refrigerant leakage emissions and avoided costs of net refrigerant leakage emissions for all measures that involve adding or replacing equipment that uses refrigerant and involves a change to the refrigerant type or to the refrigerant charge" (Energy Efficiency Branch, CPUC, 2026a).

The use of the RACC-FSC tool will allow low- or ultra-low-GWP kicker measures to claim the benefit of a lower GWP when the refrigerant and system charge differ between the measure and standard practice, or existing equipment cases. However, this update will require adding designated refrigerants to the measure, baseline, and existing case data for existing refrigeration equipment measures.

4.2 2028 DEER Scoping Document

The CPUC prepares a planning document that outlines the proposed scope, process, and timeline for updating DEER for a given program year; for program year 2028, this is the 2028 DEER Scoping Document. The 2028 DEER Scoping Document requires that PY2028 measure packages use the RACC-FSC v3.2. This applies to both new measure packages and updates to existing measure packages. The RACC-FSC v3.2 includes updated HVAC refrigerant charge assumptions based on 2025 CalNEXT residential and commercial studies. It includes increased use of low-GWP refrigerants such as R-32 and R-454B (Energy Efficiency Branch, CPUC, 2026b).

The Scoping Document also highlights that Measure Lifecycle Management (MLM) is now available in the eTRM Stats area. MLM tracks savings methodology, weather file, fuel type, whether the measure contains refrigerant, RACC dependencies, EUL, NTG, and cost inputs. It should be used starting with DEER2028 for identifying research needs, prioritizing measure package updates, and sequencing review timelines (Energy Efficiency Branch, CPUC, 2026b).

As previously mentioned, the 2028 DEER Scoping Document sets the NTG ratio for equipment using CO_2 as the refrigerant at 1.0 (Energy Efficiency Branch, CPUC, 2026b).

4.3 Measure Package Review

As part of a review of published refrigeration-related measure packages, TRC evaluated what will be required to update these measures to account for changes in baseline refrigerants resulting from upcoming refrigerant regulations. The measure packages listed in Table 13 are those using refrigerant with the highest TSB since Program Year 2023. Some measures will require updates to centralized efficiency evaluation resources to account for differences in equipment efficiency resulting from changes in standard refrigerants, such as the DEER Commercial Heat Pump Water Heater Calculator, the DEER Water Heater Calculator, and Energy Plus. Others use efficiency calculations based on data from California or federal requirements, ENERGY STAR, or DEER resolutions.

For other measures, accounting for refrigerant changes will require either gathering refrigerant data during product market analyses to update the baseline and measure product efficiencies or updating DEER data. In the second case, measure packages will need to provide updated energy/performance curves for measures that rely on them. Updating the eligibility requirements to account for the new refrigerant regulations will require additional effort to ensure that the compliance language does not slow down adoption of the new technologies.

Table 13. Measure packages with the highest TSB for equipment that uses refrigerant

Measure Package Title	Measure Package	Author(s)	Total System Benefit (TSB)	Permutations
Large Heat Pump Water Heater, Commercial and Multifamily, Fuel Substitution	SWWH028	SCE	$ 86,265,040	AR, NC & NR
Unitary Air-Cooled Air Conditioner or Heat Pump, Under 65 kBtu/hr, Commercial	SWHC014	SDGE	$ 8,132,277	NC & NR
Ultra-Low Temperature Freezer	SWCR017	PGE	$ 2,750,257	NC & NR
Reach-In Refrigerator or Freezer, Commercial	SWCR018	PGE	$ 2,138,788	NC & NR
Ice Machine, Commercial	SWFS006	PGE	$ 1,954,812	NC & NR
Multiple Capacity Unitary Air-Cooled Commercial Air Conditioners Between 65 and 240 kBtu/hr	SWHC043	SDGE	$ 800,108	NC & NR
Packaged Heat Pump Air Conditioner Commercial, Fuel Substitution	SWHC046	SCE	$ 294,969	AR, NC & NR
Heat Pump Water Heater, Commercial	SWWH031	SCE	$ 263,507	NC & NR

Measure Package Title	Measure Package	Author(s)	Total System Benefit (TSB)	Permutations
Water-Cooled Chiller	SWHC005	SDGE	$ 22,706	NC & NR
Refrigerated Chef Base	SWFS016	SCE	$ 47,675	NC & NR

4.4 Takeaways for Measure Package Development

Interviews with the SCE deemed measures team identified the following drivers and barriers.

CPUC is selective with proposed measure packages; recommend an incremental approach for creating low-GWP measure packages

Existing MPs largely do not explicitly account for refrigerants beyond eligibility and compliance. A previous proposal for layered low-GWP incentive was unsuccessful, however, the alternative of creating separate offerings for refrigerant variants is likely to be unpalatable to the market because of the added complexity introduced by the increase in permutations. **Therefore, TRC recommends starting with one or two tightly scoped offerings for a key market segment.** Frame it as a single, high-readiness offering with strong market justification, and secure an implementation sponsor. Refer to Section 3.1.5 and 3.2.4 for examples of a high-opportunity market segment in commercial refrigeration.

The success of a measure package depends on program implementer demand. The CPUC expects market-justified proposals. There is not an internal driver to develop low-GWP measure packages without program demand or top-down directives.

Low-GWP measure packages are feasible within the current structure, but data collection and eligibility will require additional effort

Financial levers are already built into the measure package structure. Existing measure package financial levers can help incentivize low-GWP refrigerants. Total system benefit (TSB) and total resource cost (TRC) improvements are the key motivators for implementers and improving net-to-gross (NTG) can materially help portfolios. The Refrigerant Avoided Cost Calculator (RACC) can already capture low-GWP benefits, but custom measures are the only way to realize them right now because current deemed measures lack low-GWP variants.

Updates to efficiency/performance calculations are straightforward, for many of the most popular measures. Many of the most popular MPs use DEER tools or EnergyPlus performance curves, therefore updating these MPs with low-GWP products would require adding low-GWP refrigerant performance curves to these centralized modeling platforms. Other MPs use ENERGY STAR equipment ratings. These ratings are independent of refrigerant, and any product would have to meet these efficiency requirements to claim the measure. Testing metrics such as Seasonal Energy Efficiency Ratio 2 (SEER2), Heating Seasonal Performance Factor 2 (HSPF2), and Uniform Energy Factor (UEF) are refrigerant-agnostic and test all equipment in the same way.

Through the review of market studies, we identified efficiency data for products using low-GWP refrigerants. See Section 3 for relevant energy efficiency data for measure package opportunities; additional data is available in Appendix D: 9.2 Low-GWP Product Availability for Common Measures. See the "Market Study of Low-GWP Refrigerants" workbook for more information. If studies demonstrate that low-GWP refrigerants do not result in significantly different performance, then low-GWP offerings may not require separate savings calculations. For example, R-290 shows similar performance as other refrigerants used for reach-in refrigerators and freezers, as seen in Figure 2.

It is important to carefully update MP eligibility and compliance language to prevent delays in adoption. Updating the existing measure packages with the new refrigerant standards will require careful consideration to avoid making the eligibility requirements overly burdensome. Overly restrictive eligibility requirements and standards will impede projects and reduce adoption.

Data for new products can be difficult to attain

Access to reliable data for refrigerant and associated technologies can be a significant challenge. The lack of cost data is a key barrier to measure development and updates, particularly when attempting to isolate the incremental cost associated with low-GWP refrigerant units relative to comparable equipment at the same efficiency level. Manufacturers may be unwilling or unable to share detailed cost and performance information.

Performance data can also be difficult to obtain. While manufacturer-provided information may be useful for initial screening and characterization, independent third-party testing is often preferred to support measure development and savings estimates. However, obtaining third-party test data can be costly and time intensive. In situations where field data are unavailable, validated simulation results may serve as an acceptable alternative for estimating performance impacts.

Top-down policy alignment would provide an incentive for low-GWP measure packages

CARB and CPUC currently differ on how to incentivize a market shift toward low-GWP products. While CARB has established regulations for low-GWP products, program administrators remain uncertain about how to enforce these regulations. Through interviews with IOUs, TRC has found that there is no clear directive for deemed measure developers for promoting low-GWP products. Currently, the CPUC does not allow rebates for refrigerant-only benefits without accompanying energy savings, and it also does not allow claiming benefits based on refrigerant recapture. Aligning these stakeholders would create a top-down incentive to push these new refrigerants, where the bottom-up efforts have failed. There is also uncertainty about the enforcement of CARB regulations in existing facilities. IOUs can emphasize replacement-triggered opportunities (AR/NR) to push low-GWP at the time of replacement. The low-GWP incentive could be an add-on option when users adopt more efficient equipment. Engage with CARB/CPUC/CEC staff on measure package development to secure top-down reinforcement while delivering bottom-up proof of concept.

5 Appendix A: References

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6 Appendix B: Workbook Contents

Tab Name	Category	Description	How it is helpful
Research Objectives	Overview	This contains the research objectives for the Review of Measure Packages and the Review of Market Studies. It also contains data sources and answers to specific questions brought up at check-in meetings.	Understanding the scope of work of this study
Regulatory Timelines	High level summary	This contains a timeline of when refrigerant GWP restrictions will come into place across state and federal regulations. Unless otherwise stated, the GWP limit begins on January 1st of that year.	Track upcoming deadlines and cross reference between EPA and CARB GWP limits.
Refrigerant Drivers + Barriers	High level summary	This data table is a searchable reference guide for key refrigerants of interest. It has information on GWP, safety class, CMC charge limits, PFAS, drivers, barriers, and common uses for each refrigerant.	It is a helpful reference for understanding refrigerants' uses, limitations, and opportunities.
Product Drivers + Barriers	High level summary	This data table is a searchable reference guide for common products in high priority end uses. It contains information on product availability, market status, drivers, barriers, and opportunities.	It is a helpful reference for understanding products' uses, limitations, and opportunities.
Product Availability	Analyses	Results from a 2025 analysis of products listed in the AHRI Directory of Certified Product Performance. It contains information on product availability by refrigerant type for common measure package products and visualizations of efficiency ranges by capacity and refrigerant type.	This identifies the availability (as of 2025) of various refrigerants in products on the market. The equipment efficiency analyses can guide whether new models need to be run for different refrigerants when developing measure packages.
EPA SNAP	Analyses	Consolidation of EPA SNAP rules regarding specific refrigerants allowance for specific end uses. Table is up to date as of May 2026 and is subject to change when new Rules or Notices are approved by the EPA.	It is a helpful reference to determine which refrigerant alternatives may be used for specific sectors and end uses.
List of Market Studies	Resource list + summaries	This contains a list of market studies that TRC collected during this task, and it contains notes and summaries for the studies that TRC performed an in-depth review of. Other studies are	Users may wish to refer to a certain study for more detailed information than is given in the memo -

Tab Name	Category	Description	How it is helpful
		included for SCE's future reference and/or review.	this table summarizes and categorizes information into quick-access columns for this purpose.
List of Measure Packages	Resource list + summaries	This is a prioritized list of existing and upcoming measure packages in California's eTRM. They are prioritized based on number of claims, total system benefit, net kWh saved, and level of impact that a refrigerant change would have on the system. The highest priority measure packages were reviewed for assumptions that would require updates due to refrigerant changes.	This can function as a prioritization guide for which measure packages would have the greatest impact on the market. It can be used as a reference for what information needs to be updated for certain measure packages.
Refrigerant Charges - Common MP	Reference materials	Table of typical refrigerant charges for commonly used measure package equipment. From TRC CalNEXT Report (2023)	This can be used to inform refrigerant recovery and leak repair incentives to identify the highest impact opportunities.
Leakage Rates - Common MPs	Reference materials	Table of average refrigerant charge and leakage rate for commonly used measure package equipment. From MCE Cadmus Report (2024)	This can be used to inform a leakage repair incentive to target the equipment with the highest leak rates.
Manufacturer Data - HPs	Reference materials	Table of manufacturer-provided equipment performance by refrigerant type for air to water and water to water heat pumps. From TRC (2024). "Market Characterization of Ultra-Low GWP Space Conditioning Heat Pumps for Commercial Buildings"	It may be helpful to give an idea of relative performance between refrigerant types, and to see how the performance has changed over time when compared to newer data. It can also be helpful to identify data gaps - for instance, there was not much efficiency data found in 2024 for R-454B, R-454C, R-744, or R-1234ze.
Simulated Data - HVAC + CR	Reference materials	Table of simulated equipment performance by refrigerant type for several common equipment types in HVAC and commercial refrigeration. From NIST (2021). "Low-GWP Refrigerants: Options and Decisions".	This can be used as a reference to determine whether new refrigerants can exhibit similar performance to current refrigerants,

Tab Name	Category	Description	How it is helpful
			and guide whether new models need to be run for measure package development.

7 Appendix C: Regulatory Environment

7.1 Refrigerant GWP limits and prohibitions

While the EPA originally banned other refrigerants because of their ozone depletion potential (ODP), most current regulations focus on GWP. The federal regulations for refrigerants have been continuously evolving and should be consistently monitored to stay up to date on current regulations. The EPA accepts petitions and makes changes to both its Technology Transitions Program and its Significant New Alternatives Policy. The following sections are current as of the end of May 2026.

In 2018, CARB responded to rollbacks by the EPA under the first Trump administration by creating the California Significant New Alternatives Policy (SNAP) to maintain the GWP limits at that time. CARB may continue to set new GWP limits in the future as well for additional subsectors, such as refrigeration equipment with under 50 pounds of refrigerant, although there are no proposed regulations under consideration now.

7.1.1 EPA AIM Technology Transitions (GWP Limits)

The American Innovation in Manufacturing (AIM) Act authorizes the EPA to phase down production and consumption of HFCs in the U.S. by 85% by 2036 (*American Innovation and Manufacturing Act of 2020*, 42 U.S.C. § 7675). To do this, the EPA created the Technology Transitions Program, which sets GWP limits for products containing restricted HFCs. While the EPA's GWP limits are mostly in place, additional limits will start in 2027 or 2028.

In 2025, the EPA proposed a Technology Transition Rule reconsideration to move **back the timeline for a GWP limit to come into place to 2032** for remote condensing units, supermarkets, and cold storage warehouses (EPA, 2025). On May 26, 2026, the EPA published the final rule, referred to as the "TT Rule Reconsideration," and on July 27, 2026, the final rule will go into effect. The TT Rule Reconsideration was passed to "address where the AIM Act was forcing more expensive technology onto consumers (through the Technology Transitions provisions)" (Phasedown of Hydrofluorocarbons, 2026). For supermarket systems, remote condensing units for food retail, and cold storage warehouses, the GWP limits were already in place this year at 150 or 300, depending on the charge size. The new final rule sets the limits for supermarket systems and remote condensing units to 1,400 effective January 1, 2027, until January 1, 2032, when the original limits of 150 and 300 become effective. It sets the limits for cold storage warehouses to 700 effective July 27, 2026, until January 1, 2032, when the original limits of 150 and 300 become effective. It also removes the installation deadline for systems in the residential and light commercial air conditioning and heat pumps subsector, where components were manufactured or imported before January 1, 2025. It does not lift the existing GWP limits on that subsector. Equipment with GWP limits < 150 currently (unless specified, these were effective 2025 or 2026):

- Remote condensing units (> 200 lbs. charge) **(effective 2032)**
- Cold storage warehouses (> 200 lbs. charge) **(effective 2032)**
- Supermarkets (> 200 lbs. charge) **(effective 2032)**
- Refrigerated food processing and dispensing equipment with 500 g of refrigerant or less and outside scope of UL 621, ed. 7 **(effective 2027)**
- Industrial process refrigeration (> 200 lbs. charge)
- Refrigeration standalone units
- Household refrigerators and freezers
- Vending machines

- Commercial ice machines with harvest rate <= 1000 lb./24 hr (batch type) or <=1200 lb./24 hr (continuous type)

Equipment with GWP limits < 300 currently (unless specified, these were effective 2025 or 2026):

- Cold storage warehouses (<200 lb. charge or high temperature side of cascade system) **(effective 2032)**
- Remote condensing units (<200 lb. charge or high temperature side of cascade system) **(effective 2032)**
- Supermarkets (<200 lb. charge or high temperature side of cascade system) **(effective 2032)**
- Industrial process refrigeration (<200 lb. charge or high temperature side of cascade system)

Equipment with GWP limits < 700 currently (unless specified, these were effective 2025 or 2026):

- Cold storage warehouses **(effective July 27, 2026)**
- Chillers for comfort cooling and industrial process refrigeration with exiting fluid above -22°F
    - Chillers for industrial process refrigeration with exiting fluid from -58°F to -22°F limit **comes into place in 2028**; colder than -58°F is not covered
- Data centers, computer room air conditioning, and IT equipment cooling **(effective 2027)**
- VRF systems **(effective 2027)**
- Residential and light commercial air conditioning and heat pump systems
- Ice rinks

Equipment with GWP limits < 1,400:

- Supermarket systems **(effective 2027)**
- Remote condensing units **(effective 2027)**

7.1.2 EPA Significant New Alternatives Policy (SNAP)

Where the EPA AIM Act sets GWP limits for specific end uses, EPA SNAP determines whether a refrigerant is an acceptable alternative for use in a certain application. EPA SNAP allowance does not mean building code approval. The local building code still needs to allow a certain refrigerant for that end use, and SNAP approval can often precede building code updates however, this is not always necessary. See the workbook for the full list of acceptable and prohibited alternatives.

SNAP specifies acceptable use for “new” and “retrofit” conditions, where “new” means newly manufactured equipment and “retrofit” means a refrigerant replacement into existing equipment. Many low and ultra-low-GWP refrigerants are accepted by EPA SNAP and are subject to use conditions which often are either charge limits and/or self-contained equipment or secondary refrigerant loops.

Ammonia is allowed by EPA SNAP for many applications, such as chillers, cold storage warehouses, commercial ice machines, household refrigerators and freezers, ice rinks (both new and retrofit), industrial process air conditioning and refrigeration, non-mechanical heat transfer, residential and light commercial AC and heat pumps, and retail food refrigeration (using a secondary loop). However, ammonia is still not prevalent because other codes and standards restrict its use, such as the local building or mechanical code or ASHRAE 34. Because it is toxic to humans, technicians must take many safety measures for the proper use of ammonia, which typically limit the equipment to use in isolated locations, such as a machinery room or industrial site.

Under EPA SNAP, propane is allowed in self-contained commercial ice machines (subject to conditions), household refrigerators and freezers, industrial process refrigeration, self-contained room AC (subject to charge limits), standalone retail food refrigeration equipment (subject to charge limits), refrigerated food dispensing equipment (subject to conditions), vending machines (subject to conditions), very low temperature refrigeration (subject to conditions), and water coolers (subject to conditions). For propane and other A3s, EPA SNAP regulations defer to ASHRAE 15-2022 and UL 60335-2-89; see the section below on these regulations. Updates to ASHRAE 15 and UL 60335-2-89 have preceded updates to SNAP rules, therefore we expect the same for future updates.

There are limited cases where a low or ultra-low-GWP refrigerant can be used for a refrigerant retrofit, and these are in ice rinks (R-717), industrial process refrigeration (R-471A, R-600, R-290, R-744), non-mechanical heat transfer systems (R-744), very low temperature refrigeration (R-744), and R-471A in food processing, remote condensing units, or supermarket systems.

R-32 and R-454B, which are standard GWP A2Ls commonly used for air conditioning, are not allowed in refrigerant retrofits and are limited to use in new chillers, air conditioning, industrial process refrigeration, and commercial ice machines. R-513A is another standard GWP alternative that can be used more broadly in new and retrofit applications; however, it is prohibited from retrofits for residential and light commercial AC and heat pumps, new or retrofitted very low temperature refrigeration, and new or retrofitted non-mechanical heat transfer.

7.1.3 California Regulations and Title 17 (GWP Limits)

AB 32 created a comprehensive multi-year program to reduce greenhouse gas emissions in California. **SB 32** requires a 40% reduction in GHG emissions below 1990 levels by 2030.

SB 1206 sets a timeline for prohibitions on the sale of virgin bulk refrigerants, shown in Table 14:

Table 14. SB 1206 GWP Threshold Timeline

GWP Threshold	Date
2200	1-Jan-25
1500	1-Jan-30
750	1-Jan-33

CARB also created the HFC Regulation in Title 17 titled "Prohibitions on the Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Stationary Air-conditioning, and Other End Uses," sometimes called California SNAP. In response to a Washington, DC, District Circuit Court ruling that limited the EPA's ability to regulate high-GWP HFCs under EPA SNAP, California adopted new regulations to cover the prohibitions covered by the EPA SNAP Rules 20 and 21. These regulations are the **CARB HFC Regulation** and **SB 1013** (2018), together referred to as California SNAP. An amendment to this regulation establishes the "Refrigerant Recovery, Reclaim, and Reuse Requirements," also known as the R4 Program. The program requires the use of a specified minimum amount of reclaimed R-410A refrigerant in new AC or VRF equipment or the service of existing AC or VRF equipment. The R4 Program calculates the required amount every year and in 2025, it was 25%.

The Title 17 list of prohibited substances sets GWP limits by end use, similar to EPA SNAP. For most end uses, the GWP limits have already been in place. Currently, the only end use where the limit has not yet come into place is for stationary refrigeration equipment in existing facilities. These limits are for refrigeration equipment containing more than 50 pounds of refrigerant charge, Companies owning or operating 20 or more retail food facilities in California must attain a company-wide weighted-average GWP of less than 2,500 (or 25% reduction from 2019 levels) by 2026 and less than 1,400 (or 55% reduction from 2019 levels) by 2030. Annual reporting will enforce these limits CARB already requires annual reports for refrigeration systems containing greater than

50 pounds of refrigerant through the Refrigerant Management Program, which identifies and repairs leaks. The South Coast Air Quality Management District (SCAQMD) also has a Refrigerant Management Program under Rule 1415 and 1415.1, which requires annual leak inspection and reporting for HVAC and refrigeration systems with greater than 50 pounds of refrigerant (or more frequently for systems with 200-2,000+ pounds); SCAQMD does not set any GWP limits.

Other end uses CARB regulates:

- GWP less than 150
  - New equipment in cold storage warehouses with > 50 lbs. refrigerant in new facilities (effective 2022)
  - New equipment in ice rinks with > 50 lbs. refrigerant in new facilities (effective 2024)
  - New equipment for industrial process refrigeration excluding chillers with > 50 lbs. refrigerant in new facilities (effective 2022)
  - New equipment for retail food refrigeration with > 50 lbs. refrigerant in new facilities (effective 2022)
  - Other new refrigeration equipment with > 50 lbs. refrigerant in new facilities (effective 2022)
- GWP less than 750
  - New room/wall/window air-conditioning, PTACs, PTHPs, portable AC, and residential dehumidifiers (effective 2023)
  - New equipment in ice rinks with > 50 lbs. refrigerant in existing facilities (effective 2024)
  - Other new air conditioning equipment (effective 2025)
  - New VRF systems (effective 2026)
- GWP less than 1,500
  - New chillers for industrial process refrigeration (exiting fluid < 35F and > -10F) (effective 2024)
- GWP less than 2,200
  - New chillers for industrial process refrigeration (exiting fluid < -10 F and > -58 F) (effective 2024)
  - New equipment for industrial process refrigeration excluding chillers with > 50 lbs. refrigerant in existing facilities (effective 2022)

7.2 Safety Codes for Flammability and Toxicity

Ultimately, the use of propane as a refrigerant comes down to the AHJ and local fire marshal's interpretation of the building code/mechanical code. The building code and mechanical code often refer to the ASHRAE standards, but the AHJ can ultimately decide to approve a system with a higher charger regardless of legislative approval, as can happen with demonstration cases of new technologies.

7.2.1 California Mechanical Code

The 2025 California Mechanical Code is based on the 2024 Uniform Mechanical Code. The process of the 2027 Uniform Mechanical Code is ongoing, and any potential changes have not yet been decided on and are subject to change. TRC reviewed the 2025 California Mechanical Code for references to A2L and A3 refrigerants.

- Ammonia refrigeration systems shall comply with IIAR 2, IIAR 3, IIAR/ANSI 4, IIAR 5, and IIAR 6 – this is not new, so it should be familiar to those who work with ammonia. Because of the stringent safety standards, ammonia is more common in applications that already follow stringent safety practices. Ammonia refrigeration equipment is permitted to be used in conjunction with a secondary coolant that serves any occupancy provided that the system is indirect (IIAR 2).
  - IIAR = International Institute of Ammonia Refrigeration

- ANSI = American National Standards Institute
- ANSI/IIAR 2, American National Standard for Safe Design of Closed-Circuit Ammonia Refrigeration Systems. The new and improved IIAR 2 is the definitive design safety standard of the ammonia refrigeration industry.
- ANSI/IIAR 3, American National Standard for Ammonia Refrigeration Valves. Specifies criteria for materials, design parameters, marking and testing of valves and strainers used in closed circuit ammonia refrigeration systems.
- ANSI/IIAR 4, Installation of Closed-Circuit Ammonia Refrigeration Systems. Written to serve as a standard for the installation of closed-circuit ammonia mechanical refrigeration systems and overpressure protection relief piping systems.
- ANSI/IIAR 5, Start-up and Commissioning of Closed-Circuit Ammonia Refrigeration Systems. Provides basic minimum requirements for the safe Start-up and commissioning of complete closed-circuit mechanical refrigerating systems utilizing ammonia as the refrigerant and additions and modifications made to such systems.
- ANSI/IIAR 6, American National Standard for the Inspection, Testing, and Maintenance of Closed-Circuit Ammonia Refrigeration Systems.

- Other than ammonia, refrigerants follow the mechanical code AND ASHRAE 15-2022. CO2 must also comply with IIAR CO2 (Safety Standard for Closed-Circuit Carbon Dioxide Refrigeration Systems).
- Refrigerants either need to be listed in the mechanical code, or be compliant with ASHRAE standard 34-2022 (refrigerant designations – AKA it must have the correct chemical composition for that refrigerant) and approved by the Authority Having Jurisdiction
- Mechanical code classifies refrigerants according to their probability of leakage into an occupied area
  - High probability systems for human comfort can only use A1 or A2L (no A2, A3, B1, B2L, B2, or B3)
  - The following occupancies can only use A1 or A2L refrigerants: assembly, business, educational, moderate hazard factory industrial, some high hazard occupations, some institutional, mercantile, residential, and some storage.
  - In low probability or machinery rooms, any refrigerant safety class is allowed (additional requirements may apply)
- Propane cannot be used unless approved by the AHJ
  - Exceptions: laboratory greater than 100 square feet, industrial occupancies, listed self-contained systems containing not more than 0.150 kg (0.331 lbs.) of A3 refrigerant (referring to ASHRAE 15)
- Charge limits are determined by refrigerant concentration limit (RCL) calculations – if charge is over the limit, then a machinery room is required → this especially comes into play with A3s
  - RCL limits refer to ASHRAE 15-2022
  - Machinery room specifications refer to ASHRAE 15-2022
- Industrial occupations don't follow RCL limits IF they have all of the following:
  - -Spaces with machinery are separated from other occupancies with tight construction and doors
  - -Access restricted to authorized personnel
  - -Detectors are installed meeting requirements

- -Where class 2 or 3 flammability is used, cannot have surface or open flame over 800F
- -Electrical equipment meets requirements
- -Parts containing refrigerant exceeding 100 horsepower (some exceptions) are in the machinery room or outdoors

Because the refrigerants of interest have higher flammability, we performed a brief review of the California Fire Code. The 2025 California Fire Code refers to the California Mechanical Code for most refrigerant-related topics. For the installation of mechanical refrigeration systems, the fire code refers directly to ASHRAE 15 for refrigerants other than ammonia, and for ammonia it refers to IIAR 2, IIAR 6, IIAR 7, IIAR 8, and IIAR 9. The fire code also has a few separate requirements to note. Machinery rooms with flammable and toxic refrigerants must meet specific detector, pressure control, and ventilation requirements. The fire code requires systems with more than 6.6 pounds of flammable or toxic refrigerant discharge vapor to the atmosphere through an approved treatment or flaring system. Flaring must incinerate all discharge and not pose health or environmental hazards.

7.2.2 ASHRAE 15 and UL 60335-2-89

The California Mechanical Code, California Fire Code, and EPA SNAP reference the 2022 version of ASHRAE 15, so that version must be followed even when new versions of the standard are released (unless references are updated). Broadly speaking, ASHRAE 15-2022 allows the use of A2L, A2, and A3 refrigerants in commercial refrigeration and allows A2Ls in human comfort applications. ASHRAE 15 sets charge limits based on the effective dispersal volume charge of a refrigerant; if the refrigerant exceeds the amount permitted by dispersion calculations, the system must be fully contained in a machinery room or installed outdoors. For A3 and B2L refrigerants to provide enough capacity to serve a commercial or industrial load, they require a machinery room or outdoor installation. B2L refrigerants are generally not permitted in occupied spaces above very small charges, and A3 equipment in occupied spaces must be in a self-contained system.

ASHRAE 15-2022 defers charge limits for self-contained systems to UL 60335-2-89, which came out in 2021; this raised charge limits on commercial self-contained plug-in displays based on open- or closed-door design. Open-door appliances have a charge limit of 500 grams, and closed-door appliances have a charge limit of 300 grams. This helps original equipment manufacturers increase system capacity. Safety standards limit most self-contained systems to 150 grams. UL 60335-2-89 applies specifically to commercial refrigerating appliances with an incorporated or remote refrigerant condensing unit or compressor. It contains requirements for factory-assembled walk-in coolers and freezers, refrigerating units, and laboratory refrigerators and freezers. Examples of appliances that are within the scope of this standard are refrigerated display and storage cabinets, refrigerated trolley cabinets, service counters and self-service counters, blast chillers and blast freezers, and commercial ice-makers.

Under current regulations, these are the suitable applications for propane:

- Reach-in refrigerators, freezers, and display cases; beverage coolers; frozen drink machines; ice cream machines and ice cream freezers
- Walk-in coolers and freezers (self-contained system with charge under 150 grams)
- Other monobloc air-to-water systems (self-contained system with charge < 150 grams)
- Demonstration projects where AHJ is willing to break code

European markets have been able to safely adopt propane sooner than the US because historically their building stock contained more monobloc systems, so the propane systems were able to retrofit more easily into existing systems. In the US, the split system is more common, where refrigerant pipes run both inside and outside of the unit. This type of system has more refrigerant and is more prone to leaks, therefore it does not work well with propane, considering the safety of the refrigerant.

7.3 Future Directions

CARB is planning to publish a roadmap this summer (draft expected July 1st according to CARB interview) – this will give a plan and recommendations for transitioning the California market to natural refrigerants.

ASHRAE is conducting CARB-funded research on A3 refrigerants and expects to publish it in 2027. This will help evaluate safe uses of propane in other end uses and be used to set new codes and standards for A3s.

See accompanying workbook for a full timeline of existing and upcoming GWP limits at the state and federal level.

PFAS ban. Currently, CA regulates PFAS in products that are more directly consumer facing than refrigerants, such as cosmetics, textiles, and food packaging (DTSC, 2026) (CARB, 2022) (Rothman, Feingold, Jordan, & Rigaudeau-Lopez, 2025). The future adoption of a PFAS ban for refrigerants is possible, considering other states are considering and adopting these regulations and similar PFAS bans. This would affect refrigerants that contain PFAS, such as synthetic R-1234 series.

8 Appendix D: Refrigerant Resources

8.1 Refrigerant Drivers and Barriers

This section provides a brief overview of the drivers and barriers for key refrigerants of interest. It is based on information gathered during the literature review of market studies. A list of these studies is in the accompanying workbook on the “List of Market Studies” tab. The “Refrigerant Drivers + Barriers” tab of the “Market Study of Low-GWP Refrigerants” workbook has more detailed information and additional refrigerants.

Standard GWP refrigerants are more common on the market today. Ultra-low-GWP natural refrigerants align with CARB’s long-term goals but may face implementation challenges in meeting the mechanical and fire codes. Ultra-low-GWP natural refrigerants each face unique safety considerations, which affect the applications that they are best suited to.

8.1.1 Standard GWP (150 < GWP < 700)

R-32, R-454B, and R-513A (150 < GWP < 700, A2L)

Drivers and Barriers

GWP <150 regulations will require the phasing out of “standard GWP” refrigerants (150 < GWP < 700). TRC will confirm how regulations affect specific C&I applications for the final deliverable. These refrigerants are common in the market now, but because they are A2Ls there is a cost surcharge due to required additional safety measures. Their A2L status also means they cannot be a drop-in replacement for A1 class refrigerants.

Applications

- **R-32:** Rooftop packaged heat pump. Viewed as an alternative for R-134A and R-410A (not drop-in replacement).
- **R-454B:** Rooftop packaged heat pump, air conditioning, water-cooled chillers, air-cooled chillers; viewed as an alternative for R-410A (not drop-in replacement).
- **R-513A:** Heat pump water heaters (HPWH), Commercial Refrigeration (display cases); alternative to R-134A (not drop-in replacement).

R-456A (GWP = 687, A1)

Drivers and Barriers

This refrigerant is in the A1 safety class, making it a potential drop-in replacement for R-134A. It has improved capacity and equal or higher COP compared to R-134A (Kim et al., 2024). It performs well at higher outlet temperatures, making it a good candidate for water heating. TRC did not come across this refrigerant beyond an academic study of heat pump water heaters by Kim et al.

Applications

- Heat pump water heating

8.1.2 Low-GWP (<150 GWP)

R-454C (GWP = 145 or 148, A2L)

Drivers and Barriers

R-454C (GWP = 145 or 148) is a blend of R-32 and R-1234yf giving it a GWP less than 150. However, this blend does contain PFAS and could be subject to PFAS bans in the future. It could be a drop-in replacement for 404A and potentially have better performance. It is a low-cost, low-barrier alternative to 404A. Market actors are interested in this product, but there are some concerns about its flammability and its many unknowns (cost, performance, and allowability in future codes). Flagging this project to keep an eye on performance and adoption in supermarket systems: **Field Assessment of R-454C Compared to R-404A / CO_2 Supermarket Systems | ETCC.**

Applications

- Drop-in replacement for R-404A (Mota-Babiloni et al., 2018); (Mostafa et al., 2021)

R-485A (GWP = 143, A1 or A2L – safety class unclear)

Drivers and Barriers

This refrigerant is not yet in the California Mechanical Code. TRC came across it in a 2024 study of heat pump water heaters by Orbia. It could be a more efficient alternative to CO_2 as it has a 10% COP increase over CO_2 at 20% lower gas cooler pressure. However, R-485A still operates at very high pressure, which could still pose safety concerns. It has the potential for efficient use in a broader range of geographies than CO_2 for cooling, refrigeration, and heating.

Applications

- Heat pump water heating

8.1.3 Ultra-Low-GWP (<10 GWP)

Synthetic Refrigerants: R-1234yf and R-1234ze (GWP = 1 for yf and = 7 for ze, A2L)

Drivers and Barriers

These synthetics are a good ultra-low-GWP alternative (GWP = 1 for yf and = 7 for ze), but they contain PFAS. This means that they are potentially going to be restricted or banned in the future, if not already banned in some jurisdictions. Currently, it is banned in five European countries, Maine, and Minnesota (HARDI, 2026).

Applications

- Water-cooled chillers, air-cooled chillers
- HPWH
- Stationary AC, heat pumps
- Refrigeration

Natural Refrigerant: Propane (R-290) (GWP = 4, A3)

Drivers and Barriers

Propane (GWP = 4) performs similarly to incumbent refrigerants with a lower pressure drop and lower mass flow rate. It is a clear choice based on performance and is already prevalent in Europe. EPA SNAP allows propane as an acceptable alternative, limited to < 150 grams per refrigerant circuit (EPA, 2018); however, other codes may restrict propane usage based on safety. AHJ may deny propane use based on acceptable charge limits. TRC will review the relevant fire codes, mechanical codes, and UL standards to determine existing limits. To accommodate the additional safety requirements, manufacturers will have to do a fundamental redesign of their equipment.

Applications

- Currently limited by regulation to residential and self-contained commercial refrigeration.
- Seen in water-cooled chillers/heat pumps, air-cooled chillers/heat pumps, commercial refrigeration (stand-alone units - display cases and reach-in refrigerators), and heat pump (HP) clothes dryer.
- Alternative to R-410A with equal or better performance, promising alternative to R-134A.

Natural Refrigerant: Carbon Dioxide (CO_2 / R-744) (GWP = 1, A1)

Drivers and Barriers

Carbon dioxide (GWP = 1) is the safest ultra-low-GWP refrigerant if it leaks (safety class = A1), but it operates at very high pressure, and if not properly designed, can pose other safety risks. The very high operating pressures and temperatures (due to the transcritical cycle) mean these units are usually less efficient. CO_2 is not a drop-in replacement – it would require a full system retrofit because of the different operating conditions.

Applications

- Commercial HVAC (water-cooled chillers, air-cooled chillers)
- Supermarket systems, display cases
- Residential air-to-air units (in the European Union/United Kingdom (EU/UK)
- Domestic hot water (DHW), HPWH

Natural Refrigerant: Ammonia (R-717) (GWP = 0, B2L)

Drivers and Barriers

Ammonia (GWP = 0) is a commonly used refrigerant in industrial applications in non-populated areas, primarily because it is an effective refrigerant but toxic to humans if it leaks. There has been a good record of minimal leaks due to service and maintenance regimens, and contractors active in industrial applications are familiar with how to design and install systems. However, applying ammonia to other applications would require a fundamental equipment redesign to account for toxicity. There are many safety codes to comply with when using these systems. The California Mechanical Code limits ammonia charge to 0.014 lb. per 1000 cubic feet of space, which aligns with the National Institute for Occupational Safety and Health's Immediately Dangerous to Life or Health (IDLH) value of 300 ppm. Assuming we need at least 1 lb. of ammonia per ton of refrigeration capacity, this limit makes it either difficult or impossible to use ammonia in indoor systems. Further investigation into the relevant codes will help determine if the use of ammonia in outdoor systems or dedicated ammonia machinery rooms is possible.

Applications

- Mainly used in industrial applications.
- Seen in some water-cooled chillers/heat pumps, air-cooled chillers/heat pumps.

8.2 GWP of Common Refrigerants

Table 15: List of Refrigerant GWPs (Phasedown of Hydrofluorocarbons, 2026)

Refrigerant	GWP (AR5)	GWP Class
R-717 (Ammonia)	0	Ultra Low-GWP
R-1233zd(E)	1	Ultra Low-GWP
R-1234yf	1	Ultra Low-GWP
R-1234ze(E)	1	Ultra Low-GWP
R-1234ze(Z)	1	Ultra Low-GWP
R-744 (Propane)	1	Ultra Low-GWP
R-600a (Isobutane)	3	Ultra Low-GWP
R-290 (Carbon Dioxide)	4	Ultra Low-GWP
R-123	79	Low-GWP
R-454C	148	Low-GWP
R-515B	299	Standard GWP
R-454B	467	Standard GWP
R-513A	573	Standard GWP
R-514A	600	Standard GWP
R-32	677	Standard GWP
R-245fa	858	High GWP
R-448A	1273	High GWP
R-449A	1282	High GWP
R-134a	1300	High GWP
R-407C	1624	High GWP
R-22	1760	High GWP
R-410A	1924	High GWP
R-404A	3943	High GWP

8.3 Training Resources for Refrigerant Safety

Table 16: Training Resources (DNV, 2024)

Organization	Summary	Sectors served	Supporting activities	Link
North American Sustainable Refrigeration Council (NASRC)	A network of supermarket industry stakeholders working to remove barriers preventing the adoption of climate-friendly natural refrigerants.	Retail refrigeration	Workforce development; Funding; Resources library; Policy advocacy; HFC Policy Tracker	**https://nasrc.org/**
Air Conditioning Contractors of America (ACCA)	National trade association that provides members networking opportunities, education, and advocacy services while championing the national health of the HVAC-R industry.	Residential HVAC; Commercial HVAC; Stationary Refrigeration	Workforce development; A2L Safety Training; Quality certifications; Policy advocacy; Industry standards	**https://www.acca.org/about-acca**
The Air-Conditioning, Heating, and Refrigeration Institute (AHRI)	Trade association representing manufacturers of heating, ventilation, air conditioning, commercial refrigeration, and water heating equipment.	Residential HVAC; Commercial HVAC; Stationary Refrigeration; Water Heating	Performance rating standards; Equipment certifications; Policy advocacy	**https://www.ahrinet.org/standards**
The Institute of Heating and Air Conditioning Industries, Inc. (IHACI)	Trade association of contractors, manufacturers, distributors, utilities, and businesses actively engaged in the HVAC-R and sheet metal industries.	Residential HVAC; Commercial HVAC; Stationary Refrigeration	Workforce development; North American Technical Excellence (NATE) certifications	**https://www.ihaci.org/education-training**
Pacific Gas and Electric (PG&E) – Energy Center	Energy efficiency, decarbonization, and electrification workforce training.	Residential HVAC; Commercial HVAC; Stationary Refrigeration; Water Heating	Workforce development	**https://pge.docebosaas.com/learn**

9 Appendix E: Market Status and Product Availability

9.1 Market Trends

9.1.1 Supply Chain & "Stranded Inventory" Friction

- **The R-454B Shortage:** While the industry flipped to A2L units, a severe shortage of R-454B cylinders drove prices up by over **300%**. This led many customers to repair old R-410A systems rather than adopt new low-GWP equipment. Despite setbacks, the industry recovered from this shortage within nine months, showing strong coordination across the supply chain and desire by manufacturers and distributors to continue the refrigerant transition (ACiQ, 2025).
- **A2Ls in the HVAC market:** HARDI estimated at the end of Q4 2025 that 91% of HVAC systems sold were A2L units, and that only 6% of inventory consists of remaining R-410A units (Heating Air Conditioning & Refrigeration Distributors International, 2025).
    - **Inventory Delays:** The EPA's 2025 Technology Transitions Rule reconsideration noted substantial concerns regarding **stranded inventory** for multi-family new construction, where builders ordered R-410A equipment years in advance but faced installation bans by 2025/2026 (Phasedown of Hydrofluorocarbons, 2025).

9.1.2 Significant Upfront & Incremental Cost Premiums

- **HVAC (A2L Equipment):** Manufacturers like **Trane, Daikin, and Lennox** implemented price increases of **7-10%** in early 2025, specifically due to the A2L transition. By early 2026, those costs are compounding with material inflation (copper and aluminum), leading to total project cost increases of **20–30%** compared to 2024 baselines (Paschal, 2026) (Why Hvac Prices Are Increasing in 2025 and What to Do, n.d.).
- **Refrigeration (CO_2 & Propane):** The North American Sustainable Refrigeration Council (**NASRC)** identifies that for grocery stores, retrofitting the existing full refrigeration system (not standalone units) to a system using natural refrigerants can cost **24% higher than HFC systems.** This creates a massive financial barrier for independent grocers and "food deserts" (NARSC, 2022)
    - (NARSC, 2025).

New tariffs on imported goods from China and on steel and aluminum have increased component and equipment costs and led to price uncertainty. Additionally, the sticker shock from the 2025–2026 transition to A2Ls is greater than most legacy workpapers assume. This has led to a shift towards a repair economy where equipment owners prefer to repair and maintain legacy equipment.

9.1.3 Workforce and Maintenance Concerns

- **Technician Readiness:** The **NASRC** cites the "shrinking technician workforce" as the single most significant barrier to the adoption of natural refrigerants. There is a critical lack of service contractors trained in the complex start-up procedures for CO_2 systems that operate transcritically (at high temperatures and pressures) (NASRC, 2025).
- **Water Heater Reliability Fear:** For commercial HPWHs, ethnography studies by **ILLUME Advising** show that "brand awareness is low" and decision makers see hot water purely as a utility that "must just

work." Owners frequently defer maintenance and perceive the complexity of low-GWP heat pump designs as a reliability risk (Powers, 2025)

There is a contractor skills gap for A2L and smart technology training to meet the demand for installing these systems. At the same time, there is a technician shortage. This presents a key opportunity to invest in technician training for A2L/smart systems. See the Appendix for a list of training resources from the CPUC.

9.1.4 Changing Regulatory Landscape

As detailed below, the phase out of legacy refrigerants requires a shift to A2Ls, meaning manufacturers must redesign equipment. For equipment owners, the decreased supply of legacy refrigerants means a full equipment retrofit may become necessary as maintenance of older equipment gets more expensive. At the same time, stricter efficiency standards (SEER2/energy efficiency ratio (EER2)) are coming into play. This means new equipment will be more efficient and potentially have a higher upfront cost.

- **The Reclaim Requirement:** CARB now requires manufacturers to use at least **25% reclaimed refrigerant** in certain new equipment (VRF systems) entered into California commerce by 2026 to foster a circular economy (CARB, 2026).
- **Phase-Out Price Spikes:** As R-410A production is slashed, the cost of reclaimed R-410A for older system repairs has risen from its baseline, now often exceeding **$40-$75 per pound** at the consumer level compared to $12-$25 per pound in 2025 (How Much Does R-410A Refrigerant Cost per Pound?, 2026).

As of **January 1, 2026**, the new California Energy Code (Title 24, Part 6) officially took effect, fundamentally changing residential and commercial new system installations.

- **Electric-Ready Mandates:** All new single-family homes and many multi-family projects must now be electric-ready, with dedicated circuits and panel capacity for heat pumps, even if gas is initially installed (California Energy Commission, 2026).
- **The Replacement Trigger:** For existing commercial buildings (retail, schools, offices), the 2025 code now requires that end-of-life RTUs be replaced with high-efficiency **heat pumps** rather than like-for-like gas units (California Energy Commission, 2025).

9.1.5 Changing Consumer Preferences

There has been an increased demand for energy efficiency, sustainability, smart technology, and improved indoor air quality (KGG Consulting, 2025). These drive the market towards new product development; these can provide savings and improved performance in the long term, at the tradeoff of a higher upfront cost. Manufacturers must invest in research and development and retooling their factories to meet A2L and efficiency requirements, but grapple with cost volatility and supply chain disruptions. There is an opportunity to support manufacturers for promoting efficient new products.

9.2 Low-GWP Product Availability for Common Measures

TRC previously conducted a market analysis of nearly 8 million products from the Air Conditioning, Heating, and Refrigeration Institute (AHRI) Directory of Certified Product Performance as of March 23, 2025, as shown in Table 17. The market analysis identified commonly available standard GWP, low-GWP, and ultra-low-GWP products for residential or C&I applications. Currently, most product types use standard GWP refrigerants (R-454B, R-454C, R-513A, and R-32) to transition away from high GWP refrigerants (R-410A or R-404A). Some products have low and ultra-low-GWP alternatives – these are mainly CO_2, propane, and synthetic HFO blends.

Table 17: Count of Products Analyzed from AHRI Directory

Product	**Count**
Chillers	3,793
Air conditioning (AC) Units	6,262,654
HP Units	1,652,528
Mini-Split HP or AC	29,348
Large Unitary Equipment	16,279
PTAC/PTHP	61
Data Com Cooling	826
HP Water Heaters	478
HP Pool Heaters	1,313
Clothes Dryers	636
Ice Machines	370
MT & LT Standalone Coolers	1809
Total	7,970,095

Based on TRC's prior analysis of the AHRI Directory products, these were the most common refrigerants in each category of GWP for several key measure packages, as shown in Table 18Table 18. If multiple refrigerants are common for a certain category, they are listed together in order of prevalence according to TRC's 2025 market analysis.

Table 18: Commonly Used Refrigerants by Products in AHRI Directory

Product	***High***	***Standard***	***Low***	***Ultra Low***
Chillers	R-134A, R-410A, R-407C	R-513A, R-32, R-515B	R-454C	R-1234ze(E), R-1233zd(E), R-290
AC Units	R-410A	R-454B, R-32	None	None
Heat Pumps Units	R-410A	R-454B, R-32	None	None
Mini-Splits HP or AC	R-410A	R-32, R-454B	R-454C	
Large Unitary Equipment	R-410A	R-32, R-454B	None	None
PTAC/PTHP	R-410A	R-32	None	None
Data Com Cooling	R-410A, R-407C	R-454B	None	None
HP Water Heaters	R-134A, R-410A	R-513A	R-454C	R-744
HP Pool Heaters	R-410A	R-32	None	None
Clothes Dryers	R-134A	None	R-454C	R-290

Product	*High*	*Standard*	*Low*	*Ultra Low*
Ice Machines	R-404A, R-134A, R-410A, R-449A	R-513A	R-454C	R-290
MT & LT Standalone Coolers	R-448A, R-134A, R-449A	R-513A	None	R-290, R-600A

TRC also analyzed how the efficiencies of the products in Table 17 vary by capacity and refrigerant type. See the following tables and figures for this information, separated by product type. As an example, Table 19 shows the results of the Large Unitary Equipment analysis. The equipment in this analysis did not have any low or ultra-low-GWP equipment options in the AHRI Directory. Most of this equipment is subject to regulations that require standard GWP (< 700) refrigerants, which are satisfied with R-32 and R-454B.

The AHRI Directory data pulled in 2025 does not encompass all the low-GWP products that we came across during our literature review. Performance data for larger systems, such as water-cooled chillers or commercial refrigeration, is typically not publicly available. TRC would have had to request performance data directly from manufacturers for systems that use ultra-low-GWP refrigerants such as CO_2, ammonia, and propane.

There is also a gap in our data for reach-in refrigerators and freezers and display cases. This data is in the AHRI Directory, but it was not within the scope of work of the 2025 market analysis to pull the data for these products. However, TRC conducted similar analyses using the ENERGY STAR data for products with low and ultra-low-GWP options, which can be found throughout Section 3.

Table 19: Large Unitary Equipment Average IEER

Refrigerant		33 Tons or more		33-16 Tons		15 Tons or less		Total	
Class	Type	Count	AVG IEER	Count	AVG IEER	Count	AVG IEER	Count	AVG IEER
High	R-410A	0	0.0	90	13.8	331	14.7	421	14.5
Standard	R-32	3381	16.6	4241	16.9	505	19.3	8127	16.9
	R-454B	601	16.0	2188	15.2	2880	15.8	5669	15.6

Figure 5: Efficiencies of Large Unitary Equipment by Capacity and Refrigerant Type.

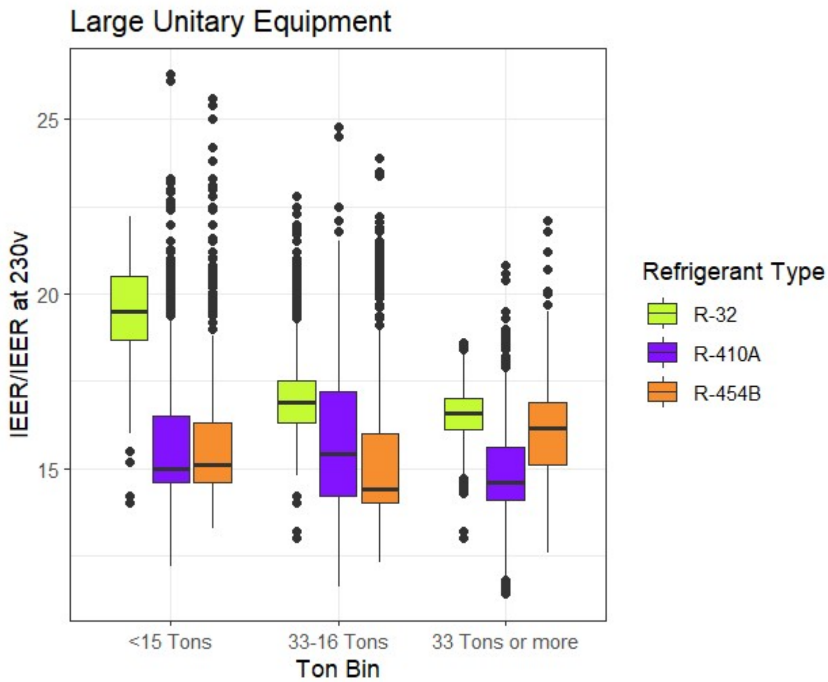

Table 20: Variable Speed Split Heat Pump Average Efficiency

Refrigerant		1 Ton or less		2 ton		3 ton		4 and 5 ton		Total	
Class	Type	Count	AVG COP	Count	AVG COP	Count	AVG COP	Count	AVG COP	Count	AVG COP
High	R-410A	3444	21.9	3093	20.5	1934	19.1	1114	19.4	9585	20.6
Standard	R-32	768	19.9	762	19.0	324	#N/A	183	#N/A	2037	19.5
	R-454B	2614	#N/A	1995	#N/A	1147	#N/A	1256	#N/A	7012	#N/A
Low	R-454C	0	0.0	0	0.0	3	18.0	0	0.0	3	18.0

Figure 6: Efficiencies of Variable Speed Split Heat Pumps by Capacity and Refrigerant Type.

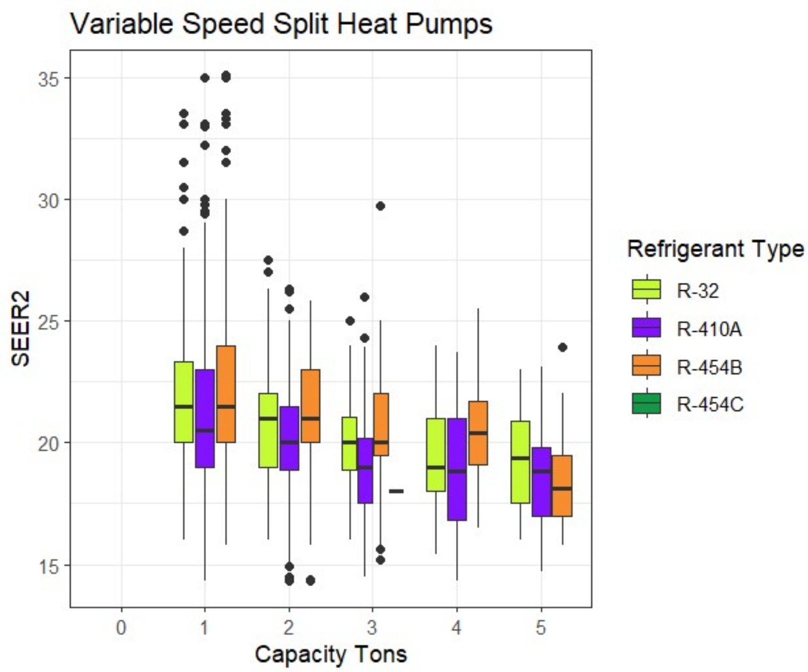

Table 21: Variable Speed Split AC Average Efficiency

Refrigerant		2 Tons or More		1-2 Tons		1 Ton or less		Total	
Class	Type	Count	AVG COP	Count	AVG COP	Count	AVG COP	Count	AVG COP
High	R-134A	0	0.0	1	0.0	0	0.0	1	0.0
	R-410A	169	16.6	586	19.7	390	20.8	1145	19.6
Standard	R-32	97	17.6	230	18.3	57	17.8	384	18.0
	R-454B	31	#N/A	63	#N/A	69	#N/A	163	#N/A

Figure 7: Efficiencies of Variable Speed Split ACs by Capacity and Refrigerant Type.

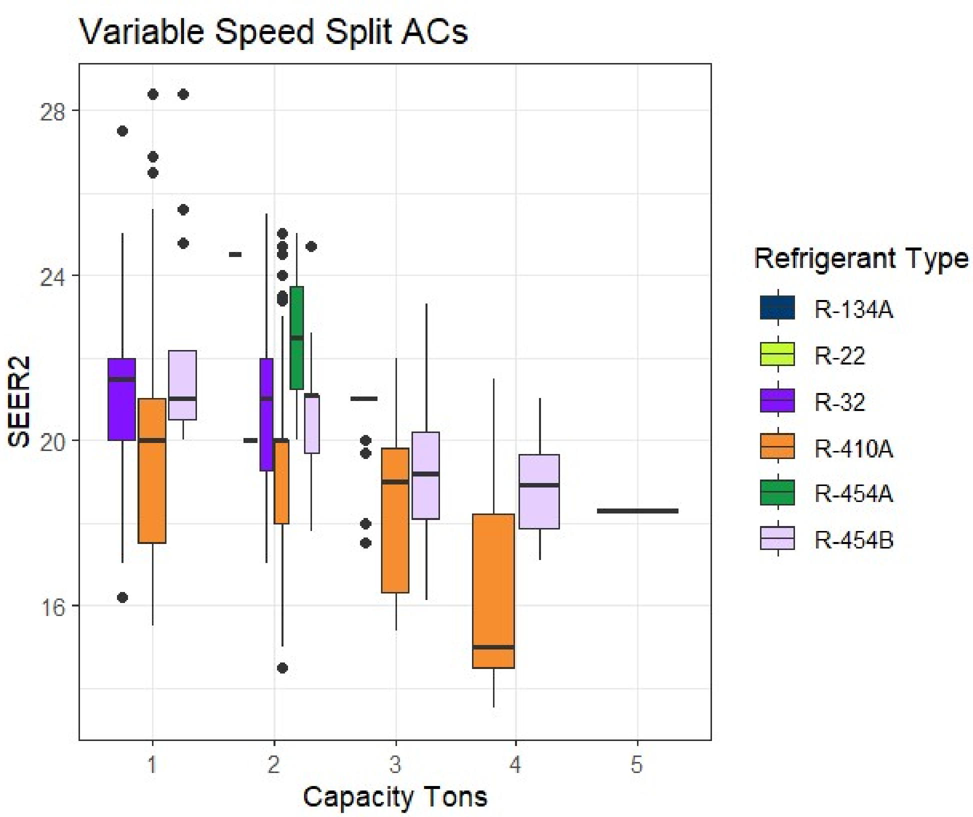

Table 22: AC Unit Average Efficiencies

Refrigerant	Class	High	Standard	
	Type	R-410A	R-32	R-454B
4 to 5 Tons	Count	46763	4921	126196
	AVG SEER2	15.0	14.7	15.2
3 to 4 Tons	Count	172872	25408	425577
	AVG SEER2	15.0	14.9	15.2
2.5 to 3 Tons	Count	142518	26809	280998
	AVG SEER2	15.1	14.8	15.3
2 to 2.5 Tons	Count	125495	20929	286276
	AVG SEER2	14.8	14.7	15.1
2 or less Tons	Count	119924	29444	267482
	AVG SEER2	14.5	14.6	14.4
Total	Count	607572	107511	1386529
	AVG SEER2	14.9	14.7	15.1

Figure 8: Efficiencies of AC Units by Capacity and Refrigerant Type.

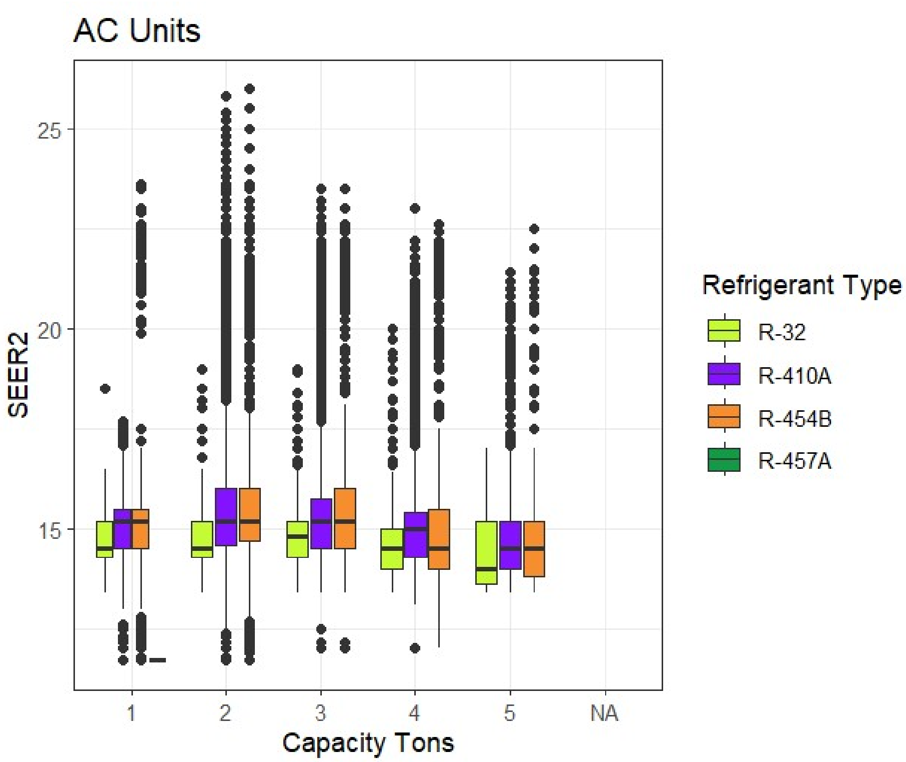

Table 23: Data Com (Computer and processing room AC) Average Efficiency

Refrigerant	Class	High		Standard
	Type	R-407C	R-410A	R-454B
> 30 Tons	Count	0	21	0
	AVG COP	0.0	3.0	0.0
> 20 Tons	Count	71	55	0
	AVG COP	2.7	2.6	0.0
> 10 Tons	Count	98	88	2
	AVG COP	3.0	2.5	3.0
> 5 Tons	Count	2	124	0
	AVG COP	2.3	2.9	0.0
5 or less	Count	34	167	0
	AVG COP	1.5	0.8	0.0
Total	Count	205	455	2
	AVG COP	2.6	2.0	3.0

Figure 9: Efficiencies of Data Com AC by Capacity and Refrigerant Type.

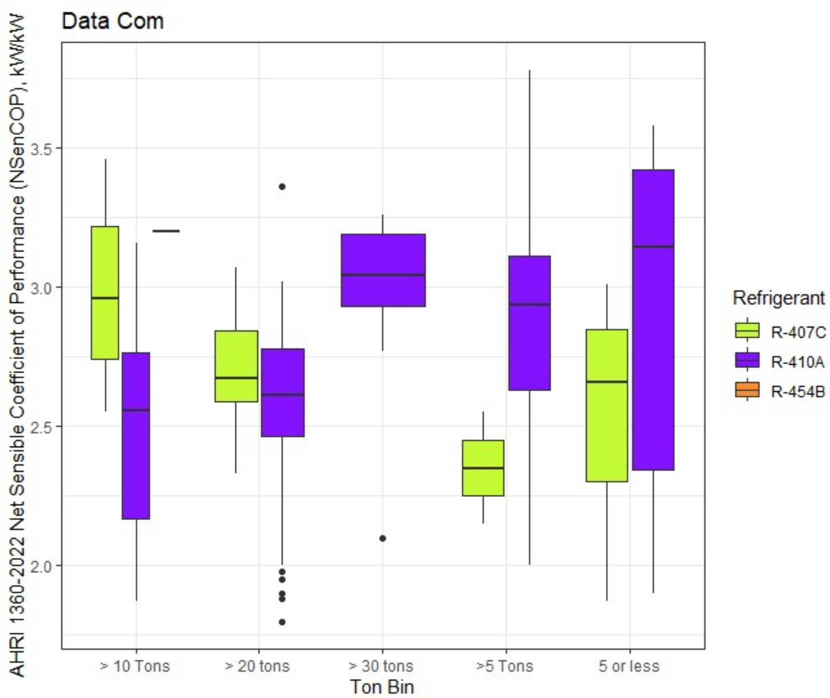

Table 24: Heat Pump Pool Heaters Average Efficiencies

Refrigerant	Class	High	Standard
	Type	R-410A	R-32
9 Tons or More	Count	295	0
	High temp COP	5.3	0.0
	Medium Temp COP	4.1	0.0
4 to 9 Tons	Count	523	1
	High temp COP	5.5	5.0
	Medium Temp COP	4.5	3.9
4 Ton or less	Count	424	1
	High temp COP	5.7	5.2
	Medium Temp COP	4.0	4.3
Total	Count	729	6
	High temp COP	9.5	10.2
	Medium Temp COP	7.3	8.2

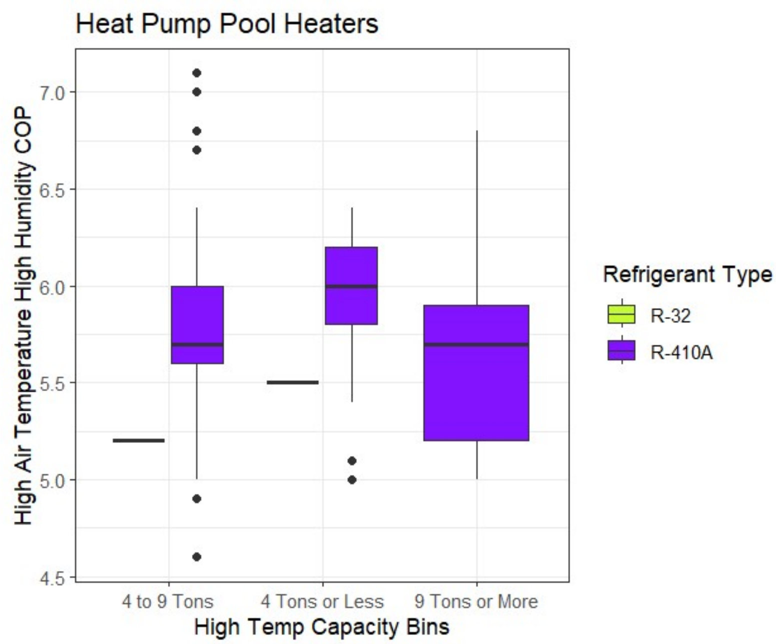

Figure 10: Efficiencies of Heat Pump Pool Heaters at Mid Humidity by Capacity and Refrigerant Type.

Figure 11: Efficiencies of Heat Pump Pool Heaters at Low Temperature by Capacity and Refrigerant Type.

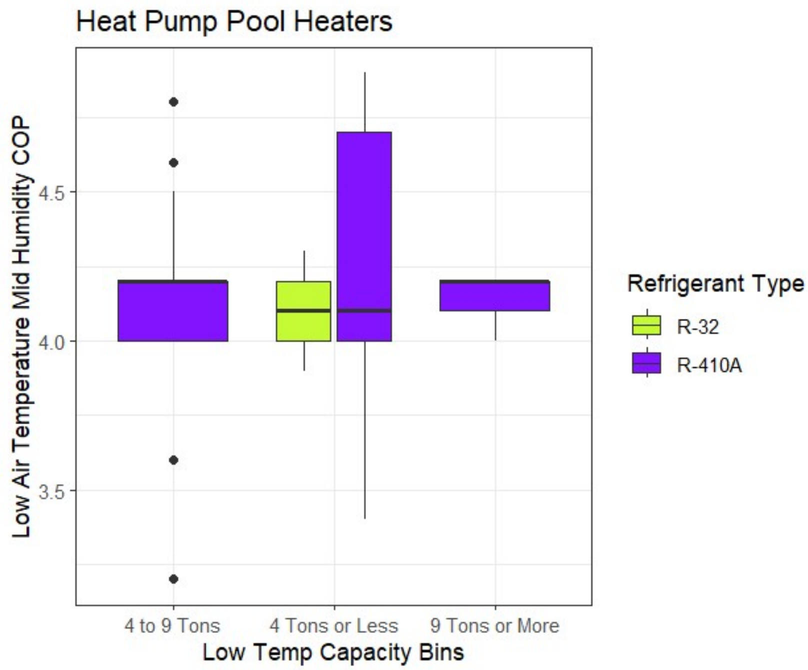

Figure 12: Efficiencies of Heat Pump Water Heaters by Capacity and Fuel Source. No refrigerant data was available from AHRI.