Packaged Propane Refrigeration Market Study

Final Report

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Disclaimer

Executive Summary

California's climate targets call for major reductions in greenhouse gas (GHG) emissions and energy use within the commercial sector where refrigeration is a significant contributor. This study examines the market potential of packaged propane (R-290) refrigeration systems for walk-in coolers and freezers (WICFs) as a low global warming potential (GWP), energy-efficient alternative to traditional hydrofluorocarbon (HFC) systems. The analysis covers technical performance, market readiness, barriers, and opportunities, with a focus on small-to-medium businesses (SMB), hard-to-reach (HTR) customers, and disadvantaged communities (DAC).

Key Findings

- **Energy Savings:** Metered data show an average energy reduction of 54% for medium-temperature systems and 38% for low-temperature systems compared to baseline HFC condensing units. These propane systems maintain 20-25% savings even against high-efficiency HFC units.

- **GHG Reductions:** Packaged propane systems achieve ~99% lower refrigerant-related emissions due to lower GWP, smaller charge sizes, and reduced leak rates. At just 5% market penetration, this technology could prevent ~450 metric tons of CO_2e annually.

- **Cost Benefits:** At current electric rates, these packaged propane systems could achieve annual average savings of $1,400 and $700 per unit for medium and low temperature systems, respectively. Additionally, the annual GHG reductions save $100 per unit in refrigerant cost savings, plus lower installation and maintenance costs.

- **Potential for decarbonization and cost reduction is significant** with 139,000+ food service and retail establishments operating an estimated 200,000 condensing units.

Stakeholder Insights

- **Manufacturers:** Demand for propane systems is growing, but U.S. offerings remain limited due to UL listing requirements and restrictive charge size standards.

- **Utilities:** Interested in supporting these technologies but currently rely on custom incentives. Prescriptive measures are absent, and pilot data is needed for program integration.

- **Contractors & Distributors:** Report limited hands-on experience, citing flammability concerns and supply chain constraints. Training and incentive alignment were identified as essential to overcome these challenges.

- **End Users:** Show interest in environmentally friendly options but face cost barriers, space limitations, and lack of awareness. Clear economic benefits and trusted guidance are essential.

- **Industry Groups:** Highlight regulatory hurdles and charge size limitations as persistent obstacles.

Stakeholders agree that targeted incentives, education, and updated safety standards are key to accelerating adoption of propane refrigeration systems in California's commercial sector.

Recommendations on Next Steps

- Expand metering and pilot demonstrations to validate performance and build confidence in propane systems.
- Develop a TRM Measure and Qualified Products List (QPL) for UL-listed systems to streamline program adoption.
- Launch targeted incentive programs for SMB, HTR, and DAC businesses, including enhanced incentives and contractor bonuses to drive participation.
- Build awareness and training through educational materials, multilingual outreach, and hands-on demonstrations to address knowledge gaps and safety concerns.

Abbreviations and Acronyms

Acronym	Meaning
CO_2e	Carbon Dioxide equivalent
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
AWEF	Annual Walk-In Efficiency Factor
CBECS	Commercial Buildings Energy Consumption Survey
CU	Condensing Unit
DAC	Disadvantaged Communities
DOE	Department of Energy
CARB	California Air Resources Board
ECM	Electronically Commutated Motor
EE	Energy Efficiency
EEV	Electronic Expansion Valve
ET	Emerging Technology
EUI	Energy Use Intensity
eTRM	electronic Technical Reference Manual
GHG	Greenhouse Gas
GWP	Global Warming Potential
HCFC	Hydrochlorofluorocarbon
HECU	High Efficiency Condensing Unit
HFC	Hydrofluorocarbon
HFO	Hydrofluoroolefin

Acronym	Meaning
HTR	Hard-to-Reach
IOU	Investor-Owned Utility
kWh	Kilowatt-hour
$MMTCO_2e$	Millions Metric Tons of Carbon Dioxide Equivalent
MBtu	Thousand British Thermal Units
NASRC	North American Sustainable Refrigeration Council
OEM	Original Equipment Manufacturer
PA	Program Administrator
PG&E	Pacific Gas & Electric
RCU	Remote Condensing Unit
RMP	Refrigerant Management Program
SCE	Southern California Edison
SDG&E	San Diego Gas & Electric
TPM	Technology Priority Map
TSB	Total System Benefit
WICF	Walk-in Cooler and Freezer

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Introduction

This project assesses the market potential and performance of packaged propane (R-290) refrigeration systems as an energy-efficient, low GWP alternative for California's food retail and food service sectors.

Food retail and food service establishments are among the most energy-intensive segments of the commercial sector, with energy use intensities (EUIs) around 240 thousand British thermal units (MMBtu) per square foot (Commercial Buildings Energy Consumption Survey (CBECS) n.d.). Refrigeration alone accounts for 25% to 70% of the electricity used in these buildings, and annual refrigerant leakage rates can reach 25% (in pounds of refrigerant per year) (2018 CBECS: Principal Building Activities n.d.). These factors underscore the need for efficient, environmentally friendly refrigeration technologies.

California has over 18,000 food and beverage retailers and more than 75,000 restaurant locations that operate an estimated 200,000 condensing units, highlighting the potential for energy and emissions savings (United States Census Bureau n.d.). This also creates a strategic opportunity for California's investor-owned utilities (IOUs) to support the transition to low GWP refrigerants and claim savings within their measure portfolios.

California has set ambitious targets to reduce greenhouse gas (GHG) emissions and energy consumption, particularly in the commercial sector, which accounts for nearly 18% of the state's total energy use. A significant portion of these emissions come from high Global Warming Potential (GWP) refrigerants. The California Air Resources Board (CARB), estimated that these refrigerants contributed to ~21 million metric tons of CO_2 equivalent ($MMTCO_2e$) emissions in 2017, representing 4-5% of the state's total emissions (California Air Resources Board 2019). This transition to low GWP refrigerants in commercial refrigeration systems will help California improve energy efficiency and meet climate goals. Packaged propane systems for walk-ins offer a low-cost alternative to traditional remote condensing system refrigerant replacement while improving walk-in efficiency.

Manufacturers are responding to environmental regulations by moving away from traditional refrigerants with GWP values between 1,200 and 4,000+ and adopting natural and low GWP alternatives with GWP values below 10. This transition is essential to reduce GHG emissions and align with state and national climate policies.

Packaged propane refrigeration systems, or monoblocks, provide an energy-efficient, cost-effective, and modular option for remote condensing applications. Early studies show 15% to 40% energy savings compared to traditional hydrofluorocarbon (HFC) units and 50% to 90% reductions in refrigerant charge (Marin and Duquette 2024). Their compact design and ease of installation make them ideal for small-to-medium businesses (SMB), hard-to-reach (HTR), and disadvantaged communities (DAC).

Through market analysis, stakeholder engagement, and performance data review, the study identifies barriers, opportunities, and strategies for adoption particularly among SMBs and underserved businesses. Findings will inform utility program recommendations and support the development of cost-effective, energy-saving refrigeration measures to support California's climate objectives.

Background

Policy and Regulatory Framework

California is a national leader in climate policy, setting ambitious goals to reduce GHG emissions through a 40% reduction in HFC emissions from 2013 levels by 2030. Complementing this is a broader target to cut overall emissions by 85% from 1990 levels by 2045 (EPA, Phasedown of Hydrofluorocarbons (HFCs): Issuing Allowance Allocations for 2024 2024). These policies are driving rapid transformation in the refrigeration sector, particularly in food retail, where efficient, cost-effective, and easy to operate and maintain technologies are urgently needed.

Technology

The commercial refrigeration market has traditionally relied on high GWP synthetic refrigerants, particularly HFC blends such as R-404A and R-134a, valued for their nonflammable and non-toxic ASHRAE A1 classification. These refrigerants are widely used in remote condensing units and refrigerated display cases, which dominate California's food retail refrigeration infrastructure.

An emerging alternative is propane (R-290), a natural refrigerant with ASHRAE A3 classification, flammable but low in toxicity. R-290 offers superior thermodynamic performance, including high latent heat of evaporation and refrigerant mass flow rate, enabling smaller charge sizes and improved energy efficiency. However, safety standards such as UL 60335-2-89 and ASHRAE 15 currently restrict the use to small charge sizes up to 150 grams per circuit for most self-contained systems, though recent updates by regulatory bodies and advocacy groups, including by UL in 2021, have increased limits to 300 grams in closed cases and 500 grams in open cases. Further, technicians must be EPA 608 certified to handle any refrigerant-containing equipment, and additional training is often necessary to handle the specific class of A3 refrigerants. There is an urgent need to update remaining safety standards in the U.S. including U.S. EPA SNAP, ASHRAE 15, and local building codes to increase adoption of R-290.

Packaged propane systems are self-contained units integrating the compressor, evaporator, and condenser components. Designed for through-the-wall or ceiling installation in WICFs, they eliminate the need for refrigerant piping, which reduces installation complexity and project lead times. With charge sizes under 150 grams per circuit, they are ideal for small-to-medium-sized applications in restaurants, grocery stores, and convenience stores. Their modularity and energy efficiency make them suitable for retrofits and space-constrained environments.

Market Conditions

California's commercial refrigeration market has more than 337,000 buildings in the food sale and food service sectors having at least one walk-in cooler and freezer (WICF) (US Energy Information Administration n.d.). Many of these are operated by small, independent retailers, particularly in DAC and HTR areas. These businesses often operate on slim margins between 3% to 5% and have limited capital, making it difficult to comply with new refrigerant regulations. Affordable and reliable refrigeration is essential for food security for the more than 2.6 million Californians living in low-income, low-access areas.

Unfortunately, many existing incentive programs, such as the F-gas Reduction Incentive Program offered by the California Air Resources Board (CARB), are designed only to support larger systems with refrigerant charges of over 50 pounds, inadvertently excluding smaller businesses from financial support during this critical transition. Programs supporting the adoption of packaged propane systems can bridge this gap by offering a cost-effective, low GWP solution that aligns with both state and federal environmental goals. Packaged propane systems offer a compelling solution by providing a low-GWP, cost-effective alternative that enables smaller food retailers to remain compliant, has potential to reduce operating costs, and maintains access to healthy foods. With targeted outreach and education leveraging tools like the USDA Food Atlas and the federal Justice40 Initiative, these systems can help overcome market barriers and drive adoption in underserved areas.

A key metric for evaluating the success of energy programs in California is the Total System Benefit (TSB). TSB represents the value of avoided costs resulting from energy efficiency improvements, treating these savings as a resource for the electrical grid. In the context of refrigeration, TSB accounts for both the avoided costs from reducing refrigerant leaks and the costs associated with switching refrigerant types or increasing refrigerant quantities. This project quantifies two main components: the avoided cost benefits from reducing refrigerant leaks, and the unit refrigerant costs related to changes in refrigerant type or volume. Designing effective incentive structures depends on accurately measuring these factors and ensuring equitable access to cleaner technologies across all market segments

Objectives

With a goal of generating practical, actionable insights to support the adoption of these systems in California, this study quantifies the market potential of these systems particularly in small and independent food retail businesses that are often underserved by existing incentive programs. It also evaluates the technical performance of these systems, focusing on their energy efficiency, reliability, and suitability for various commercial applications. In addition, the research analyzes the regulatory framework around R-290 as a refrigerant used in packaged systems and identifies key barriers that hinder broader adoption.

The energy use and technical performance assessment of packaged propane systems chart the most effective deployment options for these systems. This study also examines how current safety standards, refrigerant charge limits, and building energy codes shape the feasibility of propane-based system deployment at scale. The analysis of regulatory frameworks clarifies compliance requirements and identifies policy-driven opportunities and constraints.

To complement this analysis, the project gathered perspectives from key stakeholders—including manufacturers, contractors, utility program managers, and end users—on system availability, installation, and operation. These insights help identify adoption barriers, such as cost, safety concerns, lack of awareness, or limited technical capacity, as well as opportunities for growth. By addressing these challenges and opportunities, the research aims to guide utility-supported interventions and inform program design and future studies that promote equitable, scalable market transformation.

In the short term, the project also includes a knowledge transfer objective to facilitate the dissemination of knowledge, tools, and best practices that enable broader adoption of packaged propane systems. This includes developing training resources, supporting workforce development, and ensuring that small businesses and underserved communities have access to the information and support they need to make informed decisions. The long-term objective is to enable a sustained market shift toward climate-friendly refrigeration technologies. By laying the groundwork for widespread adoption, the project aims to contribute to California’s broader climate goals while ensuring that the benefits of this transition—such as lower energy costs, improved food security, and reduced environmental impact are shared across all communities.

Methodology & Approach

To achieve the outlined objectives, this report includes a technical review component, a market characterization study, a summary of stakeholder engagement, and program recommendations.

Methodology

The research followed a mixed-methods approach that combines both qualitative and quantitative data collection to inform program development recommendations. On the quantitative side, analysis of available metered data was used to estimate energy and GHG savings. While on the qualitative side, interviews were conducted with stakeholders, and thematic analysis of these interviews was used to extract common themes, market insights, and lessons learned to better identify program design opportunities.

Technology Review

This technology review assesses the viability, performance, and market readiness of packaged propane units versus traditional refrigeration technology used in commercial WICFs. The incumbent technology primarily consists of remote condensing units (RCUs) paired with evaporators and typically uses HFC refrigerants. The review focuses on comparing these systems to understand energy efficiency, system complexity, installation and maintenance considerations, and overall market potential.

The scope of this review is limited to commercial WICFs that are commonly served by remote condensing units. The size, scale and application of this subset of equipment is most relevant to current and emerging packaged propane system offerings. Technologies excluded from this review include self-contained refrigerated display cases, residential refrigeration units, systems served by multiplex rack systems, and industrial-scale refrigeration equipment such as refrigerated warehouses, cold storage facilities, and drive-in coolers or freezers. These exclusions are based on application mismatches and the limited market availability of packaged propane systems. The review will also evaluate advanced components that may enhance system efficiency, including modulating compressors, electronically commutated motor (ECM) fans, electronic expansion valves (EEVs), and floating head pressure (FHP) controls.

The methodology for conducting this technology review will involve a comprehensive desk-based analysis of available literature and market intelligence. This includes examining manufacturer specifications, case studies, white papers, and peer-reviewed assessments to understand energy performance metrics, refrigerant characteristics, equipment availability, and emerging industry trends. Special attention will be given to sales and distribution channels within California, market penetration of propane-based solutions, and their alignment with statewide decarbonization efforts. The goal is to provide a clear, evidence-based comparison of packaged R-290 refrigeration systems against traditional technologies, identifying both opportunities and barriers for broader market adoption.

Market Characterization

The market characterization study defines and evaluates the California market potential for packaged propane systems through a review of existing research literature, engagement with manufacturers, contractors, and retailers.

Regulations around energy use are constantly evolving to help meet climate and energy goals. To understand the influence of regulatory changes and the overall regulatory landscape on the availability of efficient refrigeration system technologies, this study reviews the codes and standards listed below and identifies the potential influence these regulations have on the adoption of high efficiency, packaged propane technologies for commercial food retailers.

- The Code of Federal Regulations
- Title 20 California Appliance Efficiency Standards (Title 20)
- Title 24 California Building Energy Efficiency Standards (Title 24)

The team conducted a literature review of current national market trends in the low GWP and natural refrigerant space examining recent market research conducted through the North American Sustainable Refrigeration Council (NASRC), and other top organizations in the field.

Equipment shipments available through the Department of Energy (DOE) are scaled to the California market to get a high-level overview of the market size and potential in California. Using the national refrigeration data and California-specific Census Bureau and Energy Information Administration’s Commercial Buildings Energy Consumption Survey (CBECS) data to determine total number of establishments, this market analysis estimates the total number of WICF systems in California in food sales and food service industries.

This evaluation assesses the overall market size, identifies the frequency and conditions under which equipment is repaired versus replaced, determines the typical age and lifecycle of existing refrigeration units, and explores prevailing ownership and financing models. By identifying where aging or inefficient equipment is prevalent, and understanding replacement cycles and decision-making drivers, the study clarifies entry points and barriers for R-290 adoption. Additionally, analyzing ownership structures (e.g., owned vs. leased) informs strategies for focused outreach and incentive alignment.

Data Collection & Analysis

Data collection and analysis were used to evaluate the performance of installed packaged propane systems. Meter data was gathered from a variety of completed installation projects. Additional resources were provided by manufacturers’ testing, pilot demonstrations, and peer-reviewed case studies.

Where available, performance data includes electric consumption, load profiles, ambient temperature conditions, and operational characteristics. Additionally, project-level economic data such as initial capital investment, equipment costs, installation and labor expenses were collected to evaluate total cost of ownership and return on investment.

Non-energy GHG emissions and operation cost reductions were estimated using methodologies defined in California's avoided cost calculator and TSB metrics to quantify the broader system impacts from energy and refrigerants.

The meter data collected from installed propane systems is primarily from climate zone 6A. Based on the IECC Climate Zone map, California is predominantly located in climate zone 3B. While the climatic conditions between these zones have different heating and cooling degree days, the new packaged propane systems are located indoors, so the effect of outdoor weather conditions on measured energy use is negligible. Where the climate zones have a direct impact on measured energy savings is where the new propane system is being compared to an outdoor baseline unit. Systems with a baseline condensing unit located indoors will have higher energy use and higher energy savings than systems with a baseline condensing unit located outdoors. Similarly, systems located in warmer climate zones will have higher energy use and higher energy savings than systems located in cooler climate zones. Therefore, the metered energy savings from climate zone 6A are likely to reflect conservative estimates compared to systems installed in California's zone 3B.

Stakeholder Engagement

Outreach to key stakeholders provides critical insights into the current and future market landscape for packaged propane refrigeration systems. From engagement with a diverse range of stakeholders, including manufacturers, efficiency program administrators, contractors, distributors, and end users, this report outlines market trends, identifies technical and supply chain feasibility, and uncovers barriers and opportunities which influence technology adoption to provide comprehensive recommendations that inform future program design, incentive structuring, and technology deployment strategies.

This approach involved conducting at least 10 in-depth interviews with selected stakeholders from across the value chain to ensure a broad and representative perspective, with a goal of adding interviews as necessary for stakeholder groups with more diverse outlooks on this technology. These interviews explored key areas such as market readiness, ease of technology access, perceived and actual energy performance, specific application suitability, and systemic or behavioral adoption challenges. The resulting insights have been summarized to provide a detailed understanding of current practices and emerging opportunities in the propane refrigeration space.

Program Peer Review

The outreach strategy focused on engaging program managers responsible for active prescriptive and custom incentive programs for commercial refrigeration and propane equipment. Interviews were held with program managers from four selected prescriptive rebate programs. Each interview was approximately 30-60 minutes and explored key areas such as incentive structure, program delivery model (with a focus on midstream approaches), stakeholder engagement strategies, key performance indicators, and challenges experienced during implementation. These programs included commercial refrigeration, kitchen equipment, natural refrigerants, and/or market-based programs for grocery/supermarkets, convenience stores, restaurants, and HTR/DAC customers. The goals of the peer review were to:

1. **Benchmark** prescriptive and custom rebate programs in other jurisdictions offering incentives for packaged propane refrigeration systems or similar equipment.
2. **Extract insights** and lessons learned from existing programs to understand design elements, delivery mechanisms, and stakeholder strategies that have been implemented in other jurisdictions and will inform new program development.
3. **Highlight market gaps** in current offerings and new opportunities, particularly within California's IOU portfolios.
4. **Document common challenges** and barriers to participation and adoption, especially at the contractor and distributor level.
5. **Learn best practices** and strategies for stakeholder engagement, incentive design, and implementation.

Selection criteria for interviews favored programs that have:

- Existing prescriptive incentives for high efficiency condensing units, high efficiency evaporator units, remote condensing units, and WICF equipment.
- Incentives administered by an energy utility or a contracted third-party implementer.
- Operated for at least six months.
- Program staff who are available for interviews.

Program Design

To inform the design and evaluation of energy efficiency programs targeting packaged refrigeration systems, this project leveraged peer review data from the ETCC project Foodservice Refrigeration*: High Efficiency Condenser and Evaporator Units Focused Pilot* (Project Number ET22SWE0054) (Shorin, et al. 2024). This foundational research provided insights into the program type, qualifying equipment, and incentive structures associated with high-efficiency condensing units (HECU) and high-efficiency evaporator units (HEEU) across foodservice and retail sectors. Data was collected on incentive levels, program budgets, delivery mechanisms, utilization rates, and estimated energy savings. The peer review data were instrumental in identifying national trends and best practices, which were then used to assess the potential for integrating or amending existing CA IOU programs to support these technologies more effectively.

To expand the prior research, a quantitative review was conducted examining five energy efficiency programs across two IOUs in California. The desk review outlines the presence and structure of prescriptive or custom rebate offerings, and their relevance to packaged propane refrigeration systems. The analysis assesses how well the current eTRM measures support the types of equipment targeted by this initiative - specifically smaller, single-compressor refrigeration systems such as those served by remote and self-contained condensing units – while identifying current gaps in coverage. Based on this comparison, recommendations were developed to guide the design of a program that effectively addresses opportunities for program expansion, leverages successful strategies from peer programs, and supports broader energy efficiency and market transformation goals.

Propane Fact Sheet

A public-facing propane refrigerant fact sheet was created to serve as an educational tool to raise awareness about the benefits of transitioning from high GWP HFC refrigerants to natural refrigerants, specifically propane. Its primary purpose is to inform HTR, DAC, and STMB food establishments about the environmental, operational, and financial advantages of upgrading to packaged propane refrigeration systems. The fact sheet uses clear, simple language and visuals to ensure accessibility and easy translation into multiple languages, making it practical for diverse audiences.

Findings

Technical Overview

This section provides an overview of the system components, design, and performance characteristics of packaged propane refrigeration systems used in WICFs. It covers walk-in applications and traditional refrigeration configurations and compares these baseline systems to emerging propane-based alternatives, including a summary of the efficiency and environmental benefits offered by packaged propane systems.

Walk-in Coolers and Freezers

WICFs are insulated, refrigerated enclosures designed for food storage and merchandising. These units are equipped with full-sized access doors and are widely used across food service, food retail, institutional, and warehouse settings.

Walk-in refrigeration systems are generally served by three distinct types of cooling equipment: centralized rack systems, remote condensing units (RCUs), and self-contained packaged systems. Each of these configurations is suited to different building types and cooling requirements. Rack systems are typically used in high-volume operations such as grocery stores and distribution centers, while RCUs and packaged units are more common in smaller facilities like restaurants, convenience stores, and cafés.

Table 1: Distribution of Refrigeration Systems by Business Type in California

Business Type	Businesses with Refrigeration Equipment (%)	Self-Contained Packaged Systems	Remote Condensing Units (RCUs)	Centralized Refrigeration (racks)
Food/Liquor (e.g., grocery and convenience)	100%	4%	40%	56%
Health/Medical-Clinic	4%	38%	62%	0%
Miscellaneous	13%	14%	85%	0%
Office	3%	42%	58%	0%

Business Type	Businesses with Refrigeration Equipment (%)	Self-Contained Packaged Systems	Remote Condensing Units (RCUs)	Centralized Refrigeration (racks)
Restaurant	97%	21%	79%	0%
Retail	13%	1%	64%	35%
School	84%	43%	57%	0%
Warehouse	3%	0%	6%	94%
TOTAL AVERAGE	64%	21%	56%	23%

(California Commercial Saturation Survey 2014)

The results presented above are weighted by walk-in floor area (ft^2). The business types provided in the table were collected from the California Commercial Saturation Survey and are reflective of the build stock that is most likely to have commercial refrigeration systems. For some of the building types listed for which the space is not commonly dominated by refrigeration loads, it's likely that these spaces have cafeterias, commercial kitchens, or walk-in coolers and freezers used to store product.

Table 1 shows that Remote Condensing Units (RCUs) are the most used refrigeration system across most business types, accounting for 56% on average. RCUs dominate in categories such as restaurants (79%), miscellaneous businesses (85%), and retail (64%), indicating a strong preference for these systems in environments that likely require flexible, scalable cooling solutions without the complexity of centralized systems. They are also highly prevalent in health/medical clinics (62%), schools (57%), and offices (58%), showing broad applicability in non-industrial settings. The California Commercial Saturation Survey does not specify what types of refrigeration equipment these systems are serving, but for the types of buildings that don't typically have refrigeration equipment that serves the primary function of the business, it's likely that the refrigeration systems are serving cafeterias, break rooms with small kitchens, and/or refrigerated product storage.

According to a Food Retailer Survey Report published by NASRC, the typical capacity of RCUs ranges from 0.5 – 90 MBtu (Zboraj 2021). The MBtu is a measure of the cooling capacity of the unit. Using the rule of thumb, 12,000 Btu/h equivalent to one ton of refrigeration, the typical cooling capacity range for RCUs is 0.04 – 7.5 tons. Sometimes the size of the unit is given by the horsepower rating of the system compressor. A specific horsepower motor can have a wide range of cooling capacities that it serves depending on the efficiency of the compressor, the refrigeration system setpoints, and the efficiency of heat transfer of the evaporator and condenser. The findings from ETCC project Foodservice Refrigeration: High Efficiency Condenser and Evaporator Units Focused *Pilot,* indicate that the majority market share for condensing units is under 10 hp (Shorin, et al. 2024). RCUs in this size range contain 2 to 50 pounds of refrigerant, depending on the system components and length of the refrigerant piping needed to connect the condensing unit to the evaporator unit(s).

RCUs require separate installation of condensing and evaporator units, along with refrigerant line sets that must be custom fit on site. This adds to the cost and complexity of installation and increases energy loss and refrigerant leakage potential. In contrast, packaged systems are delivered as integrated, sealed units typically installed through the wall or ceiling of a unit. This all-in-one format eliminates the need for field piping and refrigerant charging, leading to quicker installation and potentially lower maintenance costs. However, packaged systems have capacity limitations, and indoor-mounted units may introduce unwanted heat and noise to occupied and conditioned spaces.

Top-mount and wall-mount refrigeration units manage heat rejection based on the WICF location. When a WICF is installed inside the building, particularly in areas with interstitial space between the WICF and the building's walls or roof, the system typically discharges heat into the conditioned interior. This adds to the HVAC cooling load during warmer months and can offset heating demand in colder months. Conversely, WICFs integrated into the building shell or located fully outdoors, with walls or roof exposed to ambient air, allow the refrigeration units to reject heat directly to the outdoor environment, minimizing impact on indoor HVAC loads.

Baseline Refrigeration systems

Conventional RCUs typically consist of split systems that include two main assemblies: a condensing unit and an evaporator unit. The condensing unit houses the compressor and condenser coil and is usually installed outside the refrigerated space, while the evaporator, which contains the expansion valve and the evaporator coil, is located inside. The two components are connected via refrigerant piping that must be installed and charged on site.

This traditional configuration dominates the market for small-to-medium commercial refrigeration applications (as shown in Table 1). RCUs exist in a wide range of capacities and typically use synthetic refrigerants such as R-404A, R-134a, and R-407C. While this configuration is well-established and flexible, it involves higher installation complexity, more refrigerant, and a greater risk of refrigerant leakage compared to self-contained alternatives.

Alternative Packaged Propane Units

Packaged propane refrigeration systems are an emerging alternative for low- and medium-temperature walk-in applications. These units integrate all major refrigeration components, including the compressor, condenser coil, evaporator coil, and expansion valve, into a single, sealed unit. Unlike traditional RCUs, which have the evaporator unit installed inside the walk-in and suspended from the ceiling, packaged systems are installed through the wall or ceiling and sit flush with or abutting the partition. Figure 1 and Figure 2 show these configurations. This design frees up additional space inside the walk-in, allowing for more product storage. The pre-assembled design eliminates the need for field-installed refrigerant piping, significantly reducing labor costs, pressure drop throughout the system, and overall refrigerant charge, while also potentially reducing maintenance needs due to systems being test for defects before leaving the manufacturing facility.

Propane offers excellent thermodynamic efficiency due to its high latent heat of vaporization, high mass flow rate, and lower operating pressure. These characteristics allow for smaller compressors and reduced energy consumption. This results in more compact system designs, an especially attractive feature in retail environments where space is limited, and flexibility is key. These streamlined systems are easier to install and can often be integrated into existing infrastructure with minimal modification, an important consideration for food retailers managing tight margins and high operational costs.

Advantages to the packaged systems include faster installation times resulting in lower installation costs, space savings, and fewer refrigerant leaks by having the system pre-charged and sealed during manufacturing which also leads to lower maintenance costs. However, one disadvantage is that failure of either the compressor or evaporation system could lead to the need to replace both because they are a single pre-charged unit.

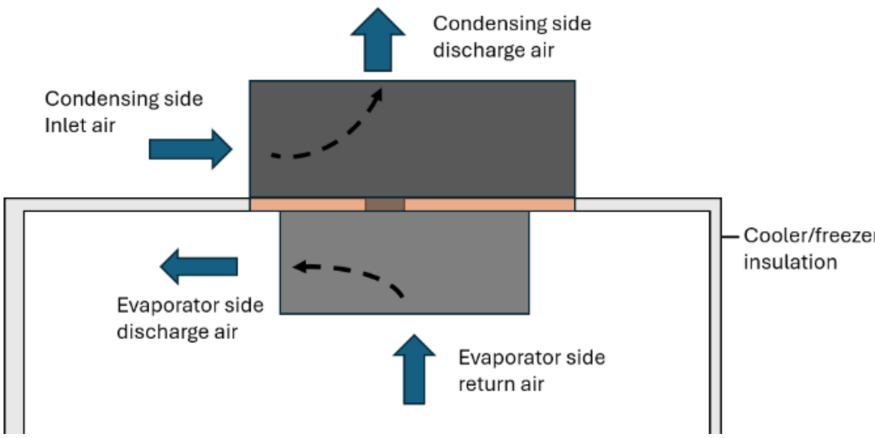

Figure 1: Diagram of top-mount design installed through the ceiling of the WICF.

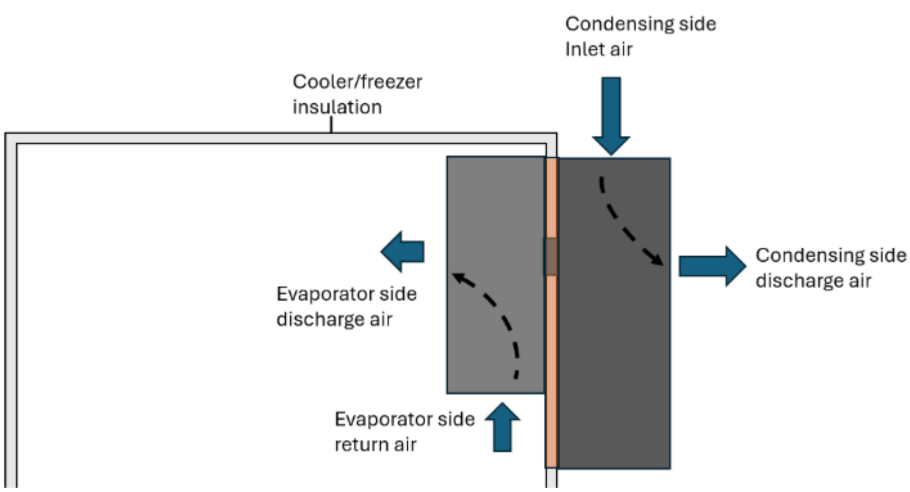

Figure 2: Diagram of side- or wall-mount design installed through the wall of the WICF.

Efficient Components

Modulating Compressor

Compressors keep a system's refrigerant both pressurized and flowing. They consume the largest amount of energy of any component in the system. A modulating compressor offers the potential for energy savings because the compressor adapts to reduce its speed to save energy when cooling demand is less than the maximum. The variable speed capability must be enabled through the unit control system interface.

ECM fans

Electronically Commutated Motors (ECMs) are high efficiency motors that result in savings over conventional, single-speed permanent split capacitor and shaded pole motors. Adaptive fan controls allow modulation of the evaporator ECM fans to meet demand based on the temperature setpoint of the refrigerated space. Different control sequences and fan cycling methods can be used if evaporator fans automatically reduce speed when refrigerated space temperatures are colder than needed. Temperature setpoints should be programmed using the unit control system interface.

Electronic Expansion Valve

An expansion valve regulates the flow of liquid refrigerant into the evaporator heat exchanger. The electronic expansion valve (EEV) allows precise tuning based on refrigerant pressure and temperature at the evaporator inlet using the unit control system interface.

As the liquid refrigerant moves through the evaporator coil, it absorbs heat and changes phase or "boils" into gas. As the refrigerant vapor moves through the evaporator coil, it absorbs more heat, to ensure that no liquid refrigerant (aka non-compressible fluid) is returned to the compressor. The heat absorbed beyond the vaporization point is called "superheat." With an EEV, superheat can be more finely tuned and reduced further than it can with other types of expansion valves. This reduces unnecessary refrigerant flow and, thus, saves energy.

Floating head pressure controls

Floating head pressure controls allow for a refrigeration system to lower the operating discharge or head pressures. This reduces the compression ratio of the refrigeration compressor and coincidently reduces the load/power required to compress the refrigerant gas.

Refrigerants

Refrigerants play a critical role in system performance, safety, and environmental impact, and their selection depends on application requirements and regulatory constraints. This section examines the major refrigerant categories and implications for system design across commercial, industrial, and food retail applications.

Hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs) are standard practice refrigerants, such as R-22 and R-404A. While these are nonflammable and allow for low-cost retrofits or drop-in replacements, regulations are shifting away from these given their high GWP (often greater than 800 and up to 14,000+ GWP).

Natural refrigerants (CO_2, propane, and ammonia) have very low GWP values and are sometimes referred to as "ultra-low". One challenge with these refrigerants is that they operate at higher pressures compared to legacy refrigerants like R-22 and R-404A. Thus, retrofitting an existing system from an

HFC or HCFC to a natural refrigerant requires replacement of the entire refrigeration system, including the refrigerant lines, which significantly increases cost. Ammonia is highly toxic (B2L) and primarily used in industrial facilities, and propane has flammability issues (A3) which limits its application in commercial buildings.

Hydrofluoroolefins (HFO) products: These synthetic refrigerants operate at similar pressures to existing HFC or HCFC systems. Many HFOs can be installed in an existing refrigeration system with fewer component replacements (e.g., compressor replacement but no changes to refrigerant lines), a much less extensive retrofit compared to natural refrigerants. However, many HFOs are classified as flammable (A2L), and therefore prohibited for use by building codes.

HFC/HFO blends: To overcome the flammability issue with HFOs, manufacturers have developed blends of HFOs and HFCs which have a higher GWP than a HFO but provide a refrigerant that can be classified as an A1 (non-flammable).

Appendix A provides an overview of different classes of refrigerants and their potential application to small food retail and restaurant facilities and is adapted from the Low GWP Refrigeration Market Impacts Study (TRC 2021).

Review of Codes & Standards

For commercial refrigeration systems, manufacturers and contractors must comply with Federal and State of California codes and standards. Those code minimums are considered the baseline that all systems, equipment, and designs must comply with. "High efficiency" is defined as a technology with an incremental increase in efficiency above code minimum requirements based on certain equipment features and configurations. To understand the baseline, the applicable regulations reviewed include:

- The Code of Federal Regulations
- Title 20
- Title 24

The U.S. Food and Drug Administration (FDA) play an important but indirect role in the oversight of refrigeration systems used in food retail and food service environments. Its primary focus is on food safety, ensuring that refrigeration equipment supports conditions that prevent foodborne illness and maintain product integrity. The FDA does not regulate the refrigeration equipment itself, but it sets standards for the environment in which that equipment operates. It is the responsibility of the refrigeration facilities to maintain food safety standards and proper equipment operation. Packaged propane refrigeration systems will have no impact on meeting those standards and may in fact make it easier to comply with food safety standards through lower maintenance needs.

Code of Federal Regulations

Commercial refrigeration products sold within the US must comply with the following sections of Title 10 of the Code of Federal Regulations:

6. Part 429 Subpart B §429.53 Walk-in coolers and walk-in freezers outline the certification procedures for compliance with energy codes set forth in Part 431.

7. Part 431 Subpart R Walk-in Coolers and Walk-in Freezers provides guidance on energy use, energy conservation standards and testing procedures as outlined in the following sections:
    a. § 431.306 Energy conservation standards and their effective dates, which outline the energy consumption requirements.
    b. Appendix C to Subpart R of Part 431 sets forth the appropriate testing method to measure the energy consumption of each walk-in cooler or walk-in freezer.

State of California Regulations

In addition to federal regulations, retailers in the state of California must also comply with state and local regulations. Under the regulations put forth by California, Title 20 and Title 24 pertain to refrigeration units and systems with a distinction between retail and beverage stores with less than 8,000 square feet and those with greater than 8,000 square feet of conditioned space. Packaged propane systems will only apply to systems less than 8,000 square feet.

TITLE 20

The California appliance standard Title 20 has published system performance requirements for various system configurations and end uses. If the measure is considered "New Construction" then the cumulative performance of the equipment shall minimally comply with the performance metrics published within the Federal and State Standards for Federally Regulated Appliances within Title 20. Table 2 details the performance requirements for WICFs, which is the main application for packaged propane systems.

Table 2: Performance Standards for Walk-in Cooler and Walk-in Freezer Refrigeration Systems Manufactured on or After January 1, 2020.

Class Descriptor	Minimum AWEF (Btu/W-h)
Dedicated Condensing, Medium Temperature, Indoor System	5.61
Dedicated Condensing, Medium Temperature, Outdoor System	7.60

(Title 20 Section 1605.1(a)5(F) Table A-12)

Along with system performance, Title 20 requires specific motor types to be utilized in refrigeration equipment that serves WICFs installed after 2008.

Table 3: Title 20 Motor Type Requirements for Evaporators and Condensers

Equipment	Requirement
Evaporator Fan Motor < 1 HP	Electronically Commutated Motor, or 3 Phase Motor
Condenser Fan Motor	Electronically Commutated Motor, or

< 1 HP	Permanent Split Capacitor Motor, or 3 Phase Motor

(Title 20 Section 1605.1(a)4E - F)

Finally, for food retail and beverage stores that are less than 8,000 square feet, California's Title 20 Appliance Efficiency Regulations apply. This is likely to include systems found in convenience stores, quick service restaurants, and cafes. Title 20 section 1605.1(a) covering commercial refrigeration appliances refers to the federal standards as a guide. There are no additional efficiency requirements specific to condensing units and evaporators reflected in the Title 20 regulations.

TITLE 24

Title 24, Section 120.6(a) provides code requirements for various aspects of commercial refrigeration systems in refrigerated warehouses. Refrigerated warehouses include spaces that are greater than or equal to 3,000 square feet and refrigerated spaces with a total of 3,000 square feet or more that are served by the same refrigeration system (California Energy Commission 2022). It can be assumed that this does not apply to the refrigeration systems included in this study.

Title 24, Section 120.6(b) applies to commercial refrigeration systems which are defined as retail food or beverage stores with 8,000 square feet or more of conditioned floor area, and that utilize either refrigerated display cases, or WICFs. These retail stores include most grocery stores, supermarkets, wholesale distribution retailers, independent markets, schools, hospitals, institutional cafeterias, and larger restaurants. Code requirements are expanded beyond refrigerated case requirements to include heat rejection equipment due to a comprehensive evaluation of the whole system rather than just self-contained cases. Section 120.6(b) sets energy efficiency requirements for condensers serving refrigeration systems and for compressor systems.

Section 120.6(b)2 of Compressor Systems, includes refrigeration compressor systems and condensing units. Section 120.6(b)2A is the only requirement applicable to the condensing units included in this study. More specifically, single compressor systems that do not have continuously variable capacity capability are exempt from this requirement. There is no requirement for condensing units to have variable capacity capability. The baseline for condensing units is a fixed speed compressor capacity.

For both "New Construction" and "Retrofit" measures, the California Building Energy Efficiency standard Title 24 requires fan-powered condensers to meet specific energy requirements, outlined in Section 120.6(b)1G & Table 120.6-C. However, there are multiple exceptions to the requirements, which are expected to be applicable when in measure development:

Exception 1 to Section 120.6(b)1G – Condensers with a Total Heat Rejection capacity of less than 150 kBTUh at the specified rating condition.

Retail food stores with over 8,000 square feet of conditioned floor area that utilize either refrigerated display cases or WICFs are required by Title 24 to comply with the applicable state and federal appliance standards. Equipment not covered under those standards is expected to meet the requirements detailed in Title 24 Section 120.6(b) as shown in Table 4.

Table 4: Title 24 Condenser Controls Requirements

Equipment	Requirement
Condenser Fan	Variable Speed Control
Condensing Unit	Condensing Temperature Reset
Compressor	Suction Pressure Reset for Variable Capacity Capability

(Title 24 Section 120.6(b)1 – 2)

Finally, under Title 24, Section 120.6(b) retail food or beverage stores with 8,000 square feet or more of conditioned floor area, and that utilize either refrigerated display cases, or WICFs, shall meet all applicable state and federal appliance and equipment standards consistent with Title 24, Sections 110.0 and 110.1. The requirements outlined in Subsections 1 through 4 apply to equipment not subject to these standards.

Refrigerant Regulations

Refrigerants must comply with various regulations, including energy efficiency and environmental requirements. An important environmental impact of refrigerants is their Global Warming Potential (GWP) value. Many legacy HFC refrigerants have a GWP greater than 1,500, meaning it has 1,500x the global warming impact of the same mass of CO_2. Because of the high GWP, there are federal and state regulations to track and reduce refrigerant leakage, and upcoming regulations that will reduce the permissible GWP of refrigerants.

OVERVIEW OF REFRIGERANT REGULATIONS

This section describes regulations for refrigerants in commercial refrigeration systems. California passed a state law in September 2016 (Senate Bill 1383) which specifies a target of a 40% reduction of statewide HFC emissions below 2013 levels by 2030. CARB's supporting regulations primarily focus on facilities with larger systems than those studied here. CARB requires that:

- Existing stores must have a weighted average GWP of <1,400 (across all a company's facilities) by 2030, or a company can reduce the GWP across all its stores by 55% by 2030. Retailers with over 20 stores must show their path to compliance and document their baseline by 2026. This regulation applies to all convenience stores and supermarkets, regardless of the refrigerant charge.
- New stores with a refrigerant charge ≥ 50 pounds use refrigerants < 150 GWP, while facilities with < 50 pounds may use refrigerants with < 2,200 GWP.

To achieve these emissions reductions goals, California developed a separate Refrigerant Management Program (RMP), which requires facilities operating stationary, non-residential refrigeration systems using more than 50 pounds of high GWP refrigerants to register, conduct regular leak monitoring, repair leaks promptly, and maintain detailed records. Low GWP systems, defined as

<150 GWP, are not subject to the RMP compliance requirements (CARB n.d.). The RMP requirements do not apply to any individual systems with a charge size of less than 50 pounds of refrigerant, which excludes the systems in this study. However, the U.S. EPA is finalizing new regulations that would require technicians to keep records when disposing of appliances containing 5 to 50 pounds of refrigerant, including the location, type of refrigerant, and amount of refrigerant (EPA, EPA's Refrigerant Management Program: Questions and Answers for Section 608 Certified Technicians 2025).

Table 5 provides an overview of each regulation and its applicability to the facilities studied here. In summary, while various requirements exist for refrigerant management, the regulation is nuanced for the smaller refrigeration systems studied here.

Table 5: Summary of Refrigerant Requirements and Impacts on Small Food Retail and Restaurants

Requirement	Summary	Applicable to small retail food facilities or restaurants?
Refrigerant Management Program (RMP)	For systems >50 pounds of refrigerant, requires periodic leak inspections and annually reporting	No
EPA requirements for refrigerant disposal (under development)	For appliances with 5 to 50 pounds of refrigerant, would require technicians to track refrigerants at disposal, including the location, type of refrigerant, and amount of refrigerant	Yes
CARB GWP limits for *new* facilities	Facilities with < 50 pounds may use refrigerants with < 2,200 GWP	Yes, although most standard practice refrigerants meet this requirement
CARB GWP limits for *existing* facilities	Per company, facilities must have a weighted average GWP of refrigerants < 1,400 GWP by 2030, or a company can reduce the GWP across all its stores by 55% by 2030	Yes, for small food facilities, but does not affect restaurants

While there is no standardized designation for low GWP refrigerant, the term broadly refers to a refrigerant with a GWP lower than standard practice.

LOW-GWP REFRIGERANTS

California’s Code of Regulations Title 17 bans the use of certain high GWP refrigerants in commercial refrigeration applications, including but not limited to, R-404A, R-407B, R-421B, R-422A, R-422C, R-422D, R-428A, R-434A, and R-507A (17 CCR § 95374). As a result, most commercial refrigeration equipment sold within California utilizes R-448 or R-449 refrigerant, which are A1 refrigerants with GWP values close to 1,400.

California’s 2022 Title 24, Section 6 includes specific language and standards applicable to transcritical CO_2 refrigeration systems. As an example, it sets a minimum specified condensing temperature and a minimum efficiency requirement for CO_2 gas coolers. However, it does not specifically address other types of refrigerant or refrigerant management apart from limited exceptions within the code (California Energy Commission 2022).

The American Society of Heating, Refrigerating and Air Conditioning Engineers (ASHRAE) classifies refrigerants in Standard 34 based on flammability and toxicity as follows: A: lower toxicity; B: higher toxicity, and 1: non-flammable, 2L: lower-flammable, 2: flammable, 3: highly-flammable. For example, refrigerants classified as A2L have low toxicity and low flammability. Ammonia is classified as B2L for its high toxicity and low flammability. The refrigerant categories are listed in Figure 3.

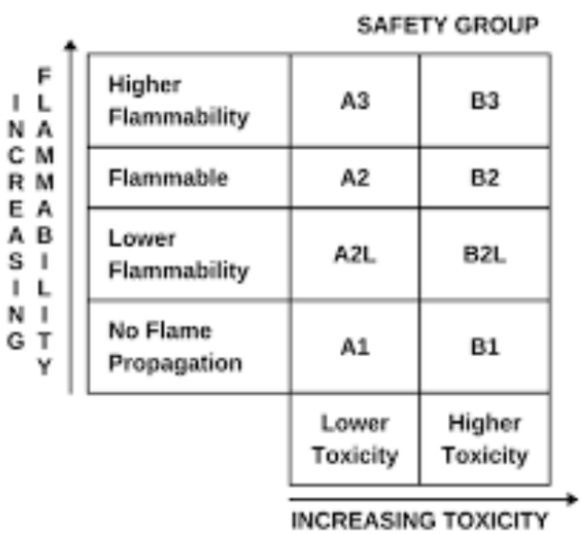

Figure 3: ASHRAE Standard 34, designation and safety classification of refrigerants. (AHRI 2023)

With changing refrigerant regulations, manufacturers continue to develop new products that strive towards the overall goals of low GWP, low flammability, improved or neutral energy efficiency performance, and limited equipment replacement needs in retrofits. While energy efficiency will be the primary focus of the packaged propane system research, it is important to consider the environmental impacts of refrigerant choices, particularly their GWP.

Metering Results

VEIC metered three installations of propane systems. Two medium temperature units and one low temperature unit were installed at small businesses in climate zone 6A - cold and humid. Two units were installed at a general store and one at a café. The average size of the walk-ins served by the propane units ranged from 300-400 ft^3. The two medium temperature propane units were 0.75 hp and the low temperature unit was 1.5 hp.

The baseline system used in this comparison was extrapolated from the pilot sites that were monitored in ETCC project ET22SWE0054 (Shorin, et al. 2024). For the medium temperature units, the baseline condensing units and baseline high efficiency condensing units matched the size of the unit that were installed and metered at a Café site. For the low temperature units, the baseline condensing units and high efficiency condensing units were larger than the metered propane unit. Baseline units were 3 hp at a general store site and 2 hp at site a coffee shop site. To create a comparable baseline, the annual energy use for the low temperature system was calculated using the average kWh per hp at the general store site and adjusting down to 1.5 hp. This conservatively assumes that energy use scales linearly with compressor size. The baseline and efficient system specifications are provided in Table 8.

The units included in this study are referred to by horsepower size to ensure that an energy comparison can be made between the baseline and efficient systems. Compressor horsepower and cooling capacity do not directly correlate. For example, a 1.5 hp low temperature unit, such as the baseline CU (LT), could provide a cooling capacity of 24,200 Btu/h to a smaller, higher temperature space, but only provide 5,600 Btu/h to larger, lower temperature space. Assuming that this 1.5 hp low temperature unit was sized appropriately for the space, the unit installed in both scenarios will still have the same average power draw. As such, the baseline and efficient unit sizes provided in Table 6 are show the compressor size in hp, rather than the cooling capacity in Btu/h.

Table 6: Baseline and Efficient System Specifications

Unit	Refrigerant Type	System Temp	System Location	Unit Size	Climate Zone	Data Source	Annual Energy (kWh/yr)
Baseline CU (MT)	HFC	Med	Indoor	0.7 hp	3	Metered	11,130
Baseline CU (LT)	HFC	Low	Outdoor	1.5 hp	3	Extrapolated from meter data	7,625
Baseline HECU (MT)	HFC	Med	Outdoor	0.7 hp	3	Metered	2,389
Baseline HECU (LT)	HFC	Low	Outdoor	1.5 hp	3	Extrapolated from meter data	4,289

New Medium Temp Propane System	Propane	Med	Indoor	0.75 hp	6A	Metered	1,806
New Low Temp Propane System	Propane	Low	Indoor	1.5 hp	6A	Metered	3,431

The two medium temperature units averaged 84% energy savings over the baseline HFC condensing units and 24% energy savings over the baseline HFC high efficiency condensing units. The low temperature unit achieved savings of 55% compared to the baseline HFC condensing unit and 20% over the baseline HFC HECU. The full metering results are shown in Table 9.

All the baseline units were metered in climate zone 3A or 3B – hot. This results in energy savings being more conservative than if the baseline units were in colder climates. The predominant climate zone in California is climate zone 3B. The physical location of the baseline units, installed inside or outside a building, also impacts energy savings. Generally, outdoor units operate more efficiently than indoor units. The baseline CUs reflect a mix of indoor and outdoor units. The medium temperature baseline CU was an indoor unit, which increases the metered energy savings compared to if it was an outdoor unit. For the low temperature baseline, the CU was an outdoor unit, which reduces the metered energy savings that would be expected with an indoor unit baseline. All the baseline HECUs are outdoor units, which is one of the reasons for lower energy savings with the HECUs over the CUs.

As part of the metering study that was conducted, VEIC developed an excel-based modeling tool to estimate the energy savings of the propane unit over the 2021 IECC energy code for an indoor condensing unit. This tool quantifies the savings from the propane unit's efficiency features, including variable speed compressors, electronic expansion valves, and smart/adaptive defrost controls. These modeled savings are shown in Table 9 to provide comparative analysis and validation of metered energy savings. For the medium temperature system, the metered energy savings of the baseline indoor CU align well with the modeled indoor CU. On the low temperature side, we see the modeled energy savings estimating additional reductions in energy use over the baseline CU savings. This discrepancy is due to the modeled energy savings for the low temperature system using an indoor baseline CU and the metered energy savings using an outdoor baseline CU.

Using a weighted baseline of indoor and outdoor CUs, and CUs and HECUs, the average metered savings are 54% for medium temperature systems and 38% for low temperature systems. Applying an average electric utility rate of $0.29/kWh, the estimated energy cost savings range from $170 - $2,700 per year for the MT systems and from $250 - $1,200 per year for the LT system (Electric Power Monthly 2025). The average energy and cost savings estimates increase if you factor in the modeling results. Additional data is needed to validate these initial results.

The average duty cycles for the metered medium and low temperature cases were 40% and 57% respectively. The modeled energy savings assumed a duty cycle of 45%. Duty cycles were not provided in the ETCC project ET22SWE0054 (Shorin, et al. 2024).

Table 7: Metering and Modeling Results

Propane Unit	Propane Unit Metered Energy Use (kWh/yr)	Baseline CU Energy Use (kWh/yr)	Propane Metered Energy Savings vs Baseline CU (kWh)	Propane Metered Energy Savings vs Baseline CU (%)	Baseline HECU Energy Use (kWh/yr)	Propane Metered Energy Savings vs Baseline HECU (kWh)	Propane Metered Energy Savings vs Baseline HECU (%)	Propane Modeled Energy Savings vs Energy Code (kWh/yr)	Modeled Energy Savings (%)
New Medium Temp Propane System	1,806	11,130	**9,324**	**84%**	2,389	**583**	**24%**	9,481	**85%**
New Low Temp Propane System	3,431	7,625	**4,191**	**55%**	4,289	**855**	**20%**	4,706	**62%**

Market Characterization

The project team investigated California market dynamics to identify opportunities for packaged propane refrigeration unit uptake. This section outlines the market prospects, key market drivers, supply chain ecosystem, and barriers to adoption.

Included in this characterization are refrigeration systems serving WICFs in equipment retrofit, end-of-useful life replacement, and new construction applications. The end-use equipment is not limited to food retail applications, but includes refrigerated spaces typically served by remote condensing units (RCUs).

Equipment Availability

To accommodate different configurations of WICFs, both top-mounted and wall-mounted units are available in the global market, as well as slim and ultra-slim designs to minimize the space taken up by the unit cooler and condensing unit systems. However, US companies are not currently making wall-mount systems, and those types of models are not yet offered in the US by foreign manufacturers because they have not yet been UL-listed. In the US, the only currently UL-compliant options are top-mounted systems, as shown in the schematic in Figure 4. In the equipment below, the white section sits inside the refrigerated space, and the black section sits above the ceiling of the refrigerated space.

4

Figure 4: Top-mounted unit, one of only a few packaged propane units currently sold in the U.S.

(Aacore n.d.)

Figure 5: The wall-mounted packaged systems available outside the US.

Numerous European companies have developed a range of packaged propane technologies as drop-in solutions to replace existing wall and ceiling mounted packaged HFC systems. Wall-mounted units provide added versatility; the condensing side can be mounted through an exterior wall making it easier to install in low-ceiling locations or as a replacement for existing split evaporator and condensing unit systems that have floor to ceiling insulation for the cooler box. Thus, due to the limited configurations available in the US, US adoption of packaged propane refrigeration technologies among end-users has been slower. For reference, Figure 5 shows a wall-mounted packaged system that is not currently available in the U.S. In this system, the small white section of the equipment sits inside the refrigerated space, and the larger gray section of the equipment sits flush to the wall of the refrigerated space.

Systems available in the US contain fixed and variable speed hermetic, scroll or reciprocating compressors, and the evaporator and condenser have EC fan motors. Available units range from 0.1 – 1.5 HP, often with controls for variable speed compressors. Common energy savings options in the US market include EEVs and hot gas defrost.

Several manufacturers, mostly European based companies, are leading the development of R-290 packaged systems. These manufacturers offer broad product ranges in international markets; however, due to the rigorous requirements of UL Listing and the limitations of propane charge sizes, only a limited selection is available in the US market. One manufacturer offers a line of packaged units with hermetic compressors, with units up to 10 HP available internationally, but only units up to 1½ HP available in the US. Another manufacturer has efficient R-290 systems with EC fan motors, hot gas defrost, and variable speed compressors, including both medium and low-temperature models. A third has a line of monoblock units, though specific capacity details are less clear. Two other manufacturers focus on standard unit coolers sized to HECU, with one featuring hermetic or scroll compressors up to 1½ HP and the other offering hermetic condensing units up to 1 HP.

While several manufacturers offer R-290 packaged refrigeration systems, there are notable limitations in sizing and stocking within the U.S. market. Domestic manufacture and stocking of these units is limited, leading to longer lead times and supply chain constraints. This hinders rapid deployment and complicates maintenance and replacement planning, especially for OEMs and contractors seeking readily available, standardized solutions.

Industry Trends

The refrigeration industry is always evolving. This section discusses refrigeration trends including the adoption of low GWP refrigerants in the market and associated challenges, as well as the global and national trends for packaged propane systems.

NATURAL REFRIGERANTS

The transition toward low global-warming potential (GWP) refrigerants is reshaping the HVACR market, with natural refrigerants gaining significant traction. Driven by domestic and global regulatory frameworks, natural refrigerants are increasingly being adopted across commercial refrigeration, cold storage, and industrial sectors.

Early adopters of natural refrigerants, particularly in food retail and large commercial applications, have embraced CO_2-based systems due to the low GWP, scalability, and A1 safety class designation of being non-toxic and non-flammable. CO2 also can have improved energy efficiency in colder climates. For industrial scale applications, ammonia has historically dominated due to its superior thermodynamic properties. Ammonia, complicated by its toxicity concerns, has not made inroads into smaller applications. This is where hydrocarbons, including isobutane and propane, made inroads in small-scale refrigeration, especially across Europe and Asia. Adoption is increasing in U.S. markets but is limited by building safety standards that limit the amount of flammable refrigerant that can be used in refrigerant-containing equipment.

CO_2 refrigerant replacements are costly due to changes needed to existing infrastructure, primarily due to the increased physical size and weight of the CO2 systems, which many existing mechanical rooms and roofs cannot accommodate without expansion and reinforcement. Comparatively, R-290 can be swapped into many existing spaces without needing to alter infrastructure. One limiting factor for R-290 is safety concerns around flammability. These challenges are being actively addressed through evolving safety standards, new equipment designs, and training. From a cost perspective, CO2 is generally 4-10x more expensive than the most common synthetic systems like R-134a and R-410, and R-290 is comparable in cost to the synthetic systems.

The supply chain for R-290 remains relatively stable, with domestic and international producers capable of scaling production. As regulatory pressure intensifies and technology matures, market penetration of natural refrigerants is expected to accelerate—supported by incentives, public-private R&D, and increasing end-user demand for sustainable refrigerant solutions that fall within the 150g charge limitations of R-290.

The supply chain for natural refrigerants is notably distinct from that of synthetic alternatives, due to differences in production scale, infrastructure needs, and regulatory oversight. Natural refrigerants like R-290 are typically derived from widely available raw materials, making them less susceptible to geopolitical or resource bottlenecks. In comparison, fluorinated refrigerants rely on more complex chemical feedstocks like fluorspar.

Manufacturing infrastructure for R-290 is simpler and more decentralized, often integrated within existing chemical or industrial gas production networks. However, distribution and storage introduce challenges—particularly with safety-rated handling requirements and compatibility with specialized equipment, which can affect logistics costs and delivery timelines. In contrast, the synthetic refrigerant supply chain dominated by a few global players relies heavily on proprietary formulations, trade-restricted precursors, and centralized production facilities, often located in China, the U.S., and parts of Europe. This creates vulnerabilities in availability, especially under trade tensions or regulatory shifts.

Broader adoption of R-290 depends on scaling production and strengthening downstream supply chain elements such as component manufacturing, technician training, and regulatory harmonization. A resilient and responsive supply chain will be key to meeting the growing demand for low GWP alternatives and ensuring that environmental policy goals can be met without significant barriers.

SALES AND DISTRIBUTION TRENDS

In Europe, R-290 equipment has been in use for more than 20 years. Over the last five years packaged propane refrigeration technologies for WICFs have become more prevalent in the European and Asian markets with many manufacturers offering the propane option. The adoption of industry safety recommendations of 150g R-290 charge limits by the International Electrotechnical Commission is widely accepted, but the UK approves charges up to 500g (Wicher n.d.) allowing for larger systems and adoption of packaged propane units across a wider swath of the market. Top-mount packaged propane systems have only been released by a few large industry players in the US in the last few years, because interest in propane options has started to build momentum. However, preliminary research indicates that sales and installation of those systems have not been widespread. Nationally, regulatory hurdles (EPA SNAP approval, UL standards, and building and regulatory codes) currently limit deployment of R-290 systems.

SALES & DISTRIBUTION

As of 2022, California was home to nearly 18,000 food and beverage retailers and more than 75,000 restaurant establishments (United States Census Bureau n.d.). Food and beverage retail buildings in CA are estimated to have nearly 29 million square feet of WICFs (EPA, Energy Use in Supermarkets 2015). Global trends show food and beverage retailers are estimated to own nearly one third of all walk-in units, with the other two thirds in other building/industry types. Table 9 below shows the number of establishments in CA by business type, which will be key in estimating the total number of walk-in units in California and the market potential for packaged propane systems.

Table 8: Total Number of Establishments in California by Business Type

Business Type	Number of Establishments in California
Convenience stores	2,866
Gasoline stations with convenience stores	6,446
Supermarkets and other grocery (except convenience) stores	7,733
Warehouse clubs and supercenters	783
Restaurant and eating places	75,115
Other (Hospitals, schools, offices, etc.)	46,472
Total	139,415

Stakeholder Feedback

Conversations with market stakeholders including manufacturers, contractors, distributors, efficiency utility program managers, and program implementers provided vital details about the market's current state from various perspectives in the procurement cycle.

The key stakeholders, interview question and takeaways for each group are as follows:

Manufacturing Interviews

Interviews with two leading manufacturers were conducted to gain a clear understanding of the current market landscape and the comparative feasibility of propane-based systems versus conventional options. These conversations explored a range of topics, including market penetration by refrigerant type and incremental cost differences between high- and standard-efficiency models. Manufacturers provided insight into customer purchasing habits and supply chain logistics. Additional areas of focus included understanding customer purchasing habits, how equipment moves through the supply chain, and upcoming innovations in refrigerants and related technologies.

Key Take Aways

- Several large US-based refrigeration companies are exploring propane packaged systems, but none of them are heavily investing in propane technology.
- Refrigerant regulation is driving end user retrofits and manufacturer timing of new products being researched, developed, and launched.
- Manufacturers are not releasing lower GWP products ahead of regulations.
- OEMs are used primarily for distribution.

- New packaged propane equipment for outdoor use is coming soon.
- ROI compared to traditional HFC systems are better due to lower refrigerant charge sizes, maintenance, and energy costs.

Utility Program Interviews

Representatives from energy efficiency utility programs and IOUs were interviewed to gain a better understanding of how existing and potential programs are supporting refrigerant technologies in food sales and food service sectors. Discussions were focused on current program offerings both prescriptive and custom including program utilization rates, eligibility requirements, equipment qualification standards, savings calculation methodologies, and baseline assumptions. Incentive structures, including bonus incentives for hydrocarbon or natural refrigerants, incentive levels, cost-effectiveness screening, and TSB metrics were investigated. Additionally, interviews explored contractor support mechanisms such as direct payment models, training and certification programs, and contractor engagement strategies. Interviews with program managers were conducted with SMUD, EVT, Eversource MA, Energy Solutions, and Mass Save.

Key Take Aways

- Utility awareness varied greatly
- Incentives for packaged propane units are through custom programs currently. Not aware of any deemed incentive programs for natural refrigerant equipment. Some utilities have offered custom incentives for full natural refrigerant system retrofits.
- Packaged propane systems are easier to install than traditional HFC systems that require refrigerant piping to connect the condenser to the evaporator.
- Smaller customers, seasonal operations, and new construction are a better market for these small, packaged units.
- Technician readiness and supply chain issues limiting market adoption
- Lab testing or pilot programs needed for some utilities to adopt incentives
- Current manufacturers are mostly European companies
- Misconceptions about these units being “dangerous” still perpetuate in the industry.

Contractor & Distributor Interviews

The project team conducted stakeholder outreach to contractors, distributors, and service providers to gather insights into the refrigeration products and services they offer. The goal was to better understand their experiences with equipment, refrigerants, customer markets, and installation capabilities, particularly with propane-based systems. The team learned about any challenges these stakeholders face, how they purchase and manage equipment, and how willing and prepared they are to work with natural and flammable refrigerants. This information helps assess the market’s readiness and identify opportunities to support adoption through training or other resources.

Interviews were conducted with contractors and distributors including, Climate Pros, Taper, and American Refrigeration Supplies.

Key Takeaways

- Contractors are generally aware of natural refrigerant technologies but haven't performed many or any installations yet.
- Most customer inquiries are for self-contained propane cases, not packaged systems.
- Limited US inventory due to UL listing and tariffs slowing adoption.
- Customers having decision paralysis due to information overload; seeking trusted guidance.
- Customers are looking to the contractors to help them future proof, but generally aren't aware of what the future proofing needs are, including the selection of refrigerant types, refrigerant charge sizes and limitations, reporting requirements, refrigerant phaseout dates, etc.
- Minimal contractor or end user knowledge about regulatory complexities.
- Barrier in limited incentives and added program complexities. High costs of new, natural refrigerant equipment slowing uptake.
- Concern with fire danger with added propane charge, especially in areas of California where fire danger is high.

Industry Stakeholder Interviews

An interview was held with the North American Sustainable Refrigeration Council (NASRC) to understand trends across the United States and California for natural refrigerant adoption. This interview centered on food retailers' interest in technology, contractor knowledge, benefits and barriers, and available resources.

Key Takeaways

- One of the biggest barriers is due to small propane charge size limitations.
- Retailers interested in technology for retrofitting walk-ins, but trending more towards CO2 condensing units due to larger size availability
- Limited investment in technology from U.S. manufacturers that focus on large grocery and supermarket retailer applications, which is the largest market share. More interest from smaller manufacturers that focus mainly on condensing units and smaller split systems.
- Contractors and end users have experienced technical challenges with packaged propane systems to date.
- The technology offers advantages such as easier servicing with removable cassettes and reduced compliance burden under AIM Act, but these benefits haven't been fully realized. Limited experience due to low available inventory.
- Distrust in propane from contractors due to flammability and concern over cutting holes in the walk-in.

End User Interviews

To better understand the decision-making process behind adopting packaged propane systems, the project team conducted outreach to end users—particularly small food service and food retail businesses. These stakeholders ultimately hold purchasing power and are key to market adoption. Gaining insights into their priorities, perceived benefits, and barriers will inform both program design and broader market potential. The project team partnered with the San Francisco Environment

Department (SFED) to identify and engage with businesses within their network, particularly those in culturally diverse communities where traditional values play a strong role in business operations. Outreach focused on understanding real-world experiences with packaged propane systems, from procurement and installation to performance and maintenance.

Despite outreach attempts, only one end user interview was conducted as part of this project, with Bi-Rite Market.

Key Takeaways

- Some knowledge and interest in natural refrigerants like propane and CO2, an interest driven primarily by the phase out of R-404A. Conducted a refrigerant inventory to access future needs and evaluate options, but no installations to date.
- Stores have limited electrical capacity and space constraints.
- Walk-ins are often located in commercial kitchen spaces which have undersized AC and high cooling demands, making the additional heat rejection into this space a concern.
- Need economics to line up with environmental benefits and operational efficiency.
- Historically they have worked with smaller, local contractors, but as their refrigeration needs increase, they are interested in finding more reliable and innovative partners.
- Facing challenges with aging contractor workforce and resistance to new technologies.

Surveys

In addition to interviews, two surveys were evaluated as part of the stakeholder feedback. One was a California-specific study conducted by Bay Area Regional Energy Network which collected 31 survey responses from small business owners on their refrigeration and operation needs. The bulk of the responses came from food service and food retail establishments that lease or rent their spaces. The second was a national Food Retailer Survey Report that was conducted by NASRC in 2021 with responses from 11 food retailers covering 16,200 United States locations.

Key Takeaways

Survey respondents expressed that businesses do not have a plan in place for replacing their current walk-in units but have interest in replacing them with the highest-efficiency system they can find when the time comes. Owners also indicated they are unlikely to replace the walk-in unit until failure is relatively certain and an interest in being environmentally friendly when possible. There was concern reflected on rising electricity rates as well as interest in rebates from utilities and government agencies in buying energy efficient equipment that would accelerate the replacement of old equipment.

The food retailer survey resulted showed national interest in R-290 condensing units, with 90% of the loads being prioritized for walk-in coolers as their primary application. The most preferred product types were packaged units for top/roof installation (56%) and standard condensing units (42%). Retailers cited propane's energy savings potential of up to 30%, its simpler technology, and lower operating pressures as key advantages over CO_2 systems. However, concerns were raised about charge size limitations, cost and complexity when multiple units are needed, and design constraints in display cases.

Program Peer Review

National Program Peer Review

Leveraging peer review data from the ETCC project ET22SWE0054, a review of 23 energy efficiency programs across 15 states reveals growing but uneven support for HECU and HEEU technologies (Shorin, et al. 2024). These systems use HFC, HFO, and blended refrigerants. Currently, there are no programs that directly and exclusively support natural refrigerant condensing units or packaged propane refrigeration systems. Table 10 and Table 11 show summaries of the programs that were reviewed. For programs that support HECU measures, the average incentive is $400-$600 per HP. For HEEU programs, the average incentive is $250 per fan.

Table 9: National Program Review by Program Type

Program Type	Number of Programs	Program Details
Prescriptive HECU and HEEU Programs	3 of 23	Offer direct rebates for packaged units. Specifically, DTE, Mass Save, and Efficiency Vermont offer rebates for HECU and/or HEEU systems. Most other programs evaluated offer rebates for select equipment and components of refrigeration systems, but not the refrigeration unit.
Custom HECU and HEEU Programs	17 of 23	Allow tailored applications for refrigeration projects, including HECU and HEEU installations, as well as system components.

Table 10: Programs, Measures, and Incentives

Program or Utility	Measures	Incentive Structure
DTE	HECU/HEEU	HECU per HP: tier 1 $400 per HP for 1-3 HP, tier 2 $200 per 3-6 HP HEEU per fan: tier 1 $150 per fan, tier 2 $250 per fan
Mass Save	HECU	Up to $1200 per unit incentive
Efficiency Vermont	HECU/HEEU	HECU: $600/HP for units < 4 HP $400/HP for units >= 4 HP, up to $2,400 per unit HEEU: $250 per fan, up to $1,500 per unit

California Programs & Measures

California's IOUs offer several programs that could integrate or expand to include packaged propane refrigeration systems. A review of the programs relevant to PG&E and SCE is summarized in Table 12 and Table 13.

Table 11: Relevant PG&E Programs

Program	Description	Relevance to Packaged Propane Systems
CoolSave	Pay-for-performance program for grocery sector. Uses real-time controls and normalized metered energy consumption.	Potential for integrating propane systems on WICFs that can be tied into rack systems and store controllers with real-time monitoring and DR capabilities.
On-Bill Financing	No-interest loans for energy-efficient upgrades.	Could support propane system retrofits with zero upfront cost, which is beneficial for HTR/DAC businesses.
California Energy Design Assistance (CEDA)	Supports electrification and low GWP refrigerants (<500 GWP).	Propane systems (GWP ~3) align well with program goals.

Table 12: Relevant SCE Programs

Program Type	Number of Programs	Program Details
Agriculture Energy Efficiency Program	Incentives for refrigeration in agriculture.	Propane systems could be piloted in ag cold storage.
Commercial Energy Efficiency Program	Targets businesses >20 kW demand, including restaurants and grocery stores.	Packaged propane systems could be added as a custom measure or retrofit option that could be bundled with other measures.

A review of the CA eTRM revealed that while there are prescriptive measures for individual components and controls that serve WICFs—such as electronically commutated motors, floating head pressure controls, and adiabatic condensers—there are currently no prescriptive characterizations that directly support packaged condensing units or evaporator unit systems. Moreover, these existing component and control measures primarily target larger multiplex refrigeration systems. The only commercial refrigeration system measures that are currently supported in the CA eTRM are for self-contained refrigerated cases – reach-ins, chef bases, and prep tables, which does not cover the equipment needs for walk-ins. This presents an opportunity to support remote, single-compressor systems commonly used in markets, restaurants, and other small-to-medium foodservice businesses.

Current Market Barriers and Gaps

Despite the promising energy efficiency and environmental benefits of packaged propane refrigeration systems, their widespread adoption in commercial WICF applications remains constrained by several market limitations. Chief among these is the restrictive 150-gram charge size limit for propane, which significantly curtails system capacity and scalability, limiting use to small applications or requiring multiple units for larger loads. Additionally, the market faces a shortage of trained technicians familiar with installing and servicing A3-class flammable refrigerants, compounded by limited contractor education, certification programs, and awareness of propane technologies. Space constraints in commercial kitchens and unconditioned areas, misinformation about propane flammability risks, and the lack of UL-listed wall-mounted systems further hinder deployment. Utility programs and incentives are often misaligned with the needs of small businesses, especially in disadvantaged communities, and typically exclude systems with low refrigerant charges, leaving a critical market segment underserved.

The barriers and market gaps identified in this study include:

- System Size Limitations (150g Propane Charge Cap): The IEC UL 60335-2-89 standard restricts propane charge sizes to 150 grams per circuit, limiting system capacity and requiring multiple units for larger applications. This constraint impedes scalability and increases installation complexity and cost. Additionally, building codes and safety standards have not been fully adapted to support broader use of propane systems. Updates to ASHRAE 15, EPA SNAP, and local codes are needed to enable higher charge limits and more flexible system designs.

- Technician Availability and Training: There is a notable shortage of technicians trained to install and maintain systems using flammable refrigerants like propane. EPA 608 certification is required, but additional training specific to A3 refrigerants is often lacking.

- Space Constraints in Commercial Kitchens: Increased waste heat from indoor-mounted units can exacerbate cooling loads in unconditioned or tightly packed spaces, making propane systems less viable in certain kitchen environments.

- Installation Space Limitations: Physical space between the top of the WICF and the underside of the roof or ceiling can be insufficient for top-mounted units, especially in retrofits. The absence of UL-listed wall-mounted options in the U.S. further restricts flexibility.

- Supply Chain and Equipment Availability: Most packaged propane systems are manufactured in Europe, with limited domestic production and stocking in the U.S. This leads to long lead times and complicates maintenance and replacement planning.

- Propane Misinformation and Flammability Concerns: Persistent misconceptions about the safety of propane, particularly its level of flammability, contribute to contractor and end-user hesitation, despite the presence of leak detection and mitigation systems in modern units.

- End-User Knowledge and Decision Paralysis: Small business owners often lack awareness of propane options and face information overload regarding refrigerant regulations and future-proofing strategies, leading to delayed decision-making.

- **Limited Awareness and Incentive Programs:** Many utilities are unaware of packaged propane systems or lack prescriptive incentives for natural refrigerant technologies. Existing programs often focus on larger systems, excluding support for small and underserved businesses.

- **Incentive Misalignment for Small Businesses:** Programs like CARB's F-gas Reduction Incentive Program target systems with refrigerant charges over 50 pounds, inadvertently excluding small businesses that operate low-charge systems.

Market Opportunities

Drawing from the findings of the technical review, market characterization and the stakeholder feedback, the following opportunities emerge as areas for growth and innovation:

- Market and decarbonization potential
- Equipment and supply chain scalability
- HTR/DAC engagement

Market & Decarbonization Potential

Packaged R-290 refrigeration technologies with on-off and with inverter compressor technologies for use WICFs in Europe have shown as high as 7-20% energy savings over R-134a MT packaged systems with on-off technology and 35-40% energy savings over R-452a LT packaged systems with on-off technologies (Energy efficiency in walk-in cold rooms through R-290 inverter compressor technology 2022). While these exact systems are not currently available in the US market, the data shows the potential savings from packaged R-290 systems. These results are consistent with the 20-25% energy savings from packaged propane units over the high efficiency condensing units referenced in the meter data results.

According to a report from the DOE, WICF units use approximately 16,200 and 21,400 kWh/yr on average, respectively (Navigant Consulting 2009). Nationally, more than 130,000 condensing units for walk-in refrigeration are sold annually in the grocery market. In California, that number is estimated to be approximately ~16,000 units. If 30% of walk-ins are small <300sf and can accommodate packaged propane systems, preliminary analysis of the energy savings potential shows that every 1% market share of packaged propane refrigeration systems could result in annual energy savings of nearly 190 MWh in California. Applying a 5% market penetration to the existing annual sales would yield 950 MWh in energy savings from 240 units. This number expands rapidly if you start looking at the market potential for retrofits and early replacement opportunities as well.

In addition to energy savings, packaged propane units also have non-energy GHG savings associated with the reduction in refrigerant leaks. This reduction comes from an overall reduction in total refrigerant volume and refrigerant leaks from the system. The average GWP of some of the most common HFC refrigerants – R-134a, R-22, R-404A, R-410A, R-407C, R-507A, R-507C – is more than 2,500 points above that of propane, which has a GWP of 3. By implementing packaged propane units with leak detection monitoring, the refrigerant leakage rate can be reduced from 15%, which is generally accepted as an industry standard value for remote condensing units, to about 5%, reflecting a 10% total reduction. Research from leading U.S. manufacturers, Bohn and Trenton, shows that the average refrigerant charge for units under 2 horsepower is about 11 pounds. In comparison, the packaged propane units have a total charge size of less than 1 pound. This refrigerant leak reduction translates to an annual savings of approximately 1.87 metric tons of CO_2e per unit, which is >99% reduction in GHG emissions, shown in Table 13. When applied to the 5% market penetration, the result is an estimated 450 metric tons of carbon emissions prevented from entering the atmosphere each year. Further analysis of the additional building types that have walk-ins is needed to determine the full market potential.

Table 13: GHG Emissions of Baseline and Propane Systems

Refrigerant	GWP (CO_2e/lb)	Charge Size (lbs)	Leak Rate (%)	Leaked Charge (lbs/yr)	Emissions (lbs CO_2e/year)	Emissions (MT CO_2e/year)
Baseline – Blend HCFC/HFC/HFO	2,500 (avg)	11	15%	1.65	4,125	1.87
Propane	3	0.33	5%	0.02	0.05	0.00

Applying the same refrigerant leak reductions to refrigerant cost has similar benefits. The phase out of HFC refrigerants is driving up the cost of the most common refrigerants in use. The average cost of refrigerant gas per pound varies significantly by type, with R-22 typically costing the most, around $90-$150 per pound installed, due to it being phased out of production in 2020 (Ayer, How Much Does R-22 Refrigerant Cost per Pound? [2025 Data] 2025). R-410A is more common and costs roughly $40-$75 per pound, but these costs are likely to rise given that it started being phased out in 2025 (Ayer 2025). Using an average cost of $80 per pound and an average leak reduction of 1.3 pounds per unit, the refrigerant cost savings to the system operator is approximately $100 per year. Savings are realized in the upfront cost of refrigerant for the initial system charge and in annual savings from the reduction in refrigerant leaks. At the same 5% market penetration, this could result in $26,400 per year in savings for CA businesses.

Scaling the Supply Chain

Packaged propane refrigeration systems present a strong opportunity for scalable deployment across California's food retail and food service sectors. The supply chain for these systems mirrors that of traditional condensing units and evaporators, with manufacturers selling to suppliers or contractors who then serve end users. This existing structure reduces friction for market entry, as contractors and OEMs are already familiar with similar procurement and installation processes. For small WICFs, packaged units can be integrated into modular walk-in systems and OEM offerings, creating a turnkey solution that simplifies adoption for businesses with limited technical capacity. Manufacturer interviews confirm that current sales of packaged propane units are almost exclusively direct from the

OEM. Currently, no distributors, contractors, or walk-in system manufacturers offer packaged propane systems as a standard product; they are only available through special requests. Encouraging these products to be stocked and integrated into the supply chain could significantly accelerate market penetration.

Scalability is further supported by the modular nature of packaged propane units. However, current limitations—such as the absence of UL-listed wall-mount options in the U.S. restrict flexibility in space-constrained environments. Certification of wall-mounted designs would unlock new retrofit opportunities, particularly for businesses with insufficient ceiling clearance. Additionally, expanding allowable charge sizes beyond the current 150-gram limit would enable larger capacity systems, reducing the need for multiple units and improving cost-effectiveness.

HTR/DAC Engagement

Packaged propane systems align well with the needs of HTR and DAC businesses, where small-to-medium commercial businesses dominate. Restaurants, corner stores, and independent groceries often operate on razor-thin margins—sometimes less than 4%—and lack access to capital for major refrigeration upgrades. These businesses are disproportionately excluded from existing incentive programs, which typically target systems with refrigerant charges of over 50 pounds. By focusing on propane systems, which are optimized for these smaller applications, utilities can create targeted programs with enhanced incentives to bridge this gap and deliver meaningful energy and cost savings to these underserved segments, supporting both equity and climate goals.

Program Design

Below is a proposed new measure development for a packaged propane refrigeration system using R-290 refrigerant. The goal is to create a new deemed measure for the California eTRM.

Measure Development Plan

- Baseline Eligibility Criteria
    - Walk-in coolers and freezers served by condensing units.
    - Indoor or outdoor condensing units.
    - Units that use HFC, HFO, and blended refrigerants.
    - Single-phase and three-phase systems.
- Replacement Scope
    - Baseline systems can be replaced with one or multiple packaged propane systems.
    - Applicable to both retrofit and new equipment installations.
- Energy Savings Validation
    - For a custom project pathway, metered energy data of refrigeration systems pre- and post-installation can be used to compare kWh savings over baseline to quantify savings.
    - For a prescriptive project pathway, use deemed savings via TRM measure.

TRM Measure Development

CHARACTERIZE BASELINE SYSTEM

- Establish the baseline using existing TRMs and EE programs for high efficiency condensing units (HECU) and high efficiency evaporators/unit coolers (HEEU).

- Collect input values and use weighted averages for:
    - Refrigerant type - uses weighted average GWP value for most common synthetic, HFC. HFO or blended refrigerants are used in small commercial refrigeration systems.
    - Compressor capacity - bin unit/compressor size using hp, kW, or Btu/h ratings.
    - Compressor EER - bin for low and medium temp, single and three phases, and capacity ratings.
    - Head pressure setpoint- identify minimum saturated condensing temperature/pressure setpoint.
    - Floating head pressure controls - use a weighted average for the percentage of baseline systems that include floating head pressure controls.
    - Condenser and evaporator fan motors – use a weighted average for the percentage of baseline systems that have PSC, SP, and ECM fan motors. Apply average fan motor efficiency, power draw, and motor quantities.
    - Condenser and evaporator fan motor controls – use weighted average for type of fan controls: no control, high/low speed, on/off, and fully modulating.
    - Defrost – categorize the baseline for defrost type (electric, air, or hot gas), the number of cycles per day, defrost duration, and, if electric, the kW rating for the electric heaters.
    - Average load – Collect details on the average design load and duty cycles of compressors.
    - Refrigeration system temperature – bin using average walk-in temperatures for low (freezer) and medium (cooler) applications.
    - Operating schedule – apply annual operating hours based on number of months of year walk-in is operational.
    - Ambient temperatures apply the average temperature of ambient space that accounts for whether the baseline refrigeration system and the new propane systems are installed outdoors, indoors in a conditioned space or indoors in an unconditioned space.
        - If baseline equipment is installed outdoors, apply California TMY3 or TMYx weather station bin data to analysis.
        - If baseline equipment is installed indoors, apply a weighted average indoor temperature to the analysis based on the percentage of indoor units that are installed in conditioned vs. unconditioned spaces.

CHARACTERIZE NEW PROPANE SYSTEM

- Collect manufacturers' specifications, case studies and use the data presented in this report to develop the propane system measure characterization.
- Collect input values and use weighted averages for similar parameters listed for the baseline system.
- Baseline systems have the same capacity as the new system assuming refrigeration loads stay constant.

DEVELOP TRM SAVINGS METHODOLOGY

- Develop TRM algorithms to establish savings methodology.

        - Calculate deemed savings values based on metered data, analysis spreadsheets, verified performance metrics, and baseline comparisons.
        - Perform additional analysis necessary to validate and aggregate the data into a format for the eTRM.
- Aggregate deemed savings across data sources using:
    - Equipment capacity (hp)
    - Non-energy GHG savings – from reductions in refrigerant GWP and refrigerant volume
    - Energy savings (kWh/hp)
- Establish Portfolio-level reporting
    - Use NMEC or deemed algorithms for portfolio-level reporting.

IOU Program Integration

PROGRAM DESIGN

- For IOUs with existing HECU programs, integrate packaged propane refrigeration systems into existing program resources, QPLs, and incentive structures with potential DAC enhanced incentives.
- For IOUs that don't have existing programs for HECUs, create a new EE measure, including program resources, QPLs, and incentive structures for energy savings and GHG reductions.
- Develop and validate a QPL for packaged propane refrigeration systems. The QPL can be integrated into an existing QPL for high efficiency condensing units, if one exists, or newly created for natural refrigerant equipment. The new QPL could be exclusive to packaged propane systems or expanded to include all: natural refrigerant and hydrocarbon, self-contained and remote, refrigerated cases, condensing units, and packaged systems.
- Ensure that all equipment is UL listed.

EQUIPMENT ELIGIBILITY REQUIREMENTS

- Packaged propane refrigeration systems that use R-290.
- Included on the Qualified Products List.
- Includes both the condenser and the evaporator in a single unit.
- The system must serve a walk-in cooler or freezer.

PROPOSED INCENTIVE STRUCTURE

- For IOUs with existing HECU programs, amend the existing HECU program and apply a customer bonus incentive:
    - $500/hp for packaged propane systems meeting equipment eligibility requirements. This is paid in addition to existing program incentives for HECUs. This is paid via the same method as the existing HECU program.
- For IOUs that don't have existing programs for HECUs, create a new prescriptive incentive structure:
    - $1,000/hp for packaged propane systems meeting equipment eligibility requirements. This is paid directly to the customer or indirectly as a pass-through incentive via the contractor or distributor.
- Optional natural refrigerant bonus:
    - $500/hp paid directly to contractor or installation technician to encourage adoption and proper installation practices. This also helps contractors recover costs for

education, training, and additional certifications required to ensure the safe handling of propane refrigerant.

Propane Fact Sheet

The propane fact sheet was designed to build awareness and promote the transition to cleaner, more efficient refrigeration technologies, especially among hard-to-reach and underserved customers. It is intended to be distributed as part of this report for IOU program managers to use as an educational and marketing tool with CA ratepayers. Shown in Appendix B: Propane Fact Sheet, the fact sheet outlines eligibility criteria for equipment upgrades, such as age, size, and current refrigerant type, while emphasizing why propane systems are a better alternative. It highlights key benefits (i.e., lower energy bills, reduced refrigerant costs, compliance with new regulations, and improved sustainability) and explains the drawbacks of older refrigerants -- rising costs and complex reporting requirements -- to show the efficiency, reliability, and environmental advantages of propane systems. The educational tool aims to empower end users, operators, and technicians to make informed decisions that align with cost savings, operational improvements, and climate-friendly practices. Finally, the fact sheet includes a clear call to action, encouraging people to contact their local electric utility provider to learn more and determine eligibility for financial incentives that make the transition even more cost-effective.

Recommendations

Expand Metering and Pilot Demonstrations

Conduct additional metering of packaged propane systems from multiple manufacturers to validate performance across diverse applications. Include both medium- and low-temperature units, from diverse manufacturers, in different climate zones, and building types. Gather additional baseline data on refrigerant types, system charge sizes, retrofit and equipment costs, and installation practices to support avoided cost calculations and TSB modeling.

Create TRM Measure Package

Define baseline and efficient case parameters, develop deemed savings algorithms (kWh/hp), and quantify non-energy GHG savings. Validate through metered data and modeling for prescriptive and custom pathways.

Establish Qualified Products List (QPL)

Develop and maintain a QPL for UL-listed packaged propane systems. Include system specifications and performance data to streamline program eligibility. In conjunction with this, a US inventory database would also be helpful to help customers and contractors identify certified units that could be implemented in their projects. Additionally, engage with manufacturers to pursue UL certification for wall-mounted units to address retrofit space constraints.

Launch Pilot Incentive Programs

Design and implement targeted incentive programs for small and medium businesses, Hard-to-Reach (HTR), and Disadvantaged Communities (DAC). Include enhanced incentives and contractor bonuses for natural refrigerant adoption. As part of this effort, develop accessible educational materials—including fact sheets, videos, and case studies—to raise awareness among small businesses and DAC communities. Ensure materials are culturally relevant and available in multiple languages to maximize reach and engagement. Additionally, work with CA IOU program managers to gather feedback on proposed program design and lessons learned. Continue developing program framework to integrate packaged propane systems into existing IOU Portfolios, as an amendment to existing HECU programs or as new measures.

Build Case Studies and Outreach Campaigns

Document successful installations and energy savings to promote technology adoption and overcome misconceptions about propane safety. Develop training resources and facilitate hands-on demonstrations to build contractor expertise in installing and servicing propane refrigeration systems. Leverage case studies to address supply chain barriers and encourage stocking of packaged propane systems by distributors and OEMs to reduce lead times and improve availability.

Advocate for Updates to Safety Standards

Collaborate with industry and regulatory bodies to accelerate updates on UL 60335-2-89, ASHRAE 15, and EPA SNAP standards to allow higher propane charge limits. Engage with Authorities Having Jurisdiction, building and code officials to increase familiarity with propane systems and facilitate permitting.

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Appendix A: Refrigerant Comparison and Potential Application in Small Food Retail and Restaurants

Low GWP System Type (ASHRAE Class.)	ASHRAE Safety Class.	Applications	Advantages	Disadvantages	Energy Considerations (Compared to high GWP systems)	Potential for application in Small Food Retail or Restaurants
Ammonia (R-717)	B2L	Industrial	• Low GWP: 0 • High efficiency	• High safety and environmental compliance burden. Generally, not used in residential areas • High retrofit cost	More efficient	No
CO_2 or Hybrid CO_2 Design (R-744)[18]	A1	Rare. A few grocery stores	• Low GWP (varies depending on 2nd refrigerant) • Low toxicity • Low reporting effort	• High retrofit cost • Complex system design and limited operational knowledge from market actors. • May have lower performance in warmer climates than a cascade CO_2 Systems • Untested maintenance	Typically, higher energy usage, can add heat recovery for hot water loads	Yes

Low GWP System Type (ASHRAE Class.)	ASHRAE Safety Class.	Applications	Advantages	Disadvantages	Energy Considerations (Compared to high GWP systems)	Potential for application in Small Food Retail or Restaurants
Micro-distributed (self-contained) propane (R-290) systems	A3	Rare but used in some grocery stores. Has potential for small commercial facilities	• Low GWP: 3, and uses less refrigerant • Low toxicity	• High retrofit cost • Control and leak detection systems are more distributed. • Added space heating load (increased energy use) if air cooled • Added cost if water cooled (extra fluid cooler, leak potential) • Flammable • Low market knowledge • Noise	Unknown	Yes
Low GWP HFO Systems (new or retrofit): R-454C or R-454A	A2L	Commercial refrigeration	• Low GWP: 148 (R-454C), 240 (R-454A) • Moderate Cost	• Flammable, so building codes restrict use	Unknown	No, due to restricted availability and flammability concerns
Moderate-GWP: R-513A	A1	Commercial refrigeration (but not freezers)	• Moderate GWP: 631, Comply with upcoming GWP regulations	• Environmental concerns over toxicity in water supply	Unknown	No, mostly used as R-134A alternative

Low GWP System Type (ASHRAE Class.)	ASHRAE Safety Class.	Applications	Advantages	Disadvantages	Energy Considerations (Compared to high GWP systems)	Potential for application in Small Food Retail or Restaurants
			• Moderate retrofit cost			
Moderate-GWP: R-448A and R-449A	A1	Commercial refrigeration. Many large grocery stores shifting to these refrigerants to meet CARB regulations	• Moderate retrofit cost. • Low toxicity so allowed by building code	• Moderate to High GWP: 1387 (R-448A), 1397 (R-449A) although meet upcoming regulations (GWP <1400) • Higher ongoing operational costs due to legacy components	Unknown	Yes
R-22	A1	Commercial refrigeration	• Near zero retrofit cost (drop-in)	• Ozone depleting substance, so phased out of most systems by U.S. EPA regulations • High GWP: 1810	N/A	No, due to phase out of ozone depleting substances
R-404A	A1	Commercial refrigeration	• Near zero retrofit cost (drop-in)	• High GWP: 3922	Standard practice	Generally, no, due to shift towards low GWP refrigerants, although balance with

Low GWP System Type (ASHRAE Class.)	ASHRAE Safety Class.	Applications	Advantages	Disadvantages	Energy Considerations (Compared to high GWP systems)	Potential for application in Small Food Retail or Restaurants
						efficiency and cost

(TRC 2021)

Appendix B: Propane Fact Sheet

WALK-IN COOLERS & FREEZERS

COST MORE THAN IT SHOULD?

GET PAID TO UPGRADE

Up to 50% cost savings, 90% refrigerant savings

If you have:

- walk-in smaller than 12 ft x 12 ft
- equipment over 10 years old
- uses refrigerants: R-22, R-404A, R134a, R-507A, R-507C, R407C

Old Refrigerants = Big Problems

- new laws, old refrigerants could cost 10x more
- may need to file complex reports just to keep them

New Refrigerants = Big Benefits

- lower electric bills
- lower refrigerant cost
- more space in your walk-in
- less heat in your kitchen
- easier maintenance

NATURAL REFRIGERANTS = LOWER GWP = FEWER COMPLIANCE REQUIREMENTS

Replace your old compressor condensing unit with a **packaged propane refrigeration system.**

Contact your local electric utility provider for more details and to see if you qualify for **financial incentives**