I'll Have What She's Having – US Adoption of European R290 Monobloc Air-to-Water Heat Pumps

Aaron Tam, Mazen Daher, Edwin Hornquist, EPRI
Randall Higa, Southern California Edison

ABSTRACT

California's decarbonization and energy efficiency goals, driven by Title 24 and building performance standards, are accelerating the shift toward all-electric technologies for space and water heating. However, widespread electrification poses challenges to grid operations, especially due to reliance on inefficient electric resistance heating. R-290 (propane) monobloc air-to-water heat pumps offer a promising pathway, combining high efficiency with minimal environmental impact associated with its ultra-low global warming potential (GWP) of 3 relative to other refrigerants currently in the market. These systems isolate refrigerant outdoors to reduce leakage risks and simplify installation and are increasingly adopted in Europe and Asia. In the U.S., a simple transition may involve the use of monobloc heat pumps that connect to ducted fan coils due to the prevalence of centrally ducted systems. However, their adoption in the U.S. faces severe regulatory hurdles, largely stemming from R-290's flammability. This risk may be safely managed with the use of monobloc heat pumps, but additional technical and market barriers must also be addressed. This paper aims to establish a foundation for the safe and scalable deployment of R-290 heat pumps in California. Key considerations include performance in California climate zones, workforce readiness, and system controls. International markets can inform safety benchmarks and installation best practices. This work supports the evaluation of R-290 heat pump technologies in California and beyond, providing data to inform future codes and standards, and utility programs.

Introduction

California has some of the most ambitious decarbonization goals nationwide (CARB, 2022). These include achieving carbon neutrality by 2045, partially through decarbonizing the building sector. A substantial barrier to achieving these goals is that most space and water heating services to buildings today are provided by combustion of fossil fuels, primarily natural gas. This is reflected in the "Residential & Commercial" category in CARB's GHG emissions inventory, amounting to ~10.6% of total emissions (CARB, 2024). Electric heat pumps are envisioned to play a large role in both statewide and broader decarbonization goals, as substantiated by a wealth of research (Hopkins et al, 2018 and Brockway and Delforge, 2018). They can operate without the need of onsite combustion of fuels, and they can achieve high efficiencies compared to electric resistance heating, i.e. strip heat, under most operating conditions. Heat pumps are often designed with some form of backup heating due to their reduced capacities at low temperatures, either due to insufficient capacity to meet the load, or as a preventive measure by contractors to avoid customer callbacks. In California, this can lead to widespread deployment of resistance heating with the state's goal to deploy 6 million heat pumps by 2030 (CEC, 2023). The use of inefficient strip heat - both as a primary heating solution in older buildings, and as a backup solution for heat pumps in newer construction - will be a notable driver of increased peak loads, estimated to be 70 GW by 2045.

While heat pump technology can efficiently electrify space and water heating end-uses, the leakage of conventional high global warming potential (GWP) refrigerants amounts to an additional 5.7% of total emissions and poses a significant challenge in meeting the state's energy goals. In fact, CARB's GHG emission inventory shows High GWP sources as one of the only categories with increasing GHG emissions in recent years (CARB, 2024). As a result, researchers and policymakers have raised concerns about the GWP of the refrigerants commonly used in heat pumps. GWP is a metric of the contribution to global warming resulting from the emission of one unit mass of the refrigerant relative to one unit of mass of CO2, which has a GWP of 1. Conventional refrigerants in space conditioning such as R-454B and R-32 are potent greenhouse gases with GWP of 466 and 675 respectively. It should be noted these values are from IPCC Fourth Assessment Report (AR4), which is used for HFC regulations by EPA and CARB. HFC refrigerants can also be expensive to manufacture and are subject to regulations based on their environmental impact. This presents an avenue for deploying energy efficiency technologies in the effort to reach emission reduction goals, as well as a potential area for decarbonization through electrification.

The transition to lower GWP refrigerants is already underway: CARB standards have limited the GWP of refrigerants used in new stationary heat pumps to 750 beginning in 2025, and the American Innovation Act (AIM) of 2020 has resulted in Federal level phasedown of high GWP refrigerants by 60% starting 2024 (SNAP, 2018 and EPA, 2023). The AIM act has a more aggressive phasedown of 85% by 2036 that is putting increasing pressure on shifting toward refrigerants with near 0 GWP. As a result, many manufacturers have already reacted and road mapped new products with near-zero GWP refrigerants such as hydrofluoroolefins (HFO). This concern has also resulted in the inclusion of refrigerant-specific steps in the assessment of building performance according to Title 24 and utility energy efficiency portfolios. Title 24's methodology for assessing source energy and marginal greenhouse gas emissions has included some computations to account for refrigerant leakage from different refrigeration components for the past few code cycles (CEC, 2022). Similarly, the avoided cost calculator used to assess the performance of energy efficiency measures includes a module to assess the avoided costs from deploying lower GWP refrigerants (CPUC, 2021).

However, GWP is only one aspect of refrigerants. There are rising concerns over additional environmental impacts, specifically the relationship between synthetic HFO refrigerants and per- and polyfluoroalkyl substances (PFAS). PFAS are known forever chemicals and removing them from the environment poses a significant challenge. Many low GWP HFO refrigerants such as R-1234yf are considered PFAS under the more stringent definition used by the European Union (EU), CA, and several other states: a class of fluorinated organic chemicals containing at least one fully fluorinated carbon atom. However, the U.S. EPA does not currently use this definition. Many EU countries are already moving towards banning such chemicals from being used in appliances. In the U.S., several states have introduced legislature on a similar path, most notably Maine (Maine, 2024), Minnesota (Minnesota Pollution Control Agency, 2023). While the proposed bans are still years away, it is important that current resources are dedicated to objective research of systems that are efficient, future-proof, and environmentally friendly.

This creates a unique challenge, since refrigerants that are low in GWP and not related with PFAS tend to be natural refrigerants that are flammable (R-290 or R-600a) or toxic (R-717). These working fluids are unsuited for circulation within the building in direct air-to-air systems, which is the predominant system architecture in the U.S. Monobloc or indirect packaged systems with secondary loops, on the other hand, may provide a safe approach to deploy these refrigerants (Issa et al, 2025). Monobloc-type/packaged heat pumps contain all the refrigerant components within a single outdoor unit, are either semi-hermetic or hermetically sealed, and transfer heat through a hydronic loop. **Error! Reference source not found.** shows a simple schematic of one such system. This approach isolates the refrigerant outdoors thus reducing the refrigerant charge (no refrigerant lines nor indoor heat exchanger). This is simpler to install because field technicians do not have to manage refrigerant piping. Leak detectors are often installed indoors to provide additional safety in the improbable event of refrigerant entering the indoor space. Several complementary research efforts are underway to advance the adoption of these technologies. CA's statewide emerging technology program, CalNEXT, has conducted a market study of propane air-to-water heat pumps, which identified a need for product evaluation and demonstration (CalNEXT, 2023).

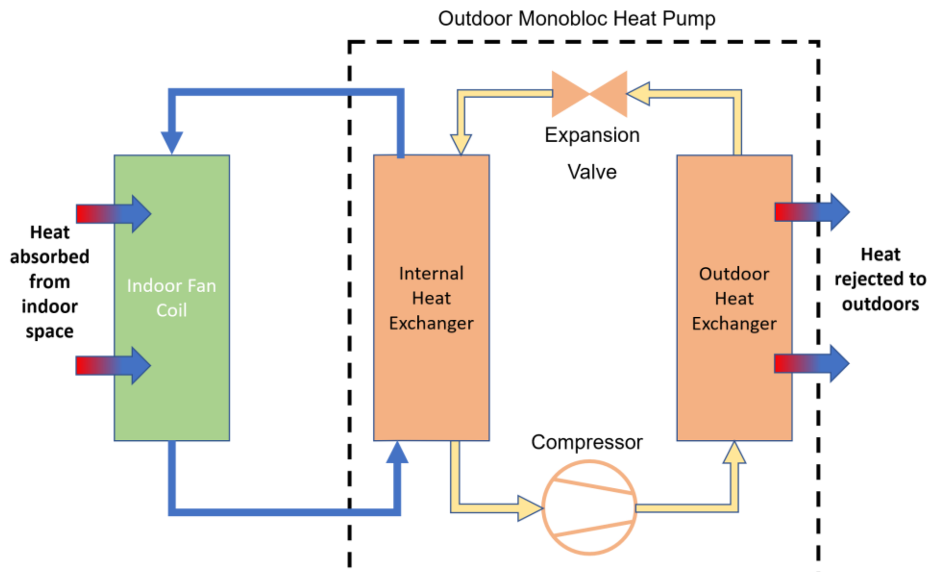

Figure 1. Simplified schematic of a monobloc heat pump (dotted box) with secondary loop (blue line) to indoors. *Source*: EPRI.

The use of secondary distribution systems can have a penalty on energy efficiency due to the additional heat exchange, but this penalty may be minimized by using advanced heat exchangers. Research has also been conducted with various secondary fluids with attractive thermodynamic properties, such as carbon dioxide distribution loops where phase change can provide superior cooling performance. The secondary loop architecture can also allow simple integration thermal energy storage, providing additional demand response capabilities. This paper investigates the potential benefits, energy and demand impact, and regulatory barriers associated with deploying R-290 refrigerant in California buildings.

Propane Refrigerant and Regulatory Landscape

Propane (R-290) is an ultra-low GWP natural refrigerant (GWP=3) with excellent thermodynamic properties, but its use in the U.S. has been limited due to flammability concerns. As a result of global refrigerant GWP phase down, the interest in using R-290 in heat pump applications has surged in recent years. In the U.S., R-290 has seen significant adoption in small self-contained refrigeration systems where the refrigerant charge is minimal. A study conducted by DNV showed that for a simulated residential heat pump, replacing R-32 with R-290 yielded system benefits valued at $259 per ton of heating capacity. The study highlighted the finding that proper end-of-life refrigerant disposal was critical for maximizing system benefit (Hoover et al, 2024).

The regulatory landscape for R-290 in the U.S. is defined by industry standards in two main categories: product safety standard and application safety standard. UL 60335-2-40 is a product safety standard which lists several requirements applicable to various electrical appliances, including air conditioners and heat pumps (UL, 2022). In particular, the standard outlines requirements for protection against hazards of various types (fire, electrical, mechanical), refrigerant leak detection, ignition source mitigation, and charge limits. All heat pumps installed in the U.S. must comply with this standard per mechanical codes, making it a de facto federal standard. With respect to propane, this standard sets stringent limits for refrigerant charge, impeding its adoption in the U.S. market. For propane (R-290), UL 60335-2-40 sets a charge limit of 114 grams. This limit is based on propane's lower flammability limit and its classification. The computation specific to propane and the charge limit methodology are considered conservative compared to other standards (Spielman et al, 2024). UL 60335-2-89, which is more focused on commercial refrigeration, allows a slightly higher charge of 300g - 500g.

ASHRAE Standard 15 is an application safety standard pertinent to the use of propane as a refrigerant in HVAC systems (ASHRAE, 2022). Titled the "Safety Standard for Refrigeration Systems", this comprehensive standard outlines requirements for the safe design and operation of refrigeration systems. This standard follows ASHRAE Standard 34's classification of propane as an A3 flammable refrigerant and imposes strict limitations on the use of such refrigerants. The standard states that Group A3 and B3 refrigerants may not be used unless approved by the Authority Having Jurisdiction (AHJ). An addendum reviewed in 2023 would allow for a higher charge limit for so-called low-probability systems (i.e. systems where leaks would be unlikely in occupied spaces and more likely to be vented outdoors) but has so far not been adopted.

In addition to UL and ASHRAE, local building codes and AHJ can also limit the use of R-290. For example, R-290 is strictly limited to applications in refrigerators in California building codes. Building codes, fire codes, and mechanical codes must all be addressed to enable widespread adoption of this refrigerant. It should be noted that codes are typically updated every 3 years, resulting in a prolonged period before all regulations are in place to adopt R-290. In addition, EPA SNAP must also approve the use of R-290 in space conditioning end uses. Figure 2 outlines the steps that are required for R-290 to be adopted across the U.S.

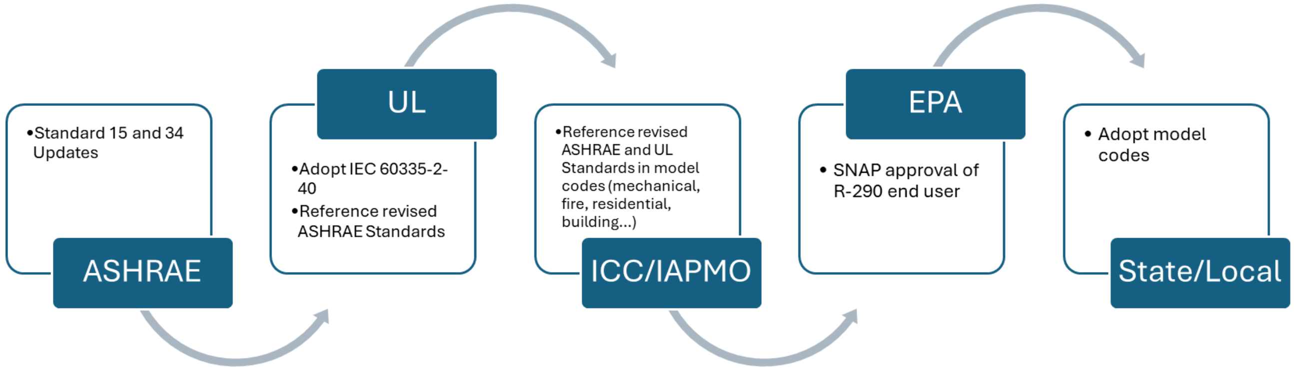

Figure 2. High level overview of regulatory process to adopt R-290 in space conditioning end-uses. *Source*: EPRI.

Together, these stringent standards create an environment in which it is challenging for manufacturers to develop propane-based heat pump technologies that would be viable for larger applications in the United States, despite successful implementation in foreign markets. R-290 advancement efforts have thus centered around 2 major approaches: 1) develop systems within the 114g limit, 2) conduct risk assessments to appeal regulatory bodies to increase the charge limit. Low charge system development has seen developments of prototype HPWHs where the 114g limit may still have adequate capacity (Elater, A et al, 2025). On the regulatory side, CARB and AHRI have begun risk assessment studies of monobloc A3 systems. Research questions surrounding the risk of monoblocs may include:

- Can refrigerant charge within monoblocs be ignited due to building fires or wildfires?
- Can monoblocs be installed in close proximity without increasing overall risks? How does this impact their application in multifamily buildings or densely populated areas?
- What are the safe minimum distances for monoblocs from building openings such as air intakes, windows, and doors?
- Can A2L mitigation strategies be effective for A3 refrigerants? Do they require higher response times due to A3's higher flammability and lower ignition requirements?

Proposed amendments to ASHRAE 15, along with IEC standard language that may come to be emulated in the US, suggest that there is potential for low-probability systems to be favored by future changes in industry norms. Given decarbonization targets and building performance standards which encourage increased adoption of heat pumps, and the increased penetration of air conditioning in California, there is ample opportunity for the penetration of propane heat pumps in the state.

Monobloc Applications in California

As R-290 is considered in CA, their deployment through indirect monobloc systems is significantly more likely than direct systems. Direct air-to-air systems require significantly higher charge due to the line set volumes and higher risk of leaking refrigerant indoors. Indoor leakage is particularly concerning for R-290 since it is denser than air, so any leaked refrigerant can collect and reach a hazardous mixture within the indoor space. In addition, direct systems are charged during installation, meaning the installation workforce will require training before any products can be safely installed.

Monobloc heat pumps can alleviate some of the concerns outlined above, particularly in residential applications. They have much lower charge amounts since the refrigerant line sets do not travel indoors, and they can potentially be factory charged and sealed so installers may not require additional training. However, monoblocs also have different design considerations and controls that must be well understood for product adoption. One key design factor is the volume of water contained in the secondary loop. This is particularly important for reverse cycle defrost, which can reduce the reliance on strip heat installations. Unlike air-to-air split systems, monobloc heat pumps will not be able to directly draw heat from the indoor air to melt frost formations on the outdoor coil. Instead, the heat pump must draw heat from the secondary loop during this defrost cycle. Therefore, manufacturers typically specify a minimum water volume for the secondary loop to ensure the secondary loop stays within a reasonable temperature band so the heat pump can operate properly and defrost effectively.

One advantage of monobloc systems is the possibility to integrate domestic water heating, i.e. combi systems. This approach simplifies the electrification of both space conditioning and water heating. The secondary loop architecture also enable integration of thermal energy storage compared to direct split systems. This is an attractive solution for utility companies to reduce the peak electric demands, which is often driven by peak building cooling or heating demand, avoiding the construction of additional capital-intensive generation and transmission. The overall operating costs can be optimized by leveraging TOU rates, while the upfront capital costs can be offset by utility financial incentives (Tam et al, 2019). Additionally, monobloc systems can be easily zoned within the building, which is an attractive option for multistory homes.

The advantages of monoblocs go beyond residential applications. There is the potential for modular installations in larger multifamily and commercial buildings, where multiple monoblocs can be utilized to condition a single secondary loop. This approach minimizes the refrigerant charge per circuit and reduces the amount of refrigerant that can be leaked per accident. Therefore, a higher total system capacity can be reached without increasing the risk associated with refrigerant leakage. Table 1 shows a comparison of 3 system designs based on manufacturer data. System 1 is a modular application of 5 monoblocs, System 2 is a similar modular use of larger air-to-water heat pumps, and System 3 is a single large air-to-water heat pump. The total capacity of these select systems are in the 20-22 ton range at rating conditions. Each individual unit in System 1 and System 2 contains 1 compressor and the larger unit in System 3 uses 2 compressors, and the total number of compressors is shown in Table 1. At this similar capacity range, the singular unit in System 3 had the highest refrigerant charge at ~22 lbs due to the larger heat exchangers and piping required for 2 compressors. On the other hand, System 1 with the monoblocs had the lowest charge at 14 lbs. When normalized against the rated capacity, System 1 still had the lowest charge at 0.7 lb/ton. This charge minimization is a very attractive feature of monoblocs from a safety perspective. For early stage field demonstrations, this can be an easier path toward AHJ approval of prototypes or non-UL listed European products.

Table 1 Comparison of System Charge in 3 R-290 Heat Pump Systems.

	System 1	System 2	System 3

Configuration	5 monoblocs @ 4 tons each	2 air-to-water heat pumps @ 11 tons each	1 air-to-water heat pump @ 22 tons
# of compressors	5	2	2
Total refrigerant charge	14 lb	18 lb	22 lb
Charge/ton	0.7 lb	0.82 lb	1 lb

It must be noted that modular applications can introduce additional complex controls challenges. Since multiple units are conditioning the same secondary loop, it is critical that secondary fluid flow rate be balanced between the operating units. If the flow rate drops below a threshold, the monobloc heat pump may default into FAULT modes, and compromises the system performance. A similar challenge has been experienced by deployments of centralized HPWHs (Daher et al, 2024). The more complicated controls can increase the overall cost of the system and increase likelihood of callbacks for contractors. When coupled with the additional hardware costs of the secondary loop, this may be yet another adoption barrier for monobloc heat pumps.

While the modular installation may be a useful feature of monoblocs, commercial buildings are predominantly conditioned with rooftop units (RTUs). This is a very challenging market segment for R-290 refrigerant, as it is a direct air-to-air end use. There is opportunities to deploy monoblocs in a unique fashion, where the monobloc and secondary loop hardware is mounted onto a singular packaged skid to mimic typical RTUs. Figure 3 shows a simplified mockup of one such design. While this opens up a path for wider adoption across building types, the efficiency penalties compared to direct air-to-air systems should be considered. Premium features (e.g. variable capacity compressors and microchannel heat exchangers) may be required to achieve comparable performance.

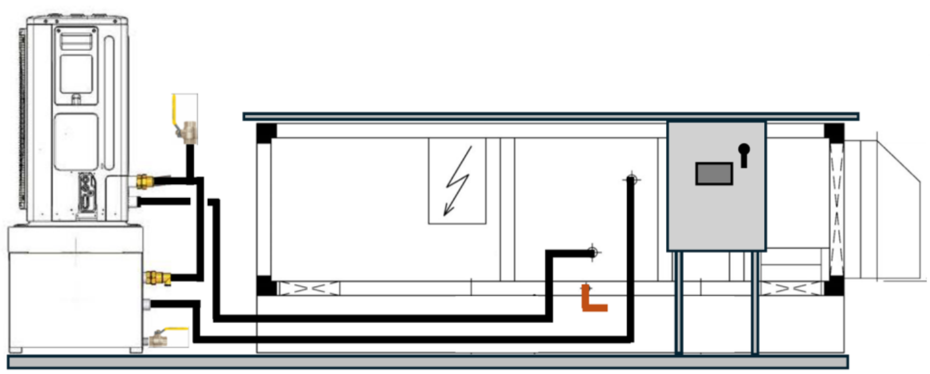

Figure 3. Rooftop package prototype utilizing monobloc heat pumps. *Source*: EPRI.

To assess the potential applicability of monoblocs to the California building stock, we consider both new construction of residential and commercial buildings, as well as the existing building stock.

California has added an average of 1,614 commercial buildings each year as of 2020. On the residential side, California issued roughly 60,000 permits for single family construction (including major renovation) and 40,000 permits for multifamily construction (including major renovation) in 2024 (California Department of Finance, 2026). These buildings and dwellings also offer an important opportunity for deploying new natural refrigerant-based systems, given that they would be unburdened by the typical challenges that accompany retrofits (such as significant upgrades triggering code reviews, asbestos abatement, working around preexisting infrastructure).

The Energy Information Administration's Residential Energy Consumption Survey (RECS) provides useful information regarding the typical age of HVAC units in California (U.S. EIA, 2020). According to the survey, 23% of homes in the Pacific region have HVAC units older than 15 years old, approaching existing Estimated Useful Life numbers used by the California Public Utilities Commission (DNV, 2023). Similarly, the most recent iteration of the California Commercial Saturation Survey (CSS) can be used to assess the potential commercial retrofit market that propane heat pumps may be able to penetrate (Itron, 2014). According to the survey, rooftop units constitute 59 percent of commercial HVAC units in California. Furthermore, at least 23% of HVAC units currently operating in commercial buildings in California were within the typically adopted EUL (Estimated Useful Life) range of 15-30 years. Another study, though older and focused on the Pacific Northwest rather than California, showed a comparable result, with 16% of rooftop units being at least 20 years old (WCEC, 2013).

While these studies are somewhat dated, assuming constant equipment turnover rates would allow us to use this data as a starting point for estimating the proportion of the building stock to which this work may be relevant. Moreover, these studies are corroborated by more recent work. For instance, a 2025 study by CalMTA (CalMTA, 2025) found that RTUs served 53% of the commercial floor space in California, with significant variations among building types. According to their analysis of Department of Energy data, RTUs conditioned over 90% of the restaurant and strip mall floor space in California, compared to a negligible portion of the large office and large hotel floor space.

For the existing building stock, Table 2 shows the typical HVAC configuration by building type as summarized by the Department of Energy and applied in the development of their EnergyPlus building types (NREL, 2008). These building models are meant to be representative of typical commercial buildings found in the United States. Therefore, the configurations used in these models can be indicative of prevailing HVAC designs by building type. Table 2 serves as a useful complement to the 2025 data presented by CalMTA for the California building stock (CalMTA,2025).

Table 2 HVAC configurations applicable to each commercial building prototype. Source: U.S. Department of Energy

Building Type	**HVAC Type**
Primary School	Packaged

Secondary School	Hydronic
Retail	Packaged
Warehouse	Packaged
Large Office	Hydronic
Small Office	Packaged
Medium Office	Packaged
Supermarket	Packaged
Restaurant	Packaged
Hospital	Hydronic
Small Hotel	Packaged
Large Hotel	Hydronic

The taxonomy displayed in Table 2 indicates the typical HVAC types for commercial buildings from DOE's commercial building prototypes. Based on the DOE's taxonomy, most buildings other than taller/larger buildings such as hospitals and office buildings would tend towards using packaged rooftop systems, which would be compatible with the monobloc systems. Taller buildings would require more modular designs to be retrofitted with air to water monoblocs.

In summary, new construction commercial and residential buildings would represent the most accessible opportunity for propane monobloc deployments. For single family residential retrofits, a monobloc replacement would require water lines to be run to a new air handling system. Commercial buildings with central hydronic plants would require modular retrofit designs as previously described. RTUs would require a skid system similar to the design shown in figure 3. Finally, buildings with variable refrigerant flow or split systems would require 1 to 1 swap with monoblocs to serve each zone.

International Market and Best Practices

Many HVAC manufacturers currently promote and offer propane heat pump products internationally. In Europe, R-290 monoblocs are particularly attractive because of refrigerant GWP regulations and mandates, the prevalent use of hydronic heating systems, and less stringent charge limits on R-290. As a result, R-290 heat pump adoption has increased exponentially in Europe (CalNext, 2023). Data shows that 38% of new residential heat pumps certified in 2024 in Europe use R-290, up from 3% in 2021 (Natural Refrigerants, 2026).

In contrast to the UL standard, IEC 60335-2-40 has a more permissive stance regarding propane (IEC, 2022). This standard is similar in scope to UL 60355-2-40, but has broader adoption worldwide, with more than fifty countries participating in the IEC system. There are two main aspects where IEC 60335-2-40 differs significantly from UL 60335-2-40 in its treatment of propane (BPA, 2024):

- Higher overall refrigerant charge limits: While the UL standard prescribes a conservative charge limit of 114 grams, the IEC standard allows for up to 4,940 grams of refrigerant for certain types of systems.

- Greater flexibility depending on design: The UL standard's limit of 114 grams applies irrespective of system configuration (e.g. indoor, outdoor), whereas the IEC standard sets different refrigerant charge limits depending on configuration. For example, a charge of up to 988 grams is allowed for monobloc heat pumps and split systems, and a charge of up to 4,940 grams is allowed for outdoor air-to-water heat pumps. Note that these allowances are predicated on the implementation of more stringent safety requirements.

Systems with higher refrigerant charge will refer to EN 378, which provides formulas for calculating allowable charge limits instead of imposing fixed charge amounts. These calculations account for system type (e.g. direct vs indirect), location, access, indoor room size, and mitigation measures. These standards refer to leakage prevention as the primary means for safety considerations. Charge optimization is also highly encouraged because leakages from multiple circuits is unlikely.

There are some best practices on deploying R-290 systems that can be gathered from international procedures and prototype system deployments in the U.S. These can be separated into passive and active safety measures:

Passive Measures:

Raising the system on a stand with no bottom enclosure and oversizing side grills. This is similar to installing cold climate heat pumps on an elevated stand. The bottomless enclosure allows propane, which is denser than air, to escape through the bottom without collection at a single location under the unit. The oversized grills allows for higher airflow to evacuate any leaked refrigerant.

Restricting access to the system, such as fencing or security enclosures, can further reduce tampering that can lead to accidental leakages. Clear labels and signs on hazardous materials can be used to indicate there is flammable pressurized gas within the system. The system enclosure can include locks to prevent any layperson from accessing the system.

Active Measures:

Dedicated ventilation systems can be used for larger systems. This approach involves refrigerant detectors inside the system enclosure. Once refrigerant exceeds a threshold, all electrical components are shut off, and a ventilation system is used to quickly ventilate the mixture. Pressure relief valves with leak detectors can be used to prevent hazardous pressure build up. Leak detectors can also be used to immediately shut off any circuits once a refrigerant threshold is detected. Leak detectors can be tied to fire alarm systems and can be installed on any nearby air intakes. Some larger systems also tie pressure relief valves to flare devices to safely incinerate all refrigerant once a leak is detected.

Future Work and Conclusion

The adoption of R-290 monobloc heat pumps is rapidly accelerating in Europe as the industry shifts towards natural refrigerants, however, the adoption in the U.S. is hindered by regulatory barriers. While national efforts on updating codes and standards are underway, several key research areas can provide complementary understanding of these systems.

There is a need to benchmark the performance of this class of products. While AHR 550/590 provides guidance on evaluation procedures, there are currently no U.S. minimum required efficiency standards for air-to-water product types. This makes it difficult to assess the expected incremental performance expected from R290 system relative to current federal baseline focused on forced air products. Being able to compare monoblocs with air-to-air split systems using equivalent metrics (e.g. SEER2 or HSPF2) will also help leverage existing incentive measures. This also helps inform future code and standards, for example, Title 24 embodies the California building standard and sets the minimum requirement for building performance including HVAC for new construction or remodels. Performance mapping may be used for a broader, statewide assessment of avoided costs from the implementation of this technology in compatible buildings.

The efficiency penalty of integrating a secondary loop can also be minimized. This may involve the use of efficient secondary fluids (e.g. CO_2), improved heat exchanger performance (e.g. microchannel heat exchangers). The simplicity to include thermal storage through the secondary loop is highly beneficial, as load flexibility is a key pillar of sustainable decarbonization. Microchannel heat exchangers may also help reduce the overall system charge, lowering the risk in the event of refrigerant leakages. The addition of odorants to R-290 can also improve system safety, and long-term effectiveness and overall impact on compressors, lubricant oils, and system efficiency need to be well understood.

Workforce development will also need to be addressed as HVAC installers will be required to have the necessary skills to design, install, and operate hydronic systems. The transition to hydronic HVAC distribution in residential applications was proven to be successful with the introduction of forced-air gas combi systems over 30 years ago. Air-to-water equipment can be made as "plug-and-play" to simplify and expedite installations with exploration into the use of quick-connect fittings, piping configuration standardization, pre-insulated flexible piping, etc. The potential for factory charged monoblocs can further simplify the installation process, if the transportation of charged A3 systems are allowed. Regulations around warehousing of A3 systems may also need to be updated, to allow storage of necessary inventory.

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