Overcoming Barriers to Natural Refrigerants: "Why can I buy a propane boiler, but not a propane heat pump?"

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ABSTRACT

Hydrocarbon refrigerants such as R290 (propane) are very attractive refrigerants from a thermodynamic perspective for air-to-water heat pumps. They can create very hot water (>160F), can operate at very low ambient temperatures (<0F), can operate with very high COP (>3), and have an extremely low Global Warming Potential (GWP): a 20-year GWP of 0.072 and a 100-year GWP of 0.02. Additionally, propane can operate in a similar pressure range as high GWP refrigerants, making it compatible with existing compressor technology.

Although propane is abundant and naturally occurring, giving it a significant advantage over new low GWP HFOs that present potentially dangerous environmental risks, its flammability disqualifies it from being used as a refrigerant under current US safety standards. Ironically, in the US, you can sell a propane boiler that burns more than three times as much propane in a minute as is allowed to be sold in a heat pump. However, heat pumps containing hydrocarbon refrigerants have passed safety standards and are available in Europe, Asia, and most of the world. The adoption of hydrocarbon refrigerants can lead to significant economic benefits and improve the manufacturing of heat pump equipment, resulting in lower costs for consumers. This presentation and discussion will investigate the advantages of hydrocarbon refrigerants, the challenges to their adoption, and how to overcome them.

Introduction

This report outlines the need for and steps to remove regulatory barriers around natural refrigerants, using propane refrigerant (R290) as the primary example. The American Society of Heating Refrigeration and Air-Conditioning Engineers (ASHRAE) and Federal agencies, such as the Department of Energy (DOE), can play a positive role in advancing energy efficiency by expediting the regulatory reform necessary for the use of natural refrigerants. This, in turn, will enable advancements in heat pump technology, drive economic growth in the manufacturing sector, and reduce consumer costs.

Three primary natural refrigerants are appropriate for use in the HVAC&R sector – ammonia, carbon dioxide, and hydrocarbons. Ammonia is toxic and can only be used in specific applications. Unlike ammonia and carbon dioxide, hydrocarbons are a class that includes multiple refrigerants – including isobutane (R600a) and propane (R290). Hydrocarbon refrigerants are used in heat pumps worldwide—in Europe, Asia, and Australia— but allowable charge quantities prevent their practical use and manufacturing within the United States. The regulatory barriers to using hydrocarbon refrigerants in heat pumps in the US are creating substantial costs to the US economy, impeding the ability of the US to decarbonize, restricting the US manufacturing sector, and forcing the use of another generation of synthetic refrigerants (hydrofluoro-olefins (HFOs)), which scientific studies indicate have the potential to contaminate drinking water (Behringer, Heydel, and Gschrey 2021; Bernton and Villa, 2020).

Hydrocarbons such as propane are widely used in the US for HVAC and cooking appliances. The volumes of fossil gases used for these purposes in homes and buildings are much larger than those required for self-contained propane refrigerant systems. However, because natural hydrocarbon refrigerants are flammable, they require safety regulations to protect installers, technicians, and consumers. Unfortunately, these safety requirements are not adequately defined. In the US, UL 60335-2-40 diverges from the safety standard used in other parts of the world - the International Electrotechnical Commission (IEC) standard – and does not prescribe pathways for the safe use of hydrocarbon refrigerants at charge limits that allow for the development of advanced heat pump technology. UL 60335-2-40 is incomplete because it does not distinguish between charge limits for indoor and outdoor installations or provide requirements for safety design features. While significant resources have been allocated to define pathways for using new HFO synthetic refrigerants in UL 60335-2-40, pathways for natural refrigerants have been overlooked. The safety requirements used in Europe, and outlined in IEC 60335-2-40 and EN 378, have been omitted from UL 60335-2-40. The DOE can fund a National Laboratory to analyze the safety requirements used worldwide and encourage UL to approve their use so US manufacturers can compete on the world stage using the best refrigerants.

However, the process of UL approval may be lengthy, and the Federal and State government are encouraged to look at other pathways to allow for key natural refrigerants use prior to UL approval. This can be done using either the Defense Production Act or an exception that allows European safety certifications to be used in place of UL for certain products that use natural refrigerants.

Some readers may wonder why CO_2 (R744), a non-flammable natural refrigerant, is not the recommended solution. CO2 excels in some applications, such as domestic water heating. However, it operates at extremely high pressures, requiring specialized components that are difficult and expensive for US manufacturers to source. Additionally, CO2 is not typically the best option for space heating applications due to the transcritical nature of the CO2 refrigeration cycle, which causes its efficiency to drop significantly with high incoming water temperatures (above ~90°F).

Although the arguments apply to all natural hydrocarbon refrigerants, propane (R290) is used as the primary example in this paper because it is a common, naturally occurring compound with excellent thermodynamic properties for heat pumps. The following section describes why developing regulations for the use of R290 in HVAC equipment is a critical policy change for the US HVAC&R market to thrive in the 21st century. The subsequent section (Code Barriers to Hydrocarbon Refrigerants and Pathways to Acceptance) describes pathways for policy change.

Natural Refrigerants Are Needed for American Manufacturing to Succeed in a 21st Century Green Economy

Propane is a common fuel, typically derived from petroleum, but production from renewable sources is possible (Rosado-Reyes and Francisco 2007; "Renewable Propane Synopsis" 2021). In addition to its uses as a fuel, its excellent thermodynamic properties make it a capable, low global warming potential (GWP) refrigerant (R290) for heating and cooling equipment. R290 is available at a far lower economic cost than the synthetic refrigerants currently in use. R290's impact on climate is negligible; according to the Intergovernmental

Panel on Climate Change (IPCC), it has a 100-year GWP[1] of 0.02 (Smith et all. 2021). By comparison, the two most common HFOs, R32 and R454b, have much higher 100-year GWP values of 677 and 467 respectively (Smith et all. 2021).

Although flammable, propane is nontoxic, non-caustic, and does not create an environmental hazard if it is released as a liquid or vapor into the air, water, or soil in small quantities. R290 is low cost, and it has superior thermodynamic properties; it can heat and cool more efficiently and with less than half the charge of most common refrigerants used today (K S Rao; Liu et all. 2020).

Economic Advantages of Natural Hydrocarbon Refrigerants: Economic Uncertainty Created by Next Generation Synthetic Refrigerants

The United States' regulatory policy regarding hydrocarbon refrigerants puts domestic heating and cooling equipment manufacturers at a competitive disadvantage and inhibits the advancement of efficient heat pump technologies. Manufacturers in the European Union and Asia-Pacific Economic Cooperation (APEC) enjoy the freedom to innovate with hydrocarbon refrigerants, with Europe witnessing a quick increase in interest (Wicher 2014; Stausholm). Major European manufacturers are investing in R290 production, including Panasonic ("Panasonic to Launch Home R290 Air-to-Water Heat Pumps in Europe") and PHNIX. Compressor OEM Euroklimat expects to increase its production of R290 equipment to 90% of its production by 2026 (Stausholm). Products in Europe use Conformité Européenne (C.E.) safety certifications, with charge limits set by EN 378, that allow for higher charges of natural hydrocarbon refrigerants. These foreign product manufacturers will increasingly represent the leading edge of innovation in the industry.

Worldwide, high GWP refrigerants are being phased out. Figure 1 shows the phasedown schedule outlined in the US American Innovation and Manufacturing (AIM) Act passed in 2020. The Act will restrict the use of refrigerants in residential air conditioning and heat pump systems to a GWP value of 700 or less, beginning January 1, 2025, with subsequent GWP restrictions likely to follow.

In contrast, the US market is moving to an interim solution using HFO refrigerants, which typically have GWP values between 450 and 700. The US approach of a multi-staged refrigerant transition increases costs to consumers and manufacturers. The cost of bringing a new product to market is high. Design, development, testing, and certifications all must be recovered through sales, so the more resilient a product to future shifts in market need, the more beneficial it will be to the economy. The cost for manufacturers and distributors to re-design, re-train, and re-certify products to UL standard 60335-2-40 in the US is high. The current US policy of requiring incremental shifts to new synthetic refrigerants will exacerbate product costs which will be passed on to consumers.

New refrigerants are rarely an equivalent replacement to existing refrigerants when higher GWP refrigerants phase out. The current US policy will require manufacturers to re-design and re-certify new equipment and re-train distribution networks multiple times. The frequent re-design resulting from the costly phased refrigerant approach limits manufacturers' abilities to (1) innovate (beyond retooling for new refrigerants), (2) finance manufacturing infrastructure improvements, and (3) provide customer support. These consequences of a multi-

[1] GWP refers to the total contribution to global warming resulting from the emission of one unit of gas relative to one unit of the reference gas, CO_2, which is assigned a value of 1.

staged refrigerant transition approach will lead to higher consumer prices, inferior products putting domestic manufacturing at a disadvantage and making it more difficult for the US to efficiently decarbonize.

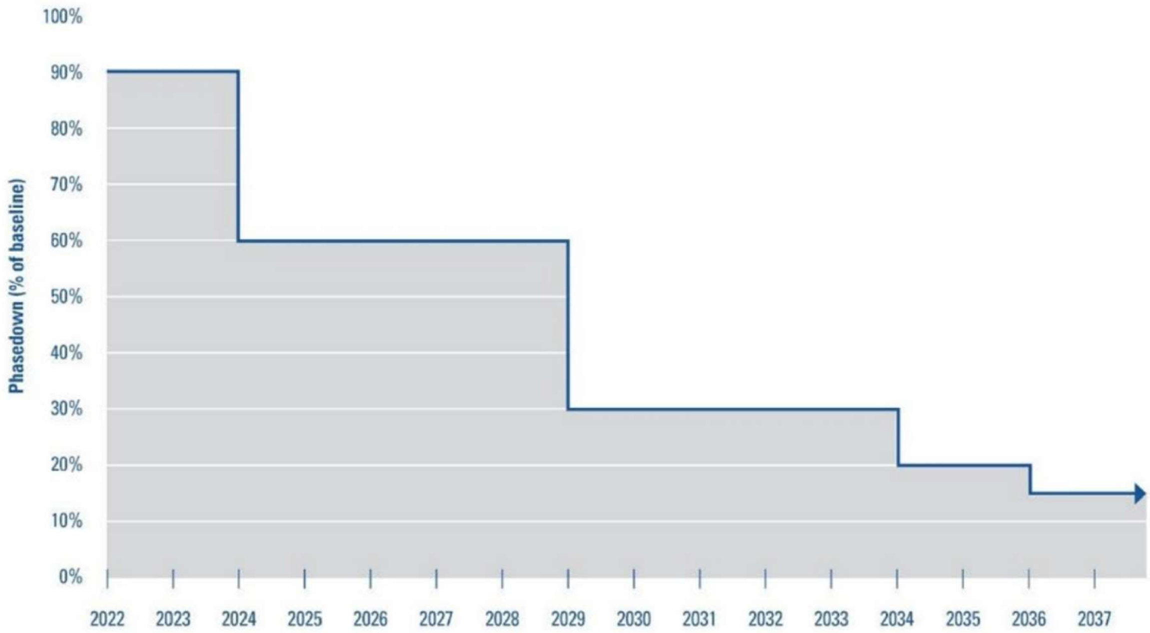

Figure 1: US AIM Act HRC Phasedown. (CalNEXT 2023 ET23SWE0041)

In addition to disadvantaging domestic manufacturing, regulations that phase-in and phase-out refrigerants will result in a confusing refrigerant and HVAC marketplace. Equipment, components, and refrigerants with varying compatibility will likely enter the supply chain in relatively small and expensive quantities. Generally, heating and cooling equipment replacements occur on a 15- to 25-year lifecycle. The current phased refrigerant policy has the potential to phase out refrigerants faster than equipment replacement cycles. Therefore, minor equipment repairs may become significantly more expensive and less reliable because the types of low GWP refrigerants, compressors, valves, heat exchangers, and other components will change over the equipment lifecycle. This market complexity will likely frustrate HVAC technicians, produce significant waste, and increase consumer costs.

These inefficiencies and detrimental impacts to the consumer can be mitigated by advancing natural refrigerants, such as R290. Products developed with natural refrigerants eliminate the phase-in/phase-out cycles and give manufacturers more flexibility to reinvest in manufacturing quality and efficiency, scaling up production and customer support.[2]

[2] According to McKinsey & Company, “the number of manufacturing firms and manufacturing plants in the United States has fallen by roughly 25 percent since 1997, reflecting an increase in closures and a slowdown in start-ups.” Although manufacturing in the United States represents only 8 percent of direct employment, it has a disproportionally large economic contribution. Analysis by McKinsey suggests that “restoring growth and competitiveness in key manufacturing industries could boost US GDP by more than 15 percent over the rest of the current decade.” (Carr et all.) Because manufacturing jobs are highly paid and contribute disproportionally to economic growth, they are critical to supporting the US middle class and global competitiveness. Policymakers have

In addition to bolstering the manufacturing sector, hydrocarbon refrigerants are less expensive than their counterparts. Refrigerant grade propane (R290) cannot be patented and is readily produced and distributed, with current prices around $7.00 per pound. Propane used for combustion costs less than $1.00 per pound; with a broader adoption of R290, the refrigerant price could further drop. By contrast, next-generation synthetic refrigerants require novel chemicals and manufacturing processes, resulting in higher estimated prices of $40.00 to $60.00 per pound and potentially greater environmental risk from the manufacturing processes and byproducts. Additionally, synthetic refrigerants are not as efficient as R290; it often requires more than twice the refrigerant charge to produce the same heating and cooling effect (McLinden and Huber 2020). Given these estimates, R290 is roughly 20 times as cost-effective per unit of heating and cooling. It has the potential to be 100 times more cost-effective as production increases. However, the cost of the refrigerant is only a small portion of the overall equipment and installation cost.

The broad adoption of R290 and other natural refrigerants is also likely to win the support of the mechanical trades when compared to synthetic refrigerants. Bypassing the synthetic refrigerant phasing plan described above could make the jobs of refrigerant technicians more straightforward and less confusing. With multiple synthetic refrigerants in various stages of availability, technicians will face a constant struggle to stock, manage, and safely deploy appropriate and available synthetic refrigerants. By moving to standardized natural refrigerants, like R290, technicians can carry standardized components on repair trucks and make repairs more quickly for consumers. This contribution to a “green collar” economy supports a “middle-out” approach to economic growth by creating jobs that engage the middle class in support of a low-carbon economy. Engaging a broader swath of the population will result in higher production quantities, more installations of heat pump equipment, and higher overall support for the decarbonization effort.

American citizens already use propane in their daily lives without licenses. Barbequing on a propane grill is part of American culture. The 20 lb propane tanks used for barbecuing are the size of what refrigerant technicians would typically carry and could recharge about 5 outdoor air-to-water heat pumps.

Fossil fuel innovations facilitated technological advancements that allow for reliable, safe transportation and use of propane. According to the National Propane Gas Association (NPGA), about 5% of all homes in the US use propane for heating. About 10% of homes are estimated to heat water with propane, and 70% of US households use propane for grilling and outdoor cooking. A quick engineering analysis indicates American homes use approximately 1,476 million pounds of propane per year for space and water heating.[3] If these homes used propane refrigerant heat pumps for space and water heating instead of combustion, the annual propane usage would be reduced to about 0.9 million pounds per year[4], about 0.05% of the current usage.

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recently passed several laws supporting this view (e.g., H.R.3684—Infrastructure Investment and Jobs Act, H.R.4346—The CHIPS and Science Act of 2022, and H.R.5376—Inflation Reduction Act of 2022) to rebuild the manufacturing sector. While federal legislation has aided the manufacturing sector, it has not addressed regulatory barriers such as the hydrocarbon refrigerant regulations in the HVAC&R industry, which stifle other policy goals to modernize manufacturing processes and grow jobs in a resilient, low-carbon sector.

[3] Analysis assumes 82 million single family homes in the US use 60 pound per year propane use for water heating and 240 for space heating.

[4] Analysis assumes 2-pound (900g) charge per space heater, 0.65-pound (300g) charge per water heater, and a 15-year equipment lifecycle. The current limit in the US, outlined in UL 60335-2-40, is ~0.25-pound (114g), well below the limit in Europe and Asia.

Such a significant reduction would reduce the amount transported and handled and certainly increase overall safety.

Perhaps the main concern with R290 heat pumps is the opportunity for air to enter the refrigerant circuit in a sufficient quantity to form an ignitable, pressurized mixture that could explode. However, the required charges are so small that, with appropriate safety mechanisms, the explosion risk can be easily mitigated. Currently, nations worldwide are effectively mitigating this potential risk from using R290.

Using propane as a refrigerant (R290) for residential and light commercial heat pumps installed outdoors has a much lower risk for potential harm than the currently permitted practices involving propane for combustion.

Efficiency, Flexibility, and Resilience from Natural Refrigerants

Since the early 1900s, natural hydrocarbon refrigerants have been the target of special interests lobbying to prevent their use. Today, only the US and Canada maintain this outdated regulatory environment[5]. Early lobbying by the ice industry resulted in the development of Freon[6], a chlorofluorocarbon (CFC) molecule. Decades later, in 1974, the adverse impact of CFCs in the atmosphere on the earth's ozone layer was identified in research (which led to a Nobel Prize). Within 12 years, the Montreal Protocol was signed by most nations of the world to regulate refrigerant production. This protocol was ratified and came into effect in 1989. The Montreal Protocol mandated a transition to a series of refrigerants deemed less hazardous to the ozone layer, first to hydrochlorofluorocarbons (HCFCs) and eventually to hydrofluorocarbons (HFCs), which are most common today. Although the transition to these hydrofluorocarbon-based refrigerants reduced human impact on the ozone layer, it was discovered that these molecules had a substantial global warming potential (GWP), just as the overall implication of increased CO2 emissions on global climate became critically apparent. This initiated yet another refrigerant transition initiative, to compounds with lower GWP. The Kigali Amendment to the Montreal Protocol, proposed in 2016, set a phase-out schedule for HFC refrigerants. As of January 2023, the Kigali Amendment has been adopted by the E.U. and 146 member states of the United Nations, including the US. Notably, the State of California adopted an accelerated implementation schedule for the requirements of the Kigali Amendment to be completed by 2026, and other states, including Washington, have followed suit.

Two classes of refrigerants meet most of the GWP criteria outlined in transition requirements: synthetic refrigerants (HFOs) and natural refrigerants. HFOs are fluorine-carbon molecules designed, manufactured, and sold by the chemical industry to replace HFCs. Although HFOs may address greenhouse gas emissions, recent research demonstrates that HFOs represent a potential new environmental risk.

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[5] Chemical manufacturers Chemours, Honeywell, Arkema and Koura (and equipment manufacturer Daikin) fund the Global Forum for Advanced Climate Technologies (globalFACT, https:// globalfact.org/), a lobbying effort that downplays the benefits of natural refrigerants and the potential environmental risks of halocarbon refrigerants.

[6] In the 1920s and 1930s, natural hydrocarbon refrigerants had an excellent safety record in home applications despite their flammability. However, ice-making and delivery companies saw the introduction of the domestic electric refrigerator as a threat to their business. Labor also opposed home refrigeration, which they correctly predicted would eliminate most jobs involving ice making and delivery. These forces lobbied for and won strict safety regulations on natural hydrocarbon refrigerants, delaying the widespread adoption of home refrigeration before the shift to synthetic refrigerants. In 1928, General Motors invented Freon (R12), the first halocarbon refrigerant, which was stable, non-flammable, and ultimately found to be destroying the ozone layer.

As HFOs degrade in the atmosphere, they generate trifluoroacetate (TFA)[7] that accumulates in rainwater and groundwater (Kauffeld and Dudita). In Europe, TFAs are considered restricted because they are considered polyfluoroalkyl substances (PFAS). PFAS are commonly referred to as "forever chemicals" because they don't break down easily in the environment or in our bodies. This finding has led the E.U. to rethink its use of HFOs as a reasonable response to the Kigali Amendment. Because of the environmental risks, the European REACH (Registration, Evaluation, Authorization, and Restriction of Chemicals) is evaluating a proposal to ban on all low-GWP synthetic refrigerants from use in the European Union.[8]

In contrast, the EPA has come to conclusions that differ from those reached by European agencies, which has resulted in American regulations that are currently more permissive.[9] However, some types of PFAS are proven to be problematic. PFAS contamination has resulted in significant costs to local water districts around the country, including in the Seattle area.[10,11]

The EPA takes a risk-based approach to regulating refrigerants, considering their environmental and human health impacts. For HFOs, the agency acknowledges the potential TFA formation and accumulation, but believes the overall environmental benefits outweigh the risks, especially compared to the current high-GWP HFCs. However, current regulations on natural refrigerants restrict the market's ability to consider a viable alternative. If subsequent research adds evidence to studies that indicate the US water supply is put at risk by HFO refrigerants, a rapid market shift away from HFOs would be necessary. The US can mitigate this risk by creating a regulatory environment that allows natural refrigerants. This will put the US and domestic manufacturing in a more resilient posture, with more options, as the environmental effects of HFO refrigerants are observed.

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[7] TFA is considered an ultra-short-chain PFAS, according to the scientific community and the Organization for Economic Co-operation and Development (OECD). According to Lydia Jahl at Green Science Policy Institute, "HFOs and TFA should be considered PFAS for their shared chemical structure, persistence and potential for harm. There's no indication that ultra-short-chain [PFAS] molecules are safe. EPA's incomplete PFAS definition leaves room for harm."

[8] REACH (Registration, Evaluation, Authorization & Restriction of Chemicals) is a European Union regulation that controls chemical use due to potential environmental and health risks. Companies must provide information about their chemicals to European Chemicals Agency (ECHA). ECHA and Member States assess the submitted information to identify potential risks. For substances of very high concern (SVHCs), companies must demonstrate safe use and lack of suitable alternatives for continued use. The most hazardous substances may be restricted or banned completely.

[9] The Centers for Disease Control and EPA agree that exposure to some PFAS may be linked to harmful health effects in humans and animals. Robust experimental and observational evidence supports the links between exposure to certain PFAS and adverse outcomes like reduced vaccine responses and liver damage. The EPA has additionally cited substantial gaps in understanding about PFAS including: (1) How to detect PFAS, (2) how to remove PFAS from drinking water, and (3) how to manage and dispose of PFAS (Ducatman and DeWitt 2022).

[10] The Seattle Times published an article on Dec. 11, 2022, entitled "More 'forever chemicals' found in WA drinking water as cleanup costs mount," (Bernton and Villa 2020) which described 121 drinking water wells in 12 water districts in the Pacific Northwest where concentrations of PFAS have reached unhealthy levels, resulting in shutdowns and repairs. Utilities in the Pacific Northwest have already started spending on repairs and workarounds. The ramifications of the lack of regulations around the use of PFAS is estimated to have already led to over $210 million in damages for Pacific Northwest water districts—a cost which does not include externalities such as healthcare expenses, loss of life and quality of life, and ecosystem damage—with more costs likely to come.

[11] A report by the German Environment Agency states about the next generation of synthetic refrigerants "The use of halogenated substitutes with a low global warming potential must be regarded as problematic in view of the persistence of TFA or trifluoroacetate in the environment. TFA or trifluoroacetate inputs into groundwater and drinking water can only be removed with considerable effort. Therefore, fluorinated refrigerants, foam blowing agents and aerosol propellants should be replaced by more sustainable solutions with halogen-free substances."

In addition to persistent environmental toxicity concerns, studies suggest next generation synthetic refrigerants break down in the atmosphere to very high GWP molecules such as R23, an effect not captured in the 100-year GWP rating (Oltersdorf 2021). There is conflicting evidence surrounding this issue, but permitting natural refrigerant options reduces risk and provides flexibility and resiliency in the face of uncertainty.

The phase-in/phase-out of harmful generations of synthetic refrigerants demonstrates the failure of chemical manufacturing to deliver safe and effective refrigerant strategies. While synthetic refrigerants are non-flammable and "non-toxic"— according to the industry definition —each generation has created additional unforeseen environmental complications and threats to human health. These unnecessary risks result in repeated and expensive efforts to make the next generation of synthetic refrigerants illegal when found harmful, only to have subsequent generations of synthetic refrigerants developed to take their place and then found harmful and retired years later. Refrigerant developments have moved from a chemical that destroys the outermost layer of the atmosphere (the ozone layer) to one that adversely impacts the whole atmosphere (global warming) to one that studies show may contaminate rainwater and groundwater.

Code Barriers to Hydrocarbon Refrigerants and Pathways to Acceptance

Despite compelling economic and environmental reasons to promote natural hydrocarbon refrigerants, they must overcome significant regulatory and institutional barriers in the US. The barriers are constructed around the fact that hydrocarbon refrigerants are designated as A3 – flammable – by ASHRAE standard 34.

UL 60335-2-40

The most significant barrier to natural hydrocarbon refrigerants comes from UL 60335-2-40 – a certification code developed by UL Solutions.[12] UL 60335-2-40 is currently required by mechanical codes for all heat pump equipment sold in the United States, so it functions as a federal standard. UL prescribes a charge limitation for R290 of 114g regardless of installation type— indoors, outdoors, or in a mechanical room.[13] The calculation below outlines the basis for the 114g charge limitation and is based on the 3rd Edition (with 4th Edition Proposed Changes) of UL 60335-2-40, published on December 31, 2021.

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[12] According to Craft.co, Underwriters Laboratories, now known as UL Solutions, is currently a private company. This represents a change from its earlier status as a non-profit organization as of January 1st, 2012. UL Solutions continues to provide a wide range of services including testing, inspection, auditing, certification, training, advisory, risk management, and software solutions across various sectors such as automotive, buildings, energy, financial services, healthcare, and more. The company, founded in 1894, is headquartered in Northbrook, Illinois, United States and generated a revenue of $2.5 billion in the year 2022. UL has undergone significant changes, transitioning from its initial non-profit foundation to its current role as a private, profit-driven corporation. Despite this evolution, it remains a pivotal authority in determining the types of equipment that can be developed and marketed in the United States, operating with minimal oversight. This level of autonomy extends to its relationship with federal agencies; for instance, the EPA, DOE, and other governmental bodies do not exert control or influence over UL.

[13] Interestingly, UL 60335-2-89 (Particular Requirements for Commercial Refrigerating Appliances and Ice-Makers with an Incorporated or Remote Refrigerant Unit or Motor-Compressor) allows for much higher charge limits on similar equipment, but still not equivalent to what are permitted in Europe per EN 378 and IEC 60335-2-40.

- Page 153 of 460 has Table BB-1 that gives Propane Lower Flammability Limit of 0.038 kg/m3, or 38g/m3
- Page 91 of 460: 22.115DV (specifies that the maximum refrigerant charge per circuit for A2/A3 is m1.)
- Page 199 of 460: For propane (and similar for most other hydrocarbons), per GG.1.2DV.1, m1 = 3 x LFL = 3 x 38g = 114 grams

A charge limit of 114g is equivalent to 0.25 lbs or 1/80th of a typical propane BBQ tank. 114g is too restrictive of a charge limit and inhibits manufacturers from designing, manufacturing, and selling heat pumps using R290 in the US. This charge limitation even prevents manufacturers from producing air-to-water heat pumps meant for outdoor installation from using natural hydrocarbon refrigerants.

UL 60335-2-40 is an updated version of UL 1995, which is meant to align with International Electrotechnical Commission (IEC) safety standard IEC 60335-2-40. However, IEC 60335-2-40 allows for 988g of R290 in monobloc heat pumps and split systems and 4,940g of R290 in outdoor air-to-water heat pumps. The higher charge limits for propane (R290) were approved in a unanimous vote for use in household air conditioners, heat pumps, and dehumidifiers by countries in the subcommittee overseeing the IEC update, including the US. Nearly every other country in the world allows for safe and reasonable use of natural hydrocarbon refrigerants at IEC levels (Leer, Inc.; Wicher 2014).

The UL standard is updated through voting by a Standards Technical Panel (STP). UL typically hires subcontractors to develop proposed changes on which the STP will vote. Table 1 shows the breakdown of STP voting members as of April 2023, with no members representing government or international interests. Over 50% of the committee members are from the supply chain and producers.

Table 1. UL 60335-2-40 STP Voting Breakdowns as of April 2023.

Authority Having Jurisdiction (AHJ)	Commercial/ Industrial User	Consumer	General	Gov't	Int'l Delegate	Producer	Supply Chain	Testing & Standards	Total
6	2	1	10	0	0	17	17	8	61
9.84%	3.28%	1.64%	16.39%	0%	0%	27.87%	27.87%	13.11%	

Due to the current composition of the STP and the process UL uses to update its codes, UL 60335-2-40 over-represents the interests that benefit from restricting the use of A3 refrigerants like R290. This unfortunate outcome poses substantial and unnecessary economic and health risks for the US. To promote and protect American interests, US agencies – including the Department of Energy (DOE) – can allocate funding to update UL 60335-2-40 and align the natural refrigerant charge limits with IEC 60335-2-40. Federal agencies can:

- Fund scientists, government officials, and international representatives to sit on the UL 60335-2-40 STP and provide more balanced industry representation.
- Fund a national research laboratory to review the safety standards proposed in IEC 60335-2-40 that claim to safely allow 988g of R290 in monoblocheat pumps and split systems and 4,940g of R290 in outdoor air-to-water heat pumps. These standards are already adopted around the world.
- Fund a national research laboratory to confirm IEC findings or propose additional measures, if needed, to use A3s in the US safely. Use the findings to propose updates to the current UL 60335-2-40.

ASHRAE 15 and ASHRAE 34

Other standards, like ASHRAE Standards 15 (ANSI/ASHRAE Standard 15-2022 2022) and 34 (ANSI/ASHRAE Standard 34-2022 2022), influence refrigerant use and describe limitations. Although these standards are not always referenced in formal regulations, they contain language that aligns ASHRAE standards with UL requirements and are generally influenced by the same industry actors engaged in the UL standard-making process.

- Standard 34 is focused on identifying the classifications and characteristics of refrigerants and is the basis of much of the designation language used in the industry.
- Standard 15 is focused on best practice deployment of refrigerant systems and, therefore, has implications for refrigerant and equipment selection. For example, in Standard 15, the use of A3 refrigerants (like propane) is generally discouraged: “7.5.3 Higher-Flammability Refrigerants - Group A3 and B3 refrigerants shall not be used except where approved by the AHJ.”21 This language is followed by a series of exceptions that prescribe limited applications under which these refrigerants can be deployed, somewhat softening the impact. Still, the message to the design community is clear: A3 refrigerants are generally to be avoided.

There is no need to change Standard 34, which sets classifications. However, Standard 15 should be updated to give more guidance on how to use A3 refrigerants safely. Members of the ASHRAE committee can determine methods for a safe A3 installation. Standard 15 can provide guidance on installing leak detection and ventilation systems to prevent risk in A3 systems and differentiate safety requirements on indoor and outdoor products.

Committee members can refer to international standards that allow natural hydrocarbon refrigerants and assess the feasibility of adopting similar safety measures. DOE can support updating Standard 15 by providing direction to the ASHRAE committee members, funding national labs to participate in the effort, and providing analysis with the explicit goal of exploring avenues for safe A3 installations.

EPA Significant New Alternatives Policy (SNAP)

EPA SNAP policy sets charge limits at the more conservative of the UL and ASHRAE standards. If UL is updated, the EPA will almost certainly update SNAP.

By directly referencing UL and ASHRAE as opposed to developing requirements for the safe use of R290[14], the EPA is limiting its ability to promote an American green economy. Additionally, SNAP's "double-dimensioning" of UL and ASHRAE creates industry confusion and a less flexible regulatory environment. Complexity and inflexibility are counterproductive and even dangerous during a period when industry needs to rapidly transform to meet efficiency, environmental and economic challenges.

While it is reasonable that EPA references industry standards, it would be more productive for SNAP to provide refrigerant charge limits that promote health, the environment, and economic growth. EPA can play a positive role by updating SNAP to refer to charge limits set by IEC 60335-2-40 and encourage UL and ASHRAE to follow.

Conclusions

Current US policy can be adjusted to support a rapid transition to natural refrigerants and avoid the unnecessary economic impacts and potentially harmful environmental impacts of a fourth generation of synthetic refrigerants. Supporting a pathway to use natural hydrocarbon refrigerants will promote robust economic growth in manufacturing, US technological competitiveness in heat pump technology, and provide resiliency in the face of potential environmental risks posed by HFOs.

Natural hydrocarbon refrigerants like R290 are flammable. However, flammable natural gas and propane are already piped into homes for cooking and heating in stoves, open-flame fireplaces, furnaces, and water heaters. These existing uses involve volumes of flammable gas well beyond those in a self-contained propane refrigerant system. As a result of current fossil fuel infrastructure, technologies and management strategies exist to safely support broad deployment of hydrocarbon refrigerants. Adopting a natural hydrocarbon refrigerant strategy supports cost-effective innovation and deployment of energy efficient building decarbonization technologies. Alleviating the risks described in this report requires a shift in federal policy supporting natural refrigerants, including modern regulations for flammable refrigerants, financial and regulatory incentives, and support for the research and development of natural refrigerant equipment.

Expanding the application of R290 and other natural hydrocarbon refrigerants in heating and cooling equipment would result in significant economic and environmental benefits. Now is the time to remove barriers and create opportunities for technologies that will allow future generations in the US to compete globally in heat pump manufacturing. Building a heating and cooling economy around natural refrigerants will create a safer, more equitable, more resilient

[14] EPA.gov states: "EPA works to ensure that:
• Americans have clean air, land and water
• National efforts to reduce environmental risks are based on the best available scientific information
• Federal laws protecting human health and the environment are administered and enforced fairly, effectively and as Congress intended
• Environmental stewardship is integral to U.S. policies concerning natural resources, human health, economic growth, energy, transportation, agriculture, industry, and international trade, and these factors are similarly considered in establishing environmental policy
• All parts of society--communities, individuals, businesses, and state, local and tribal governments--have access to accurate information sufficient to effectively participate in managing human health and environmental risks
• Contaminated lands and toxic sites are cleaned up by potentially responsible parties and revitalized
• and Chemicals in the marketplace are reviewed for safety."

future, reduce costs, and increase the supply of advanced energy efficient heat pump equipment needed for decarbonization.

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