Honeywell

California Air Resources Board
1001 I St #2828
Sacramento, CA 95814

October 30, 2023

RE: Request for Information for Senate Bill 1206 Assessment Report

Honeywell International, Inc. (“Honeywell”) is pleased to provide the following information to support California Air Resource Board’s (“CARB’s”) development of an assessment report that will specify how to transition California’s economy, by sector, away from hydrofluorocarbons (“HFCs”), as directed by California Senate Bill (SB) 1206.[1] Honeywell is a global leader in providing energy efficient technologies and innovations that can help the world solve its energy and environmental challenges. Since the 1990s, we have helped businesses replace ozone-depleting and high-global-warming-potential (“GWP”) substances used as refrigerants, foam blowing agents, solvents, aerosol propellants, with alternatives that have less impact on the stratospheric ozone layer and global climate change.

Honeywell supports the goals of CA SB 1206 and applauds CA’s proactive and transparent approach to orderly HFC transitions. For example, setting non-sector specific GWP sales limits for HFCs in future years gives industry a clear signal for technology transitions and gives downstream manufacturers and distributors clear guidance on expected availability of specific products over time.

Honeywell appreciates the opportunity to provide comments in response to CARB’s request for information (“RFI”). Please see overarching comments below and detailed responses to specific questions starting on page 3.

1. Honeywell encourages CARB to align its efforts under SB 1206 with federal HFC phasedown initiatives and, in particular, the US Environmental Protection Agency’s implementation of the American Innovation and Manufacturing Act of 2020 (“AIM Act”).[2] The AIM Act creates a harmonized, efficient, and orderly approach to the US HFC phasedown and major deviations from this national framework in the form of patchwork regulations risks harm to the goals of the HFC phasedown and additional uncertainty for regulated entities.

2. While some sectors have transitioned or plan to transition to ultra-low GWP technology, not all sectors are positioned to do the same. This is due to a variety of different reasons, including compatibility of ultra-low GWP substitutes with existing equipment design, developing building codes and standards, and difficulty/cost of equipment replacement. The coming transition plans for various sectors in CA should be built around specific technology readiness in each sector.

3. The motor vehicle air conditioning (“MVAC”) sector is largely capable of achieving near full use of ultra-low GWP R-1234yf in both new internal combustion engine and electric vehicles. To address aftermarket MVAC decarbonization, Honeywell and partners have recently submitted a SNAP application to the US EPA for retrofit of R-1234yf in certain types of existing MVAC systems that originally used HFC-134a. We expect to hear back

[1] SB 1206 (Skinner, Stats. 2022, Ch. 884); Health & Saf. Code § 39735, 39736
[2] 42 U.S.C. 7675

from EPA on this in 2024 and believe that this new use of R-1234yf could support accelerated achievement of CARB's HFC reduction goals in the MVAC sector.

4. Global warming potential ("GWP") is an important but only partial measure of a substance's climate impact. Alongside GWP, Honeywell supports CARB's continued assessment of total lifetime environmental impact associated with a product's final use, which would include system manufacturing emissions, energy consumption during use, and water consumption during use. Safety is another consideration for any high ultra-low GWP HFC replacement and should be a criteria for prioritization in future regulatory action. Reviewing these criteria together will ensure a holistic approach to the HFC phasedown that best prevents the transition to regrettable substitutes which could be energy inefficient, unsafe, or costly to consumers.

Thank you in advance for consideration of the below responses to CARB's RFI questions. For any follow-up questions, please reach out to Joshua Shodeinde, Sr. Manager of Regulatory Program Management, at joshua.shodeinde@honeywell.com. We look forward to ongoing collaboration with CARB in the successful implementation of CA SB 1206.

Sincerely,

DocuSigned by:
Laura Reinhard
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Laura Reinhard
Vice President and General Manager
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Honeywell

Section 1: Commercial and Industrial Stationary Refrigeration (Retail Food, Cold Storage, Industrial Process Refrigeration, and Ice Rinks)

Question 1. What potential technological solutions are available for existing facilities and how can their adoption be accelerated?

Refrigeration equipment utilizing refrigerants such as R-404A or R-22 at existing facilities is designed to use nonflammable refrigerants for operation, meaning retrofit options are limited to nonflammable solutions. Currently, there are no low or ultra-low GWP nonflammable refrigerants with thermodynamic properties similar to R-404A or R-22. However, R-448A (GWP 1,386[3]) and R-449A (GWP 1,396) are lower-GWP options that are available and widely used retrofit options in both medium-temperature and low-temperature applications. R-448A and R-449A possess thermodynamic properties similar to R-404A and can, at times, be used as direct “drop-in” refrigerant replacements to R-404A systems. This convenient conversion is quick and low cost compared to other types of refrigerant conversions and can lead to improved energy efficiency. Honeywell recommends that CARB continue to allow facilities to convert to lower-GWP options such as R-448A and R-449A, as this solution is an environmentally responsible retrofit option with reasonable capital expenditure.

If an existing facility opts for a more extensive system changeout—or a partial remodel—one refrigerant option to consider is R-513A (GWP 630). R-513A has a boiling point of -20.6 °F and can be used in medium-temperature applications and in some low-temperature applications. One drawback to using R-513A is its lower capacity compared to R-404A. Nevertheless, additional compressors can be employed to make up for the capacity difference between the two refrigerants. Implementation of a dedicated mechanical subcooling system can also help to enhance R-513A capacity. Furthermore, suction lines need to be evaluated for reuse suitability. Therefore, as a result of these potential system enhancements, use of R-513A in existing facilities is expected to entail a higher capital investment when compared to R-448A or R-449A retrofit due to the need for additional components and equipment. Partially remodeling a refrigeration system to use R-513A may not be suitable for all existing systems and for low-temperature applications below -20 °F.

For medium-temperature applications in the retail food sector, refrigerant options such as R-471A (GWP 144) and R-482A (GWP 144) can be considered for an existing refrigeration system changeout. Both refrigerants are A1 (i.e., not flammable) [4], possess low GWP (<150), and are suitable for partial remodeling in medium-temperature applications. Nevertheless, equipment overhaul and component changeout are required to account for the capacity variation when compared to existing high-GWP systems. This could include adding supplementary compressors, reducing load requirements by introducing doors to open refrigerated display cabinets, implementing a dedicated mechanical subcooling system, and suction line resizing. While existing compressors and liquid lines may be retained when undergoing a partial remodel

[3] GWP values presented in this document are taken from the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (AR4) for all substances, including blends.

[4] ASHRAE Standard 34, “Refrigerant Designations and Safety Classifications” assigns a designation consisting of two to three alphanumeric characters (e.g., A2L or B1) to refrigerants. The initial capital letter indicates the toxicity, and the numeral and trailing letter, if any, denotes the flammability.

from a R-404A refrigerant to R-471A/R-482A refrigerants, the required equipment modifications are extensive and costly.

<u>Question 2.</u> What incentives are needed to transition existing refrigeration facilities and what GWP limit should be set for technologies supported through incentives?

Transitioning existing facilities to either near drop-in lower-GWP solutions (such as R-448A or R-449A) or to solutions that require equipment overhaul (such as R-471A) takes time away from facility operations due to system downtime for system tuning and rebalancing, and also involves some level of capital costs. Even the least intensive and involved facility retrofit project (i.e., retrofitting to drop-ins) can potentially be hundreds of thousands of dollars in capital cost. Honeywell supports CARB in allowing a range of lower-GWP technological solutions that best fit an owner's refrigeration and operational needs. This would include lower-cost retrofit options such as R-448A and R-449A and new system creation such as those using R-471A and R-455A (GWP 146). Removing lower-cost options from the table could discourage equipment owners from any transition and could cause continued use of inefficient and very high GWP systems. Honeywell recommends that CARB considers providing financial incentives to existing facilities who transition to a refrigerant with GWP less than 1,400.

Since retrofitting or remodeling existing facilities to any of the available lower-GWP refrigerants would require significant capital investment, government-funded financial incentives would help to alleviate some of burden to owners and operators.

<u>Question 3.</u> What safety testing and safety standard updates, if any, are needed for the transition to ultra-low GWP or no-GWP alternatives in this sector?

UL 60335-2-89 is the product standard for commercial refrigeration equipment and ice machines. A second edition of this standard was published in October 2021. However, further clarifications are still required in the standard to clarify how the charge allowance is interpreted for field-installed systems. These discussions are currently ongoing with the UL 60335-2-89 committee, and the third edition of UL 60335-2-89 is expected to clarify these requirements. Further, ASHRAE 15 specifies requirements for the safe design, construction, installation, and operation of refrigeration systems, and may require modifications to complement the 3rd edition of UL- 6-335-2-89. These safety standards along with the model building codes that refer to these standards need to be adopted across all jurisdictions to promote accelerated adoption of ultra-low GWP A2L refrigerants. Along with finalizing the building codes and standards, technician training is also essential to successfully adopt ultra-low GWP A2L options.

<u>Question 4.</u> What barriers exist in bringing technologies such as ejectors, CO2 condensing units and others, to the California market, particularly for smaller refrigeration systems such as those found in convenience stores?

The main barriers to bringing CO_2 into the California market for small refrigeration systems are: (1) the loss in energy efficiency when using CO_2 refrigerants, especially in warmer climates; (2) the high operating pressure of CO_2; and (3) the complexity of CO_2 control systems, which leads to high capital investment costs. Furthermore, CO_2 refrigerants are industrial gases and byproducts of industrial processing of fossil fuels (e.g., natural gas and coke) resulting in other

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environmentally harmful byproducts such as NO_x, NH_3, HCN, HCl, methane leaks, and slags, etc. This should be taken into account as CARB supports adoption of CO_2 in the California market.

Inefficiency of CO_2 Systems and Suboptimal Performance in Warmer Climates

As a refrigerant, CO_2 is thermodynamically less efficient than HFC/HFO based solutions and its performance in trans-critical cycle is significantly lower than these refrigerants (which operate sub-critically). Moreover, the efficiency of CO_2 systems further decreases in warmer ambient conditions, which leads to significantly higher energy consumption at peak loads and higher operating costs to store owners. To improve the efficiency of CO_2 systems requires various system enhancements such as the use of a multi-jet ejector to recover throttling losses and the use of adiabatic condensers to lower the operating pressure. These necessary enhancements, however, increase the complexity of the system, resulting in higher initial cost as well as heightened maintenance cost of CO_2 systems compared to HFC/HFO based solutions. Also, these modifications may present significant issues to service technicians who may be unfamiliar with the complexity of using ejectors and other CO_2 system-specific equipment add-ons. Furthermore, use of adiabatic condensers demands substantial amounts of water for operation, which can exacerbate water scarcity problems present in California.

High Operating Pressures of CO_2 Can Cause Safety and Reliability Issues

CO_2 has high operating pressures when compared to other refrigerants (10 times that of current refrigerants) that require complete redesign and retooling of all major RHVAC equipment. Due to this higher operating pressure, system leaks quickly result in the air emission of the whole refrigerant charge, leading to non-functionality of the overall system and potential respective products losses (food, medicines, etc.). More frequent refrigerant servicing is likely required and can reduce overall efficiency when low charge conditions exist (particularly important for small commercial chillers, etc.). Furthermore, since CO_2 refrigeration systems operate at extremely high pressures, technicians need to be trained specifically for handling CO_2. The design of CO_2 systems also needs to consider effects of unplanned events such as power failures which can lead to a rise in system pressure beyond the system design pressure rating which could potentially lead to the loss of the entire CO_2 refrigerant charge, leading to refrigerated product loss. An auxiliary system is required to maintain the pressure of CO_2 within the system design pressure rating levels to prevent partial/complete loss of refrigerant.

Complexity of the CO_2 control system

The problems outlined above are magnified in smaller refrigeration systems due to the cost and the complexity of the units required to meet energy standards established by DOE—for example, the annual walk-in energy factor (AWEF) for unit cooler and the condensing units. Due to these additional system complexities and the requirement to employ specially trained technicians, the maintenance cost of CO_2 systems is often higher than HFC/HFO-based systems. For smaller refrigeration systems, this may mean investing in technologies to boost energy efficiency (for example twin-stage compressors) and highly complicated and sophisticated control systems. Conclusively, CO_2 as a refrigerant is a very expensive alternative for the commercial refrigeration industry in California, irrespective of the size of the store (from convenient stores to supermarkets), both in terms of installed system cost and energy consumption.

Section 2: Stationary Air Conditioning & Space Conditioning Heat Pumps

Question 5. There are limited ultra-low-GWP and/or no-GWP technologies for this sector. How can technological innovation be encouraged?

Chillers

Chillers can be broadly categorized into three types of systems: (1) high-pressure systems which traditionally used R-410A; (2) medium-pressure systems which traditionally used HFC-134a; and (3) low-pressure systems which traditionally used R-123. For the medium-pressure and low-pressure chillers, R-1234ze(E) (GWP 1) and R-1233zd (GWP 1) are ultra-low GWP options, respectively, which are commercially available and provide energy efficiency similar to or better than existing HFC refrigerants. Ultra-low GWP options for high-pressure chillers are not available currently. Nevertheless, high-pressure chillers can be adapted to use ultra-low GWP medium pressure fluids like R-1234ze(E) and R-1234yf (GWP 1) through technological innovation and development of compressor technology (scroll, small centrifugal). These advancements will enable ultra-low GWP refrigerants to match the efficiency of existing high-pressure chillers designed with R-410A.

Furthermore, the operating pressure levels of ultra-low GWP options are significantly lower than R-410A, and their use will require larger heat exchangers to match the efficiency of existing high-pressure R-410A systems. Consequently, Honeywell encourages CARB to support the development of heat exchanger designs which can be optimized for ultra-low GWP refrigerants and ensure that the cost of compatible heat exchangers can be minimized. There have been some technological advancements already by original equipment manufacturers (OEMs) in the development of scroll compressors using R-1234ze(E) and R-1233zd(E).[5,6]

US Residential and Commercial Air Conditioning Systems

For the US residential air conditioning segment, a low GWP option is R-454C (GWP 148). Ultra-low GWP options include R-1234ze(E) and R-1234yf. However, R-454C, R-1234ze(E) and R-1234yf cannot be used in existing system designs because these systems are optimized for high pressure refrigerants such as R-410A and R-454B (GWP 465). Investment in advancement of compressor technology (scroll, small centrifugal, etc.) for low and ultra-low GWP refrigerants to match the efficiency of air conditioning systems using R-410A could accelerate adoption. Consequently, Honeywell encourages CARB to work with industry and support OEM development of new heat exchanger technology and designs which can be optimized for ultra-low GWP refrigerants and ensure that the cost/size of heat exchangers can be minimized. CARB should note that for any new technology developed, time should be provided for commercialization and implementation of this technology to ensure a smooth transition and minimize market disruption.

Question 6. What types of ultra-low GWP technologies for this sector are available in other markets globally, but not in the US? What do you see as the primary market barriers to the adoption of these technologies in the US?

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[5] See https://www.keyter.com/keyter-commercializes-first-ever-scroll-chiller-using-r1234ze-ultra-low-global-warming-potential-refrigerant-honeywells-solstice-ze/#news

[6] https://www.daikin.com.sg/product-series/WMTC-with-HFO-Refrigerant-R-1233zd(E)

In Asian markets, propane is an ultra-low GWP technology used in mini-split systems and small portable ACs. The primary concern with using propane is its flammability, as propane is rated as a Class A3 refrigerant by ASHRAE (i.e., highly flammable). Propane has a very low lower flammability limit, making it flammable even in low concentrations of air. Thus, an air-conditioning system using this flammable fluid in a DX configuration is a high flammability risk inside the house, especially in the event of a leak occurring in the evaporator or the connecting lines. Current US building codes and safety standards (e.g., UL-2-40) do not permit the use of propane in the US residential sector. Safety standards and building codes are being revised and updated to allow use of mildly flammable A2L refrigerants for the US air-conditioning market, paving the way for ultra-low GWP refrigerants such R-1234yf and R-1234ze in these applications. Technological innovations discussed in Question 5 should be promoted to accelerate the adoption of these ultra-low GWP A2L refrigerants.

<u>Question 10.</u> What are the benefits of and potential for expanding the use of integrated heat pump technology (units that prove space conditioning and water heating and/or other uses) in California?

Integrating space heating and cooling with domestic hot water has the primary advantage of eliminating direct emissions from fossil fuels at the site by reducing or even eliminating the need for gas furnaces (depending on the climate) and gas water heaters. This technology can also be implemented with thermal storage which can enable load balancing, taking advantage of lower electricity costs on off-peak hours. Another potential benefit is that heat recovered during comfort cooling heat rejection can meet domestic hot water demands. The use of integrated heat pump technologies could also increase the overall efficiency of the space and water heating system, so long as the unit is not primarily cooling with a relatively small coincident heating load (the cooling efficiency is dramatically lower when heat rejection has to be at a much higher temperature than it would have been otherwise – preheating can be more appropriate at times).

There is significant potential for space conditioning and water heating to transition to ultra-low GWP solutions, especially using refrigerants such as R-1234yf.

A great example of such systems has been developed by the French company Veotherm,[7] which offers a fully integrated R-1234yf heat pump system for large residential and commercial buildings. Their technology highlights the capability of using smart control of the system to provide space conditioning heating, cooling, domestic hot water and any other heating demands. The system can provide hot water at up to 158 ºF, and chilled water at 41 ºF for cooling simultaneously. In milder climates such as most of California's sixteen climate zones, this system would be an ideal replacement to traditional air-conditioning and gas furnace systems and there is great potential for use of integrated heat pumps in the state.

Section 3: Non-Space Conditioning Heat Pumps (Water Heaters, Clothes Dryers, Pool and Spa Heaters)

[7] See https://www.veotherm.com/

<u>Question 13.</u> There are limited ultra-low-GWP and/or no-GWP technologies for these equipment types. What can be done to spur technological innovation?

For these applications, ultra-low GWP refrigerants such as R-1234yf and R-1234ze(E) are already used in Europe. HFC-134a is still most widely adopted for tumble dryers and dishwashers, especially in Europe. OEMs have recently been driven by the global HFC phasedown to introduce HFO systems to replace HFC-134a ones. These new refrigerants have high critical temperatures which allow higher air temperatures that reduce the run time of the equipment. Furthermore, these A2L refrigerants can also be used indoors with acceptable charges compared to hydrocarbons and achieve higher efficiencies than CO_2. Hydrocarbons pose a safety risk for applications such as clothes dryers and dish washers since these appliances require operating temperatures near 212 ^{o}F, increasing the risk of flammability if a leak were to occur. To promote innovation for these equipment types, Honeywell recommends two actions: (1) R&D funding for use of R-1234yf and R-1234ze(E) in dishwasher, tumble dryers and water heater applications over gas-based appliances; and (2) subsidies on appliances using ultra-low GWP heat pump technology.

Section 4: Motor Vehicle Air Conditioning (MVAC)

<u>Question 15.</u> What emerging ultra-low-GWP and no-GWP technologies show promise in integrating passenger comfort cooling and heating systems as well as thermal management for batteries and other vehicle systems and components for electric vehicles, and what barriers exist for their commercialization?

There are predominantly four ultra-low-GWP or no-GWP technologies being considered for electric vehicle (EV) Thermal Management Systems (TMS). These are described in detail below.

R-1234yf

R-1234yf is the globally-preferred, ultra-low GWP replacement refrigerant for HFC-134a in motor vehicles, including plug-in hybrid electric vehicle (PHEV) and battery EV types. R-1234yf is in use in over 200 million light-duty vehicles around the world today and has a GWP of less than 1. Every major manufacturer of EV light-duty vehicles that are sold in the US is successfully using R-1234yf in their EV vehicles. Most current R-1234yf EV systems use newer technology heat pumps with loops that manage thermal control (heating and cooling) for battery modules, electric motors as well as other power electronics. R-1234yf provides reliable, safe, and energy efficient heating and cooling in EV HVAC systems. There are multiple, large scale, R-1234yf manufacturing plants operating globally to support the strong growth in demand for R-1234yf as vehicle makers around the world convert production models still using HFC-134a to the ultra-low GWP refrigerant.

R-1234yf is also widely used in the aftermarket in the US to service vehicles in the field and it is available in over 15,000 retail auto stores across the country. Aftermarket demand for R-1234yf has also been growing in the US, Europe, Japan, Turkey and South Korea as vehicles made for those local markets convert to R-1234yf. There are R-1234yf products in the USA that have been specially developed for use in professional repair shops and there are R-1234yf products in the USA that have been specially developed for lower income do-it-yourself users.

Since its introduction almost 10 years ago, R-1234yf has built a strong record of reliability, energy efficiency, and safety in use. Its toxicology and flammability have been exhaustively studied in risk assessments and the refrigerant has been accepted globally. It is used equally in EVs (both with and without a heat pump) and in internal combustion engine (ICE) vehicles across many categories. It is SNAP-listed for use in new passenger cars, light-duty trucks, medium-duty passenger vehicles, heavy-duty pickup trucks, complete heavy-duty vans, and nonroad vehicles. SNAP listings for Heavy Duty (on road) vehicles, buses and HFC-134a retrofits of each category are expected in the near future. In Europe, several famous brands of heavy-duty vehicles have already started converting their models to R-1234yf with plans to convert the entire European fleet of new heavy-duty vehicles.

Honeywell has recently worked with our partners to submit a SNAP application to EPA for allowable use of R-1234yf to repair/retrofit older light-duty vehicles that today use HFC-134a. The retrofit process to do this would be remarkably simple as the physical properties of R-1234yf and HFC-134a are very similar. This use could allow for significant reductions in aftermarket HFC use in CA and the associated environmental benefit. SAE International procedures are under development for retrofitting older HFC-134a vehicles that would not require any under hood part replacements. Permanent new fittings would be used to convert these HFC-134a vehicles to R-1234yf.

CO_2 (R-744)

R-744 is another ultra-low GWP fluid possibility for MVAC as it has a GWP of 1 and it has been used in a small number of serial production EV models in Europe. There are some fundamental drawbacks to using CO_2: (1) significantly higher pressures are required (10 times that of current refrigerants), forcing a redesign of every component in the system and requiring all new controls; (2) the cost and investment required to use this fluid in a light-duty vehicle are significant when compared to R-1234yf; and (3) while cost of production of CO_2 systems is unlikely to achieve parity with current R-1234yf systems. The higher operating pressures of CO_2 also create problems for refrigerant retention, driving higher maintenance cost and reduced reliability. We have seen this already in European models that offered CO_2 systems as an option. There have been estimates that vehicles may need to be recharged every year or every other year to maintain capability. EV lithium-ion batteries need a consistent and reliable cooling system to function properly. Overheating these types of batteries remains a major concern for EV manufacturers based on battery fires that can happen from thermal run-away. The reliability of CO_2 HVAC systems gives rise to safety concerns as battery cooling failures could lead to thermal issues and a shutdown of a vehicle's powertrain when underway on the highway.

Higher pressures and refrigerant leaks can also cause other problems. During service and in the event of a collision, rapid refrigerant release could cause safety issues. Shrapnel from damaged components in a collision can be concerning. The relative low number of CO_2-based vehicles on the road today does not allow us to judge this risk accurately. Refrigerant leaks into the vehicle cabin can also be concerning. Even small leaks can contribute to anesthetic effects for drivers in the best case and severe headaches and a loss of consciousness in the worst. Current vehicles using R-744 generally employ a CO_2 sensor in the vehicle to detect leaks and the accuracy of these sensors over time creates some concern.[8] Respiration occurs for adult drivers in a generally common zone but children, infants in car seats and pets can make detection problematic in vehicles using CO_2 systems.

[8] CO2 Sensor: Types, Working, Interfacing & Its Applications (elprocus.com)

A significant weak point in CO_2 systems is their poor efficiency and performance at higher ambient temperatures. CO_2 refrigeration systems become trans-critical at a gas cooler outlet temperature of 31°C (87.8 °F). The resultant concerns with CO_2 systems are well documented in numerous papers and studies.[9] Gas coolers (like condensers) are rarely 100% effective (gas outlet temperature the same as the ambient temperature). That means in ambient temperatures as low as 25°C (77°F) efficiency and performance can suffer. This can be further exacerbated by low-speed city traffic or tail wind conditions that increase the air temperature into the gas cooler. As the industry looks for improved efficiency and performance (to cool the cabin as well as the battery, motors, and electronics) the effects of global warming are becoming easily observable. Sustained record high temperatures across much of the globe are becoming commonplace. The light duty automotive and heavy-duty vehicle markets in North America are unlikely to choose R744 as an effective or efficient ultra-low GWP replacement.

Finally, SAE International standards for CO_2 have never been fully developed, and there has been little to no work done to generate the kind of standards that would be necessary to implement CO_2 in mass production across the MVAC industry.

Finally, CO_2 is an industrial gas produced largely from the fossil fuel industry (steam methane reforming is one pathway). As the US, EU, and California look to reduce reliance on fossil-fuel energy sources, introducing new fossil-fuel based products to the auto market would be counterproductive to achievement of these goals.

In summary, while CO_2 meets the definition of an ultra-low GWP refrigerant, based on minimal recent use in light duty EV vehicles in Europe, it brings issues related to cost, performance, reliability, range impact, and more. In addition, quick retrofit of HFC-134a cars to CO_2 in the field is not an option.

Propane (R-290)

R-290 has a GWP of 4 and is under evaluation now as a possible ultra-low GWP refrigerant for future EV production. However, it has not been commercialized for automotive use. There are several issues with propane in EV thermal management systems. The primary concern is the flammability of the fluid which, as noted elsewhere, is rated as A3 by ASHRAE (i.e., highly flammable). Propane has a very low lower flammability limit making it flammable even in low concentrations of air. It has a very high flame propagation speed which tends to make it more explosive. It requires very little energy to ignite (0.25 mJ – less than a typical static spark) and it gives off significant energy when burned. The high amount of energy released makes it likely that a refrigerant ignition could translate into a vehicle fire.

Propane is being studied in a dual secondary loop application to try to mitigate flammability. This creates a relatively small compact system that can be mounted in such a way as to reduce (not eliminate) refrigerant leaks in a collision. The system uses a chiller to refrigerate coolant that is then pumped into a heat exchanger in the cabin for cooling. This reduces the possibility of propane getting into the cabin. The system also uses a heat exchanger to transfer heat to a

[9] RTOC-assessment -report-2022.docx (unep.org) (page 194 and 197); An updated review of recent advances on modified technologies in transcritical CO2 refrigeration cycle - ScienceDirect (introduction); R1234yf and R744 as alternatives to R134a at mobile air conditioners (abstract) "An efficiency drop also occurs with HFC systems when the ambient temperature increases, but the change is not as great as it is with R744 when the change is from sub- to transcritical". CO2 as a Refrigerant — Introduction to Transcritical Operation (copeland.com)

second coolant loop that circulates the coolant to a radiator in front of the vehicle. That said, requiring two secondary loops adds significant cost to the system and significantly reduces its efficiency. It is also doubtful that the system would have sufficient capacity in hot weather. The condensing side of the circuit would struggle to develop significant temperature difference with the air to be effective in very hot weather.

A study has been initiated within SAE international to develop a flammability risk assessment for this type of system. Initial work suggests that additional mitigation features will be necessary to mass produce an acceptable risk system for vehicle production. Developing these mitigation features will take time, testing and development, and will add additional cost to a system that already has cost burdens over traditional refrigerant systems. This technology is neither ready-now nor near-term.

Finally, propane is an industrial gas produced by the fossil fuels industry. As the US, EU, and California look to reduce reliance on fossil-fuel energy sources, introducing new fossil-fuel based products to the MVAC market would be counterproductive to achievement of these goals.

Low GWP refrigerant blends (e.g., R-474A)

Recently, a few lower GWP refrigerant blends have been proposed by refrigerant producers specifically for use in EV thermal management systems. Most of these blends are developed to meet a 150 GWP limit and many of these are not considered ultra-low or no-GWP refrigerants under CA SB 1206 definitions. R-474A is a blend that has a GWP of less than 1 and is comprised mostly of R-1234yf. There has been no risk assessment or long-term testing run on this blend yet and it certainly is not ready-now. Blended refrigerants often claim range improvements and improvements in low temp heating performance, however not a single carmaker anywhere in the world is using one in production. This is likely because R-1234yf has demonstrated better performance and/or superior economics vs. the proposed blends. Some refrigerant blends show azeotropic behavior and act as a single fluid would while others are zeotropic in behavior and separate during evaporation. The difference between the boiling temperatures in a zeotropic blend is generally referred to as “glide”. While blended refrigerants are commonly used in stationary applications because glide can be managed and even optimized by appropriate evaporator design, automotive systems do not work in this way.

Refrigerants with high glide will create significant problems for compressor control in a vehicle because changes in refrigerant flow will affect where the different refrigerants boil in the evaporator. This is the primary reason why blended refrigerants with glide have never been used in automotive applications. R-474A shows high and variable glide at common evaporator conditions (the glide varies based on the evaporator pressure). Accounting for these variable conditions will reduce capacity and system efficiency of R-474A systems. R-474A also runs at significantly higher pressures than current refrigerants which will cause some component re-design and will add cost. Nonetheless, concerns for consumers on range loss in cold weather are real and do represent one of the barriers for acceptance of electric vehicles to the wide population.

R-474A is also not SNAP-listed by the US EPA and currently no entity has submitted a SNAP application for its use in MVAC. The approval process would take more than a year and would undoubtedly come with use restrictions based on the other blended refrigerant begin rated as a B2 refrigerant (higher toxicity and significant flammability). Not knowing what the final use restrictions could be makes it difficult for the industry to invest in R-474A. Refrigerant blends are not ready solutions (now or later) for the MVAC sector.

<u>Question 16.</u> What barriers exist for the transition of medium-duty, heavy-duty, and off-road vehicles to ultra-low-GWP and/or no-GWP alternatives?

Honeywell does not see significant barriers to transition any of these sectors to ultra-low GWP refrigerants. SNAP listing has been granted for the use of ultra-low GWP R-1234yf refrigerant in newly manufactured passenger cars, light-duty trucks, medium-duty passenger vehicles, heavy-duty pickup trucks, complete heavy-duty vans, and nonroad *(off road)* vehicles. EPA also recently finalized a rule to restrict the use of refrigerants with GWPs above 150 in these vehicle types.[10] All of the hardware needed to convert these vehicle types to R-1234yf on the assembly line is readily available. R-1234yf is available at more than 15,000 auto parts stores across the USA in professional or in DIY packaging. R-1234yf is a ready-now solution for these vehicle types. Concerning new heavy-duty vehicles, Honeywell is working with partners to finalize and submit a SNAP application to EPA for the use of 1234yf in heavy duty on-road vehicles. This is expected to be submitted in October 2023 and feedback from EPA could be received by the end of 2024.

<u>Question 17.</u> What are the opportunities and barriers for transitioning MVAC systems in existing light-duty, medium-duty, heavy-duty, and off-road vehicles to ultralow-GWP and/or no-GWP alternatives?

Transitioning existing MVAC vehicles (currently using HFC-134a) to ultra-low GWP and or no-GWP refrigerants could be possible in the near future by using R-1234yf. Honeywell has worked with our partners to recently submit a SNAP application to EPA to allow the use of R-1234yf as a retrofit fluid for servicing of these types of vehicles that are operating in the field with HFC-134a. We expect the EPA to review this application and provide guidance in 2024. Other ultra-low GWP and/or no-GWP refrigerants cannot be used in this way. As mentioned previously, CO_2 systems require all new components/controls and would require a time-consuming customized solution in each individual application that would not make commercial sense. Further, CO_2 cannot be used as retrofit fluid in the aftermarket for servicing older 134a units. R-290 (propane) would also take an extensive under-hood hardware rework and customization to create the secondary loop architecture necessary. Propane and R-474A have not been approved for use in any vehicles and are not currently suitable for retrofitting any vehicle with HFC-134a. Customized retrofits would also have questionable safety conditions and it would be difficult to assess the safety of each iteration. Blended refrigerants like R-474A would also have major challenges as a retrofit fluid and would also require extensive customized solutions per vehicle at high cost.

<u>Question 18.</u> What are the opportunities and barriers for transitioning the MVAC systems in new light-duty, medium-duty, heavy-duty, and off-road vehicles to ultra-low GWP and no-GWP alternatives?

R-1234yf is a ready-now, ultra-low GWP solution for all types of vehicles when newly built—and after SNAP listing, is expected to be used for retrofits of HFC-134a vehicles.

[10] EPA's Technology Transitions Rule, 88 FR 73098.

New CO_2 system vehicles would require safety testing for service and collision conditions as well as cabin exposure testing to determine the effectiveness of any CO_2 sensors. SAE International standards would need to be developed to account for good CO_2 system design practices and to specify CO_2 purity and R&R machine standards. An original attempt was made to develop these standards within SAE but there was a lack of interest from the European manufacturers looking into commercializing CO_2. All work on these standards has stopped.

There are currently no standards for R-290 use in vehicles at all. Significant safety testing would be required to ensure that refrigerant ignition and vehicle fires do not pose unacceptable risk.

There are currently no standards for blends like R-474A. A SNAP submission has not been developed and a formal risk assessment has not been done. No purity specifications have been established or fittings defined to charge or recover the refrigerant.

Section 7: Workforce Training

Question 32. What workforce training will be required for technicians to transition to ultralow GWP and/or no-GWP alternatives?

Ample training material exist and currently available to technicians after the advent and approved use of A2Ls. Because of the similarities between some HFOs and HFO blends with refrigerants such as R-410A and R-404A, the general service and maintenance practices, procedures, and trainings applicable to these A2Ls are similar to existing HFC refrigerants. Honeywell encourages CARB to make this training mandatory and require proof of certification for purchase of refrigerant. Further, rigid training should be developed and mandatory for A3 refrigerants due to their flammable and explosive nature. Mandatory training should also be established for servicing high-pressure CO_2 systems due to their complexity and extremely high operating pressures. Making training mandatory will help increase technician awareness of how to handle mildly flammable solutions and other alternatives.

Section 8: Other Non-Refrigerant HFC Sources (Fire Protection, Aerosol Propellants, Foams, Solvents, MDI)

Question 35. Are there emerging technologies for non-refrigerant HFC end-uses (including products with application-specific allowances) that show promise in addressing the transition to ultra-low GWP or no-GWP alternatives?

Foams

In the case of foam blowing agents, most of the high-GWP blowing agents have been already replaced with low or ultra-low GWP blowing agents. HFO-1234ze(E) and HFO-1233zd(E) both have GWPs of 1 are already in wide use in a broad range of blowing agent applications. Both of these HFO blowing agents provide excellent insulation performance and are safe and cost effective in their intended applications. Honeywell supports CA's intended implementation of the state's 150 GWP limit for this sector as this approach standardizes CA with the US EPA approach. Furthermore, Honeywell supports further reduction of this GWP limit to achieve goals set out in SB 1206.

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Metered Dose Inhaler Propellants

The majority of metered dose inhalers (MDIs) produced today use HFC-134a. AstraZeneca is partnering with Honeywell to develop an MDI that uses HFO-1234ze as the propellant.[11] This product is expected to be commercially launched in 2025. The product has a GWP less than 1, is nonflammable, and is currently being evaluated by other MDI producers. While there are other possible delivery methods for administering critical medicines, each delivery method has different attributes that limit adoption. Dry powder inhalers require the user to inhale deeply to get the medication into the lungs to be effective, which may be difficult for elderly or very young patients, or those with certain respiratory conditions such as Chronic Obstructive Pulmonary Disease (COPD) or for someone suffering from a sudden asthma attack. Nebulizers are another option, but they often take 5-15 minutes to deliver the medicine and are bulky and less portable than typical inhalers.

Aerosols

Over the past several decades, industrial gas technologies have been adopted in the vast majority of aerosol applications. Presently, HFC-134a and HFC-152a are used in a few applications. Honeywell believes that even those few remaining HFC aerosol applications can transition to ultra-low GWP HFO-1234ze which is non-flammable, non-VOC and with a GWP less than one, aligned with the GWP phasedown limits set forth in SB 1206. Honeywell is not aware of any significant technical barriers to eliminating HFC from all aerosol applications. While other non-fluorinated propellant options exist, they all have limitations. Hydrocarbons are the leading propellant in aerosols, but their high flammability makes them unsuitable for certain applications with exposure to charged electrical circuits and open flames of other similar flammability risks. In addition, hydrocarbon propellants are volatile organic compounds (VOCs) which contribute to ground level ozone. Compressed gases such as CO_2 or Nitrogen can be used in certain applications, but as the aerosol can is used the vapor pressure inside the container drops significantly, impacting the spray pattern and droplet particle size, delivery rate, velocity and length of the stream emitted from the aerosol container. In addition, CO_2 cannot be used with water-based formulations because it forms carbonic acid inside the aerosol container. Pump sprays are also viable for certain applications but pumps generally create coarse sprays with high water content that is often sticky and slow drying.

Solvents

Over the past several decades, many low GWP technologies have been adopted in several solvent applications. These products have varying performance against a range of attributes including effectiveness, safety, cost, environmental impact and ease of use. No one product meets all of the needs of all of the solvent applications. In a few critical high value applications such as precision cleaning, oxygen system cleaning, flushing applications and carrier fluid, high-performing ultra-low GWP, VOC exempt, nonflammable HFO based products provide the required cleaning and carrier fluid properties and safety for these important applications. Given the highly diverse range of applications and performance needs for solvents Honeywell supports

[11] https://www.honeywell.com/us/en/press/2022/02/honeywell-teams-with-astrazeneca-to-develop-next-generation-respiratory-inhalers-that-use-near-zero-global-warming-potential-propellant

allowing a range of options to permit users to select the optimal solvent for their specific application.

Fire suppression

Honeywell has recently introduced an ultra-low GWP product for total flooding fire suppression application.[12] The product is a 50%/50% blend of HFO-1233zd and FK5-1-12 with a GWP of 1. This product has been SNAP-listed and is included in the NFPA and ISO Global Standards. In addition, the product is UL listed. This product is currently being evaluated by a number of fire suppression equipment producers.

Section 10: Overarching Questions

<u>Question 38.</u> What factors around PFAS (per- and polyfluoroalkyl substances) should be considered as California transitions to ultra-low- and/or no-GWP alternatives?

As California continues implementation of SB 1206, CARB should consider collaborating with US federal authorities and aligning with the National PFAS Testing Strategy laid out by the Biden administration's EPA. None of the present regulatory actions proposed at the federal level—whether it be on the recently published guidance on PFAS reporting per the TSCA reporting rule,[13] the PFAS framework for addressing future PBT chemistries,[14] or the PFAS TRI reporting[15]—structurally capture HFOs 1233zd, 1234ze, or 1234yf or their breakdown chemistries.

In addition, Honeywell echoes the concerns highlighted by Governor Newsom's recent veto statements for AB 246, 727 & 1423 expressing reservations that each of these bills prohibiting PFAS in a wide range of consumer products lacks adequate regulatory oversight and suggested that the Department of Toxic Substances Control work to find alternative approaches for regulating chemicals in consumer products.

An impactful avenue could involve fostering stronger collaboration between CARB and the EPA's Office of Air and Radiation (OAR) on their PFAS strategy. As highlighted in the most recent SNAP 25 publication by EPA's OAR, EPA clearly states:

> *"In evaluating alternatives using its comparative risk framework, SNAP already considers potential risks to human health and the environment. Regardless of what definition of PFAS is used, not all PFAS are the same in terms of toxicity or any other risk. Some PFAS have been shown to have extremely low toxicity, for example. If a chemical has been found to present lower overall risk to human health or the environment, it might be found acceptable under SNAP regardless of whether or not it falls under a particular definition of PFAS. Likewise, SNAP might not find a potential*

[12] https://sustainability.honeywell.com/us/en/initiative/solstice-quench#physical-properties
[13] See 88 FR 70516
[14] https://www.epa.gov/system/files/documents/2023-06/PFAS%20Framework_Public%20Release_6-28-23_Final_508c.pdf
[15] See 88 FR 41035

alternative acceptable if it presented greater overall risk, regardless of whether or not it falls under a particular definition of PFAS."[16]

The alignment of CARB's approach on PFAS with the EPA OAR is of paramount importance to ensure a cohesive and comprehensive response to addressing PFAS issues. Failure to do so could result in regulatory inconsistencies, enforcement challenges, and a lack of standardized protection measures for both public health and the environment.

<u>Question 39.</u> What types of ultra-low GWP and/or no-GWP pilot or demonstration projects from other regions or countries could be implemented in California? Please be specific as to types of equipment/applications.

Honeywell is interested in working with California on small-scale demonstration projects involving HFO-1234yf in motor vehicles. One project could be retrofitting existing light-duty motor vehicle air conditioning systems that currently use HFC-134a with HFO-1234yf. EPA has approved use of 1234yf in many vehicle types and risk assessment data has shown that retrofitting 134a to 1234yf in specific types of existing MVACs can be done safely.

Honeywell would also be interested in working with California on the use of low GWP insulation in net zero energy homes, multifamily units, and commercial buildings to reduce energy usage in the state.

<u>Question 41.</u> Do you have any suggestions for legislative, or regulatory changes that are needed to transition away from HFCs and to ultra-low GWP and/or no-GWP alternatives?

Although ultra-low GWP HFO 1233zd is able to be used in many sectors, it is not yet VOC exempt in the state of CA. This prevents wider adoption of this important product in a number of end-uses, and receipt of VOC exemption would increase adoption. Honeywell worked to submit information supporting VOC exemption of this product to CARB and OEHHA in the past, and would be interested in following up to address any outstanding questions.

Next, as California implements SB1206 and its state-wide HFC phasedown, alignment with Federal AIM Act implementation and especially with technology transitions GWP limits[17] is of paramount importance. Industry worked closely with the US EPA to implement GWP prohibitions in many sectors established by recent EPA rulemaking, and ensured transition timelines and limits were achievable. As California implements increased standards and requirements around HFCs, it should coordinate wherever possible with the EPA to ensure elimination of redundance or duplicative requirements.

Finally, global warming potential is an important but partial measure of an HFC-replacement's climate impact. Alongside GWP, Honeywell would support CARB's continued assessment of total lifetime emissions associated with a product's final use, which would include system manufacturing, energy consumption, and water consumption. Safety is another consideration for any HFC replacement, and should be a criteria for prioritization in future regulatory action. Reviewing these together will ensure a holistic approach to the HFC phasedown that best

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[16] See 88 FR 26382

[17] See 88 FR 73098

prevents the transition to regrettable substitutes which could be energy inefficient, unsafe, or costly to consumers.