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March 8, 2018

Mary Nichols, Chair
California Air Resources Board
1001 I St
PO Box 2815
Sacramento, California 95812
Via online submission

RE: Comments by Honeywell International Inc. on Proposed Regulation for Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration and Foam End-Uses

Dear Chair Nichols,

California Air Resources Board (CARB) Staff has proposed regulatory language that would adopt the U.S. EPA's dates by which uses of hydrofluorocarbons (HFCs) in certain applications are unacceptable under the Significant New Alternatives Policy (SNAP) program of the federal Clean Air Act. CARB Staff is proposing to incorporate only those phase out dates that apply to certain stationary refrigeration, air conditioning, and foam applications.

Honeywell strongly supports the proposed regulation, but urges CARB to extend this proposed action to include the phase out dates set by SNAP Rules 20 and 21 for all applications addressed by those rules. Doing so would provide certainty to California businesses and continue the transition to low-global-warming-potential (GWP) substitutes that is already well underway.

We applaud CARB's leadership in taking steps to reduce HFC emissions 40% from 2013 levels by 2030. CARB should take the following actions that will have an immediate impact and send a clear signal that California will continue to support and lead the transition out of high-GWP HFCs. We believe item (1) on aerosols can be and needs to be implemented quickly in the current rule, while items (2)-(4) can be implemented in subsequent rules, but in 2018.

(1) **Aerosol Propellants**. CARB should include aerosol propellant end-uses in the proposed regulation. The EPA SNAP 20 rule prohibited HFC-134a in consumer aerosol products as of July 20, 2016. As far as we know, all users of HFC-134a in non-exempt applications have transitioned away from HFC-134a to low climate-impact solutions. **This is an easy, no-additional-cost action to implement quickly, since the transition is already complete, and it is imperative that it be included in the current rule.** On the other hand, not including aerosols in the proposed action would likely result in most aerosol product manufacturers reverting to using HFC-134a propellants, immediately *increasing* annual HFC emissions in California by as much as 1-2 million metric tons CO_2e. Product manufacturers can switch back to an HFC propellant in a matter of weeks to months. We are hearing from our customers that many are seriously considering, if not already taking steps toward, conversions back to HFC-134a.

(2) **Mobile Air-Conditioning**. CARB should plan for future phase out of HFC-134a in mobile air-conditioning as near to model year (MY) 2021 as possible. Automakers are transitioning to low-GWP solutions in this application, owing in no small part to EPA's SNAP 20 phase out date for HFC-134a in mobile air-conditioning. A clear signal from CARB will maintain the momentum of conversions in this end-use.

(3) **Foam-Blowing Agents**. Expand the proposed regulation to include all foam applications covered by SNAP Rule 20 and SNAP Rule 21. As currently written, the proposed regulation includes only foam applications with phase out dates

that have already past. While CARB has indicated that applications that were targeted for later dates will be included in future CARB regulations, the industry needs certainty now to continue planning for future phase out dates.

(4) **Stationary Refrigeration**. Honeywell supports CARB's proposed adoption of EPA SNAP dates for some stationary refrigeration end-uses and urges CARB to take further action as described below.

Adoption of all SNAP 20 and 21 dates would continue California's long history of demonstrated leadership on environmental policy. We expect that other states will view California's approach as a simple and relatively easy way to drive significant greenhouse gas emissions reductions in the face of regulatory uncertainty at the federal level. CARB's continued action will provide continuity, business certainty, and environmental benefit in an area where the successful transition to environmentally preferable solutions is already well underway. The transition is at a high risk of disruption absent clear regulatory action from California and other states. We appreciate the opportunity to comment on this critical regulatory proposal and expand on our four main points below.

1. **Aerosols: CARB Should Explicitly Include All Aerosol End-Uses Covered by EPA SNAP Rule 20**

As stated earlier, many aerosol applications that used high GWP HFC-134a have already transitioned to lower GWP solutions because of EPA's SNAP 20 rule, which had a phase out date of July 20, 2016. From our discussions with CARB, it has become clear there was confusion about whether those applications were included in the California Consumer Products regulations prohibiting certain consumer products using propellants with a GWP of 150 or greater. In fact, many of the major aerosol applications (e.g., tire inflators) are actually NOT included in the Consumer Products regulation. So it is imperative that CARB act immediately to ensure that the aerosol applications included in SNAP 20 do not revert back to HFC-134a. EPA SNAP Rule 20 prohibits HFC-134a, HFC-227ea, and blends thereof, in all propellant applications, except in certain end-uses listed in the rule.

We have identified the following applications in which use of an HFC propellant would be unacceptable under the SNAP Rule 20, but would not be covered by the current GWP prohibition in the California Consumer Products regulation:

- Tire inflators-unacceptable 7/20/16
- Silly string- unacceptable 7/20/16
- Disinfectant spray-unacceptable 7/20/16
- Mine warning devices- unacceptable 7/20/16
- Smoke detector functionality testing[1]- unacceptable 1/1/18
- Personal care products- unacceptable 7/20/16
- Rust/corrosion inhibitors that are not lubricants- unacceptable 7/20/16

Manufacturers of these products have converted to low-GWP solutions and because it is relatively easy to switch propellants in these products, there is an almost certain likelihood that they would revert to use of an HFC propellant absent additional action by CARB. Manufacturers of the products listed above can switch back to an HFC propellant in a matter of weeks to months. We are hearing from our customers that many are seriously considering, if not already taking steps toward, conversions back to HFC-134a. If companies selling aerosol products in California were to switch back to HFC-134a in the above applications, **emissions in California would increase by 1-2 million metric tons CO_2e annually**, further adding to California's already challenging goal of reducing HFC emissions 40% from 2013 levels by 2030.

We suggest revising the proposed regulatory language in the following way to include the applications already covered by EPA's SNAP Rule 20.

Add the following to Table 1 of the proposed regulation:

[1] Sensitivity testing would still be acceptable.

§ 95374. List of Prohibited Substitutes.

(a) The following table lists prohibited substitutes as of their relevant dates:

Table 1: End-use and Prohibited substitutes.

General End-use	Specific End-use	Substitute	Status and Effective Date
Aerosol propellants*	Tire inflators	HFC-125, HFC-134a, HFC-227ea, and blends thereof	Prohibited as of September 1, 2018
	Silly string		
	Disinfectant spray		
	Personal protection		
	Mine warning devices		
	Smoke detector devices (functionality testing only)		
	Personal care products		
	Rust/corrosion inhibitors that are not lubricants		

*Note: aerosol propellants with a global warming potential of 150 or greater are prohibited in other consumer products that are listed in Table 94509(n)(1) of California Code of Regulations, title 17, section 94509.

Add a similar enforcement provision for the aerosol sector to the one that CARB has already issued for the foam sector:

Insert in proposed "section 95375. Requirements", a new paragraph (e) as follows,

(e) *Disclosure and Recordkeeping for Aerosol End-Use Categories.*

(1) *Disclosure Statement*. As of the effective date of this subarticle, any person who manufactures for sale or enters into commerce in the State of California any aerosol product in an end-use category listed in Table 1 [see additions above], section 95374 of this subarticle, must provide a written disclosure to the buyer as part of the sales transaction and invoice. The required written disclosure must state: "*The propellant in this aerosol product is a California compliant propellant in accordance with California Code of Regulations, title 17, section 95374. This disclosure statement has been reviewed and approved by [THE COMPANY] and [THE COMPANY] attests, under penalty of perjury, that these statements are true and accurate*."

(2) *Recordkeeping*. As of the effective date of this subarticle, any person who sells or places into commerce in the State of California, any aerosol product in any end-use category as listed in Table 1, section 95374 of this subarticle, must maintain for five years and make available, upon request by the California Air Resources Board's Executive Officer, a copy of the following records:

(A) Name, address, telephone number, and email address of the person purchasing the aerosol products for sale.
(B) The type of aerosol end-use category.
(C) Date of manufacture of the aerosol product.
(D) Date of sale of the aerosol product.
(E) The propellant used in the aerosol product.
(F) The complete invoice containing the disclosure statement.

We urge CARB to amend the proposed regulatory language to include aerosol propellants as described above.

2. CARB Should Plan for Future Phase Out of HFC-134a in Mobile Air-Conditioning as Near to MY21 as Possible

We ask CARB to be mindful of the importance of a regulatory measure prohibiting HFC-134a in motor vehicle air-conditioning (MAC). The air-conditioning credits available to automakers in meeting CARB's emissions standards provide valuable incentives for transition, but the credits are not sufficient to drive a complete conversion from HFC-134a. A phase out date would provide needed certainty for industry and the environment.

As Staff points out in the Initial Statement of Reasons (ISOR) for this proposed rule, HFC emissions from light-duty mobile air-conditioning systems account for two-thirds of the total emissions from end-use sectors not covered by CARB's proposed rule. While many automakers have switched (about 60% of new light-duty vehicles sold in the U.S. in 2018 will use HFO-1234yf), regulatory uncertainty in this space could slow or reverse adoption. The combination of a HFC-134a use ban and the EPA GHG credit system have been highly effective at motivating carmakers to end their use of HFC-134a in new vehicle production. Since California already has a similar credit system in place, we would highly recommend that CARB backstop that rule with an HFC-134a use ban similar to the provisions of SNAP Rule 20. We encourage CARB to make the use ban effective as soon as possible to deter carmakers from moving back to HFC-134a.

Without regulatory certainty, the transition of California's fleet to low-GWP MAC solutions would back slide, increasing emissions in California. We urge CARB to adopt a phase out date for HFC-134a in MAC as near to the EPA phase out date as possible, MY21.

3. Honeywell Supports CARB's Planned Adoption of Additional Phase Out Dates for HFCs in Foam End-Uses

Honeywell supports CARB's move to include phase out dates for HFCs in foam end-uses, where EPA phase out dates are already in effect, in the proposed regulations. The ISOR states that CARB plans to adopt additional regulations addressing the remaining foam end-uses in implementing the Short-Lived Climate Pollutant Strategy. We look forward to CARB's additional planned regulations and urge CARB to include phase out dates that are at least as soon as the dates in EPA's SNAP 20 or 21 rules for the remaining foam end-uses.

Low-GWP solutions are widely available for appliance, panel and spray foam applications and transitions are underway. Anticipating a January 1, 2020 transition date for most polyurethane foams and January 1, 2021 date for extruded polystyrene, most foam manufacturers have technically qualified low-GWP solutions and a majority of them are even selling them commercially (see Figure 1 in the attached Appendix). In the absence of regulation, there is a significant risk that the transition to low-GWP blowing agents will not continue and the industry will revert / continue to use HFC blowing agents, adding to California's already challenging goal of reducing HFC emissions 40% from 2013 baseline in 2030. Further, foam use is highly correlated with economic growth as it is used extensively in construction and appliance industries; with increasing population and economic growth that California is experiencing, foam use, and with it HFC emissions, will grow rapidly. Adopting the SNAP phase out dates for foam applications could reduce 2-3 million metric tons of CO2e in California over the entire life of the foam.[2]

4. Honeywell Supports CARB's Proposed Adoption of EPA SNAP Dates for Some Stationary Refrigeration End-Uses But Urges CARB To Take Further Action

We applaud CARB's quick action to propose these regulations adopting EPA SNAP phase out dates for HFCs in certain refrigeration end-uses. This action will continue the significant reductions achieved by the EPA SNAP regulations—California can reduce annual HFC emissions by about 1.2 million metric tons CO_2e from its approximately 2,800 supermarkets alone.

[2] This number represents 12.5% of total U.S. CO_2e reductions resulting from replacement of high-GWP blowing agent with a low-GWP blowing agent. Near-term reductions, prior to end-of-life emissions, would be about 700,000 mmtCO_2e per year in California.

With respect to other refrigeration and air-conditioning applications, we understand that it is Staff's intention to include HFC prohibitions in later rulemaking actions that will implement the Short-Lived Climate Pollutant measures. We generally support those efforts, but offer a couple of caveats, as follows:

Applications	CARB Proposal	Honeywell Position	Comments
Sales restrictions on refrigerants	2020, no GWP ≥ 2500 or greater 2024, no GWP ≥ 1500	✓	Most impactful overall approach – It influences the total market and yields GWP improvements.
New refrigeration systems, 20-50 lbs	2021, no GWP ≥ 1500	✓	Safe, low-GWP solution is available today
New refrigeration systems, 50+ lbs	2021, no GWP ≥ 150	X	GWP > 150 would drive flammable options **Recommend GWP limit of 1500**, where safe solutions available
New a/c systems, including residential AC and rooftops, 2+ lbs	2021, no GWP ≥ 750	✓	A/C needs an A1 solution to be safe in the home and on rooftops. Honeywell solution available in 2019.
New low and medium pressure chillers (refrig. & a/c)	2021, no GWP ≥ 150	✓	HON supports a specific chiller carve-out; low-GWP solution available today. These applications are professional managed and very different than residential a/c. A2Ls are acceptable.
New high pressure chillers	2021, no GWP ≥ 150	X	GWP > 150 would drive flammable options **Recommend GWP limit of 750**; HON's A1 a/c development refrigerant can work in these applications

Honeywell is a global leader in providing energy efficient technologies and innovations that can help the world solve its energy and environmental challenges. Our Fluorine Products business is a recognized leading innovator in the development of environmentally preferable fluorocarbons for use as refrigerants, foam blowing agents, solvents, aerosol propellants, and other uses. Since the 1990s, we have helped businesses replace ozone-depleting substances in these applications with alternatives that have less impact on the stratospheric ozone layer and global climate change.

Attached is additional technical information that we provided to EPA in support of the proposed SNAP 20 and 21 rules, updated to reflect more recent data. We urge CARB to continue to support the transition to low-GWP alternatives already underway by continuing to adopt HFC phase out dates that are at least as soon as the phase out dates in EPA SNAP Rules 20 and 21.

Sincerely,

Sanjeev Rastogi

Sanjeev Rastogi
Vice President & General Manager
Fluorine Products
Honeywell Performance Materials & Technologies

APPENDIX: ADDITIONAL TECHNICAL INFORMATION

I. Aerosols

End-Use	Product	EPA Phase Out Date	Supporting Information	Supply of Alternatives
Consumer Aerosols	HFC-134a	July 20, 2016 for many applications, including tire inflators and novelty aerosols	• Multiple/wide-ranging low-GWP commercial products and/or shelf-ready prototypes currently available	• Large, commercial-scale plants for low-GWP alternatives in operation to supply global demand (Hydrocarbons, HFC-152a, HFO-1234ze(E), CO_2)
Technical & Medical Aerosols	HFC-134a	July 20, 2016, with exceptions	• Multiple/wide-ranging low-GWP commercial products and/or shelf-ready prototypes currently available	• Large, commercial-scale plants for low-GWP alternatives in operation to supply global demand (Hydrocarbons, HFC-152a, HFO-1234ze(E), CO_2)
All Aerosols Applications	HFC-125	Jan. 1, 2016	• Multiple/wide-ranging low-GWP commercial products and/or shelf-ready prototypes currently available	• Large, commercial-scale plants for low-GWP alternatives in operation to supply global demand (Hydrocarbons, HFC-152a, HFO-1234ze(E), CO_2)
All Aerosols Applications	HFC-227ea	Jan. 1, 2016, except in metered dose inhalers	• Multiple/wide-ranging low-GWP commercial products and/or shelf-ready prototypes currently available	• Large, commercial-scale plants for low-GWP alternatives in operation to supply global demand (Hydrocarbons, HFC-152a, HFO-1234ze(E), CO_2)

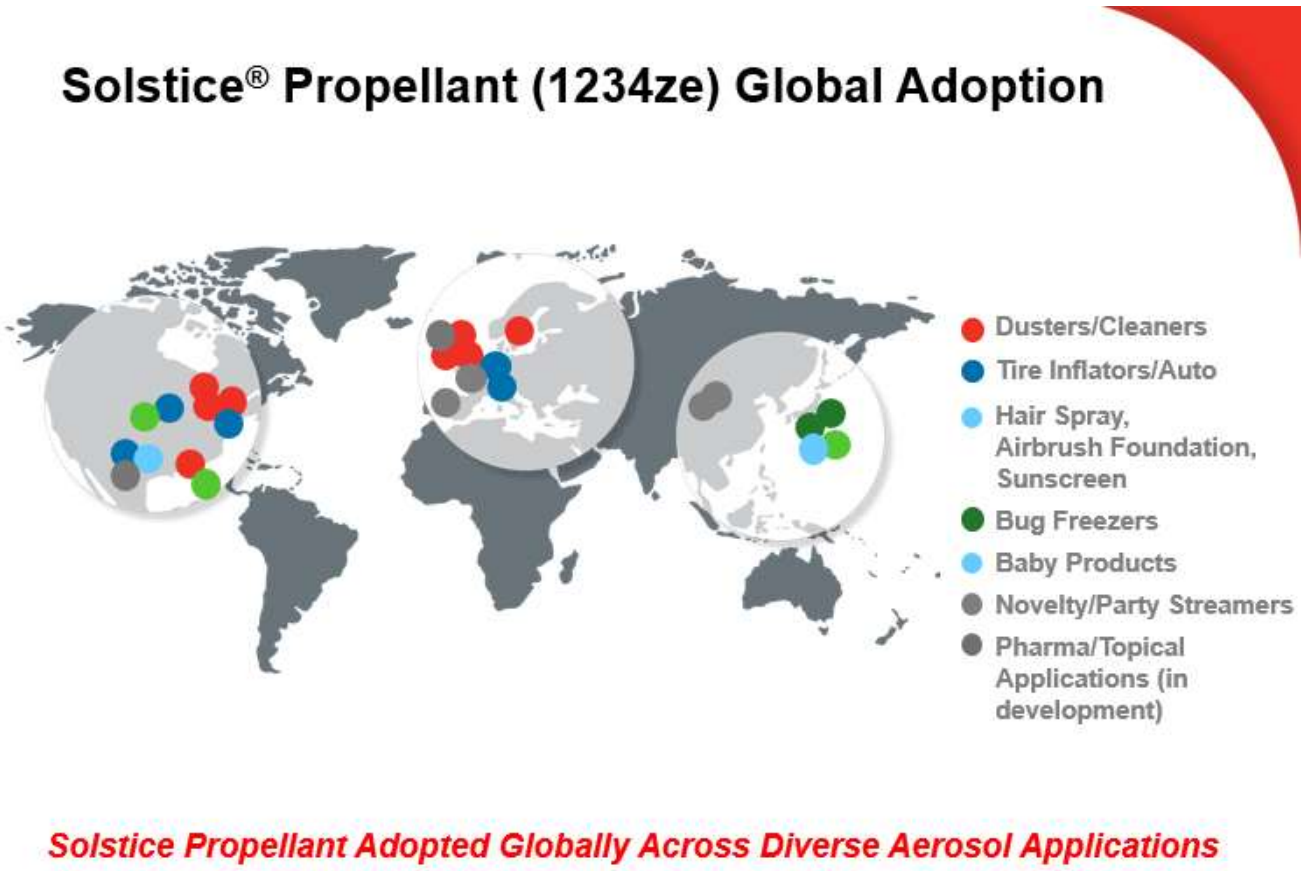
Aerosol product manufacturers have already transitioned away from HFCs, since EPA SNAP 20 Rule listed HFCs in many common applications as unacceptable as of January 1, 2016. Aerosol product manufacturers have several options that are listed as acceptable under SNAP and are currently available.

Honeywell has invested significant capital ($33 million) at its Baton Rouge, Louisiana manufacturing facility to ensure high-volume manufacturing capability for HFO-1234ze(E).[3,4] As announced on September 16, 2014, construction of the plant has been completed and commercial operations began in Q3 of 2014.[5] The investment provides more than sufficient capacity to meet growing demand for low-GWP product necessary for compliance with the EPA SNAP Rules 20 and 21.

Below is a map showing global adoption of Solstice propellant.

[3] http://honeywell.com/News/Pages/Honeywell-To-Invest-$33-Million-In-Louisiana-Facility.aspx
[4] http://honeywell.com/News/Pages/Honeywell-Announces-Investments-Of-$200-Million-In-Louisiana-Facilities-Backed-By-Tax-Incentive-Framework-Agreement.aspx
[5] http://honeywell.com/News/Pages/Honeywell-To-Increase-Production-Of-Low-Global-Warming-Materials-Reduce-Hydrofluorocarbon-HFC-Production-By-Nearly-Half.aspx

Figure 1.0 Global Adoption of Solstice in Propellant Applications



Aerosols manufacturers have already transitioned away from HFCs to other alternatives. Because transitioning to substitutes in the aerosols industry requires little investment, the uncertain fate of EPA's SNAP Rule 20 is likely to cause a large number of aerosols manufacturers to revert back to using HFCs. It is therefore critical that CARB extend its proposal to incorporate EPA SNAP Rule 20 by reference to the aerosols applications covered by that rule.[6]

II. Mobile Air Conditioning

End-Use	Product	EPA SNAP Phase Out Date	Supporting Information	Supply of Alternatives
Motor Vehicle Air Conditioning (MVAC)	HFC-134a	Model year 2021 (with narrowed use limits for export to countries without servicing infrastructure through model year (MY) 2025)	• The EU MAC Directive prohibited the sale of new cars using HFC-134a in the EU28 countries as of Jan. 1, 2017 • Turkey has adopted a rule similar to the MAC Directive and will phase out use of HFC-134a in new vehicles starting Jan. 1, 2018 • Korean carmakers will begin voluntarily converting their local market cars from HFC-134a to HFO-1234yf starting Jan. 1, 2018 and should be completely converted by 2020. They have a rule similar to CAFÉ on the books now.	• HFO-1234yf commercial scale production has been expanded. Plants operating today in China, Japan and the US

[6] SNAP Rule 21 did not contain any unacceptability listing decisions for aerosol applications.

End-Use	Product	EPA SNAP Phase Out Date	Supporting Information	Supply of Alternatives
			• Only minor modifications to A/C system hardware have been made to convert car models from HFC-134a to HFO-1234yf use. • 60% of the new cars sold in the US in 2018 will already have been converted from HFC-134a to HFO-1234yf. The adoption of a SNAP-like rule and timeline will encourage OEMs to continue to convert their models. SNAP-approved; GWP = .31	

EPA's unacceptability listing for HFC-134a in this application will result in emissions reductions of approximately 10 million $MtCO_2e$ annually. The transition to low-GWP alternatives is well underway.

- All of the Tier 1 suppliers of A/C system hardware to the auto industry currently offer cost competitive A/C systems to accommodate alternatives to HFC-134a like HFO-1234yf. The U.S.-based car companies, including Ford, GM, and Chrysler, have already converted more than 70% of their production to HFO-1234yf ahead of the MY21 SNAP deadline. In the EU, the Motor Vehicle Air Conditioning Directive prohibited the sale of passenger cars using HFC-134a effective January 1, 2017. In anticipation of the phaseout, 100% of European production moved to HFO-1234yf in Q3 and Q4 of 2016 as the MY17 vehicles began production.

- Ford, General Motors, and Chrysler are already selling more than 30 models using HFO-1234yf including high volume models such as the Ford F-150 pickup, Ford Focus and Fusion, almost all of Fiat Chrysler's product line made for the U.S. market, and all of the high volume GM products including Chevrolet Silverado pickup trucks, Chevy Malibu and Impala and almost all of GM's SUVs. In total, 8.4 million new MY17 cars using HFO-1234yf were sold to owners in the U.S. In 2018, we expect 10 million cars to be sold in the U.S. market with HFO-1234yf, representing about 60% of the total market.

- Adequate refrigerant solutions exist. The EPA has already SNAP-approved HFO-1234yf, HFC-152a, and CO_2 (R-744) for motor vehicle air conditioning systems and, as noted above, low-GWP motor vehicle systems are currently in widespread use in the U.S. and Europe.

- Production capacity has been significantly expanded for HFO-1234yf around the world. There are multiple production sites operating today in China and in Japan. In addition, Honeywell initiated production at its world scale plant in Louisiana in April of this year.

- With respect to concerns about the flammability of low-GWP substitutes, not a single safety issue related to the use of HFO-1234yf in passenger vehicles has been reported, and today there are almost 40 million cars on the road globally safely using the new refrigerant. Other low-GWP options like HFC-152a are much more flammable than HFO-1234yf and may need more complex and costlier systems developed before they can be deployed safely in passenger vehicles. HFO-1234yf systems can safely utilize the same system architecture as HFC-134a systems, as documented by the Society of Automotive Engineers (SAE) study CRP1234, which adequately protects against any flammability risks. Using HFO-1234yf in motor vehicle A/C systems does not require a secondary loop design like an HFC-152a system would.

HFO-1234yf also has no measurable energy efficiency difference compared to HFC-134a systems. To the contrary, auto manufacturers that have tested and used HFO-1234yf in their vehicles have found that

systems designed for the properties of HFO-1234yf are at least as efficient as those using HFC-134a, and in some cases systems HFO-1234yf systems were found to be more efficient.

III. Blowing Agents in Foam Applications

End-Use	Product	EPA SNAP Phase Out Date	Supporting Information	Supply of Alternatives
Polyurethane Foams: Rigid, flexible, integral skin, board and bunstock	HFC-134a, HFC-245fa, HFC-365mfc, and blends	Jan. 1, 2017 (subject to narrowed use limits, which expire Jan. 1, 2022)	• Flexible and integral foam customers already transitioned away from HFCs	• HFO-1233zd(E) • HFO-1336mmz • Methyl formate • Water
XPS	HFC-134a, HFC-245fa, HFC-365mfc, and blends	Jan. 1, 2021	• Numerous alternatives approved by SNAP and in use • EU and Japan largely do not use HFC-134a • HFO-1234ze(E) offers both low-GWP and high energy efficiency (even better than 134a) • Low cost of transition – 5-9% higher board costs	• CO_2 • Butane • HFC-152a • HFO-1234ze(E)
Polyurethane foam applications (including appliances, commercial refrigeration, sandwich panel, marine flotation, high–pressure spray foams)	HFC-143a, HFC-245fa, HFC-365mfc and blends	Jan. 1, 2020	• Significantly lower GWP alternatives SNAP-approved • Quickest transition (6-18 months) and easiest application • Improved performance (energy efficiency) and lower cost (raw material yields) • Approximately half of Honeywell's foam customers have commercial low-GWP systems	• Water • HFO-1233zd(E) • HFO-1336mzz • Hydrocarbons • Methyl formate
Low-pressure spray polyurethane foams	HFC-134a, HFC-245fa and blends	Jan. 1, 2021 (subject to narrowed use limit)	• Low-GWP one-component foam commercial since 2008 • Low-pressure low-GWP two-component pour foam systems commercially available • Low-pressure two-component spray foam – technical solutions being developed and optimized	• HFO-1234ze(E) • HFO-1233zd(E) • Methyl formate • HFO-1336mzz

Recently, several customers across many applications have already transitioned from high-GWP to low-GWP foam blowing agents. Below is a select list of customers across various foam applications that are already selling products commercially:

- Extruded polystyrene (XPS)—Jackon, Abriso, Knauf, Fibran, Austrotherm
- Appliances—Whirlpool, Midea, Haier, Hisense, Festivo;
- Spray foam—Lapolla, Demilec, SES, NCFI, , Elastochem, Toyo, Asahi, BIP;
- Panel—Kingspan, All Weather Panel;

- Commercial refrigeration equipment—Porkka, Okamura;
- Refrigerated trailers—CIMC China; and
- One-component foam—Dow, Fomo, Soudal.

Across most applications, many additional customers globally are in various stages of commercial development. Some customers have only recently started trials and our expectation is that these customers will be able to reach commercial solutions well within the timelines established by the EPA SNAP 20 and 21 rules.

Customers have several available SNAP-approved options from Honeywell and other chemical manufacturers. According to EPA, even more options will become available in the near future. Honeywell is operating large-scale manufacturing plants for HFO-1233zd(E) and HFO-1234ze(E), which are replacements for HFC-134a, HFC-245fa, and HFC-365mfc. Chemours has full-scale production of HFO-1336mzz (a substitute for HFC-245fa, HFC-365mfc, and blends thereof). As noted above, several customers in the U.S. and abroad have adopted substitutes for HFC-245fa, HFC-134a, HFC-365mfc and blends thereof. Strong regulatory action will continue to drive conversions away from high-GWP HFCs to products with much lower climate impact.

In many instances customers are seeing benefits of better performance, energy efficiency, non-flammability, and better product yields (less foam for the same performance), in addition to greenhouse gas emissions reduction. For example, refrigerators made with HFO-1233zd(E) are 8-10% more energy efficient than those manufactured from flammable hydrocarbons and 2-4% more efficient than those that use HFC-245fa, so appliance manufacturers can either reduce foam thickness or improve energy efficiency at the same foam thickness. Similar energy efficiency benefits are being seen across spray foam and other foam applications as well, offering customers better performance and/or lower cost alternatives across a range of applications.

Many low-GWP substitute solutions, such as HFO-1233zd(E) for polyurethane (PU) foam or HFO-1234ze(E) for extruded polystyrene (XPS), are similar or better on a life-cycle analysis basis. They are of similar or better energy efficiency than the HFCs they are replacing and significantly lower in GWP. Hence their life-cycle impact is order(s) of magnitude better than the HFCs they are replacing. For example, a thorough life cycle analysis of HFC-245fa and HFO-1233(zd)(E) in closed-cell spray foam[7] showed that the impact of using HFO-1233zd(E) improved the GWP payback by up to 90% compared to HFC-245fa. Therefore, in addition to offering direct GWP savings, several substitutes for HFCs are expected to dramatically reduce the CO_2e emissions on a life-cycle basis as well.

a. HFC-134a in XPS Applications

For XPS users, several solutions are already available, listed as acceptable under SNAP, and have been in use globally for some time. For example, in Europe, approximately 80% of the industry uses solutions other than HFC-134a, including CO_2, HFC-152a, isobutane, and HFO-1234ze(E). Similarly, in Japan, all XPS is produced with alternatives to HFC-134a, such as isobutane and HFO-1234ze(E). All of the above solutions are listed under SNAP as acceptable and are available to U.S. customers, some of whom are already using these low-GWP technologies in other parts of the world. HFO-1234ze(E) has been commercial since 2008, and is being used by customers in Europe and Japan. Honeywell is now running a large, world-scale commercial plant in Baton Rouge, Louisiana, which started operating in September 2014.

[7] Bogdan and Pascual, Environmental assessment of next generation blowing agent technology using Solstice LBA in ccSPF, Polyurethane Magazine, 5 (2012).

Energy efficiency and cost are two important factors to consider in evaluating alternatives. First, with respect to energy efficiency, the table below shows that HFO-1234ze(E) is an excellent foam-blowing agent and results in energy efficiency properties that are comparable and in some instances better than HFC-134a. Vo and Fox from The Dow Chemical Company published a peer-reviewed study, which noted, "… [T]hermal insulation performance of foams obtained with HFO-1234ze(E) and co-blowing agents is very similar to those blown with HFC-134a produced today."[8] Jackon has been selling boards in the EU with energy efficiency that is better than HFC-134a since mid-2011 and four other EU customers are using HFO-1234ze(E) commercially. A major Japanese producer has also been commercially been selling boards made with HFO-1234ze(E).

Table 1.0 Comparison of Energy Efficiency Performance of Foam Blowing Agents[9]

Blowing Agent	**CO_2**	**HFC-134a**	**HFO-1234ze(E)**
Aged lambda (lower = better)	34-38	29-30	27-30
% improvement over CO_2	—	~12-15%	~12-20%

In addition to HFO-1234ze(E), which offers comparable or better energy efficiency as HFC-134a in XPS, companies like The Dow Chemical Company have commercialized other solutions to improve energy efficiency with CO_2. For example, Dow's XENERGY technology, according to Dow, is the "[t]hermal insulation of the future. XENERGY™ combines proven features of STYROFOAM™ with up to 20% higher insulating properties made possible by a new manufacturing process using CO_2 and reflecting particles in the foam cells. The result: reduced heating costs - increase efficiency, comfort and sustainability."[10]

b. HFC-134a in Polyurethane Applications

HFC-134a is also used extensively in PU foam in rigid applications, such as continuous and discontinuous panels, commercial appliances, and spray foam. Across the various applications, a variety of solutions are available, including hydrocarbons, methyl formate, formic acid, methylal, HFO-1234ze(E) and HFO-1233zd(E), and HFO-1336mmz. Both HFO-1234ze(E) and HFO-1233zd(E) have large-scale U.S. manufacturing plants: Honeywell's HFO-1233zd(E) plant began operating in May 2014 and HFO-1234ze(E) plant started up in September 2014. Chemours now operates a HFO-1336mmz production plant. Several customers in a variety of industries, including construction and commercial appliances have trialed HFO-1233zd(E) and HFO-1234ze(E) and are in various stages of transitioning to those substances. They are seeing benefits of not only significantly lower climate impact but also improved thermal insulation performance.

HFC-134a is used in three main PU foam applications, each of which is described below (and further described in comments by the Center for Polyurethanes Industry (CPI) and the American Chemistry Council):

- Low-pressure one-component foams: Honeywell's HFO-1234ze(E) has been commercially sold in the EU in low-pressure one-component foam since 2008 by companies like Dow, Fomo, Saudal. Hydrocarbons are also used extensively in these applications.

[8] Vo and Fox, *Assessment of hydrofluoropropenes as insulating blowing agents for extruded polystyrene foams*, JOURNAL OF CELLULAR PLASTICS, 49, 423 (2013).
[9] Honeywell analysis based on customer information.
[10] http://www.dow.com/products/market/construction/product-line/xenergy-extruded-polystyrene-insulation/

- Low-pressure two-component foams used in commercial appliance and other pour applications: Customers have several solutions that are low-GWP and acceptable under SNAP, including Honeywell's HFO-1233zd(E) and HFO-1234ze(E).

- Low-pressure two-component spray foams: Honeywell's HFO-1233zd(E) and HFO-1234ze(E) product and blends thereof are being technically proven in this application by several customers, several of whom are optimizing the product.

Overall, across all foam applications, including XPS and PU foams, customers have either commercialized non-HFC-134a solutions or have technically feasible solutions ready for commercialization, and there are sufficient number of SNAP-acceptable solutions to enable customers to transition to low-GWP substances relatively quickly. The relative cost of transition to low-GWP substances compared to continued use of HFC-134a has decreased dramatically, due in part to the rising costs of HFC-134a imported from China due to anti-dumping actions against Chinese manufacturers.

c. High-Pressure Spray Foam Applications for Polyurethane Foams

In Honeywell's view, this is the easiest and quickest application to transition. For example, high-pressure spray foam was one of the last applications that Honeywell started to commercialize with customers, but the first low-GWP product commercialized in the U.S. was in a spray foam application with West Development Group.

Several low-GWP and non-flammable alternatives have been listed as acceptable under SNAP for use in spray foam applications. Honeywell has been selling HFO-1233zd(E) commercially in this application since March 2013 in the U.S. and globally. HFO-1233zd(E) was also successfully trialed in Philippines by UNIDO in 2012. In the U.S., several customers, including small businesses such as Lapolla industries, Demilec, SES, and Elastochem, have commercialized low-GWP spray foam formulations containing HFO-1233zd(E). Several US customers have also commercialized spray foams with HFO-1336-mzz; these customers include Accella, BASF, Gaco Western, Natural Polymers. In Japan, spray foam made with HFO-1233zd(E) has been commercialized by numerous customers including Toyo, Asahi, and BIP. In our experience, in the U.S., it took just 6-18 months from start of development to a formulated system that was technically and commercially saleable, with all the requisite regulatory approvals. Further, several U.S. customers are close to commercial systems and will be undergoing product certification shortly. We expect the commercialization timelines to continue to shorten. The supply chain of additives (catalysts, surfactants) has also developed substantially, so customers have a wide variety of components to formulate with HFO-1233zd(E). As another proxy for how quickly spray foam can transition, recently, when new materials such as HFC-365mfc blends have come to market, the industry has indicated that it can transition rapidly, typically in less than six months.

Low-GWP alternatives in spray foam applications are high performance, low cost, and in ample supply. Customers who have already commercialized low-GWP spray foam based on HFO-1233zd(E) are seeing benefits of better energy efficiency as well as reduced cost. HFO-1233zd(E) has demonstrated better yields (more foam per pound of liquid component) by as much as 10-12%, which results in large cost savings. In addition, these foams have shown 4% to 8% improved energy efficiency, which means that customers can either improve the energy efficiency for the same thickness of foam or reduce the thickness to further bring

down cost. On a total life-cycle analysis basis, which includes both direct and indirect GWP, foams with HFO-1233zd(E) are shown to reduce CO_2e life-cycle emissions by up to 90%.[11]

These alternatives are available to supply the U.S. market. Honeywell's HFO-1233zd(E) large-scale plant started up in May 2014 and Chemours recently started operating its HFO-1336mmz plant. Below is a map showing the adoption of Honeywell's low-GWP foam blowing agents globally.

Figure 2.0 Global Adoption of Solstice in Foam Blowing Applications

[11] Bogdan and Pascual, Environmental assessment of next generation blowing agent technology using Solstice LBA in ccSPF, Polyurethane Magazine, 5 (2012).

IV. Stationary Refrigeration & Air Conditioning

End-Use	Product	EPA SNAP Phase Out Date	Supporting Information	Supply of Alternatives
New Retail Food Refrigeration and Vending Machines (stand-alone)	HFC blends R-507A, R-404A HFC-134a	Jan. 1, 2019/Jan. 1, 2020	• SNAP applications for HFOs are under review, (R-448A (Solstice® N40) for Vending Machines) after which full industry evaluation will occur • HFOs could provide optimal balance of safety, performance and GWP improvement • Adoption of hydrocarbons and CO_2 requires costly redesign; limited components are available for CO_2 systems	• R-448A is SNAP-approved in low-temperature (i.e., temperatures at or below 32°F (0°C)) stand-alone equipment • R-450A is SNAP-approved for vending machines and other applications and available today • Commercial quantities of HFO-1234yf available today, subject to SNAP approval for vending machines • Propane, R-744a supply available, subject to component availability
New Retail Food Refrigeration (Condensing Units and Supermarket Systems)	9 HFC Blends	Jan. 1, 2018 (condensing units); Jan. 1, 2017 (supermarkets)	• Multiple HFO blend options available today including R-448A and R-449A. They offer excellent performance and lower energy consumption compared to R-404A. • R-448A has been qualified with numerous manufacturers • Oak Ridge National Labs evaluation of R-448A showed excellent performance	• R-448A and R-449A currently being widely adopted
Retrofit Retail Food Refrigeration (Condensing Units and Stand-alone)	9 HFC Blends	July 20, 2016	• Multiple options exist today including R-407A, R-407F, R-448A, and R-449Awhich have been used successfully in thousand of retrofits • Extensive adoption is now occurring with R-448A	• R-407A and R-407F widely available and SNAP-approved • R-448A currently being widely adopted
New Chillers	HFC-134a, R-404A, et al	Jan. 1, 2024 (subject to narrowed use limits thereafter)	• HFOs have much lower GWPs • HFOs offer comparable or better energy efficiency • Time needed to allow for changes to standards, building codes, and industry training to handle mildly flammable refrigerants of some of the alternatives • There are multiple OEMs that have adopted HFO alternatives into their equipment	• Chillers are available today using both 1233zd and 1234ze • HFO-1233zd(E) and HFO-1234ze(E) are being produced in commercial quantities today • HFO-1233zd(E) and HFO-1234ze(E) are SNAP-approved for chillers • R-450A SNAP-approved and available today

a. Chillers

Alternatives such as HFO-1233zd(E), and HFO-1234ze(E) are both commercially available, SNAP-approved, and have comparable or higher efficiencies than HFC-134a and much lower GWPs than HFC and HCFC refrigerants currently used in chillers. Many of the leading chiller manufacturers have already introduced chillers with low-GWP refrigerants. Carrier and York/Johnson Controls also have lines of chillers

based on HFO-1233zd(E). Several other manufacturers currently offer high-efficiency chillers based on HFO-1234ze(E) in sizes ranging from tens of tons to hundreds of tons. These HFO-1234ze(E) chillers largely have been launched in the EU where the formal promulgation of the F-gas regulation has motivated manufactures to develop and commercialize these units. EPA SNAP 21 Rule has similarly accelerated commercial development in the U.S. CARB should continue to support this transition while the future of EPA's SNAP rules is uncertain.