

## **Preparing for Next-generation Air Conditioning and Refrigeration Technology**

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### **Abstract**

World leaders will reach a new global agreement on climate change in Copenhagen or later and responsible national governments are already implementing stringent limits on greenhouse gas emissions. Most significant to the choice of next-generation refrigerants and technologies is the global realization that high-global warming potential (GWP) HFCs are environmentally and economically unsustainable and will be phased down rapidly under the Montreal Protocol or a Climate Convention. Innovative companies and their suppliers have important targets of opportunity. New refrigerants are being commercialized with low global warming potentials, new technologies are being introduced with better energy efficiency, and natural refrigerants are gaining market share. In order to maximize the environmental benefits of next-generation air conditioning and refrigeration technology, it is important that new technologies have the highest achievable life-cycle climate performance. The challenge is to introduce new refrigerants and next-generation technologies where and when they are environmentally superior and to assure consumer safety and satisfaction. This presentation gives an overview of global and U.S. actions that promote next-generation refrigeration and air conditioning technology with better life-cycle climate performance (LCCP), focusing on refrigerant choice for mobile air conditioning as a case study. It also describes how government and industry strategies impact the choice of refrigerants and suggests ways that government and nongovernment organizations worldwide can cooperate in protecting the climate and fragile ozone layer.

### **1. Introduction**

Over the last year, there have been important climate change policy developments. For the first time, the world's two largest greenhouse gas emitters—China and the United States—have both pledged greenhouse gas emissions targets. In November 2009, China announced its first greenhouse gas target: by 2020, China aims to reduce its greenhouse gas intensity by 40 percent compared to 2005 levels. Also in November, US President Obama announced that at the international climate change meetings in Copenhagen, the United States would pledge to reduce greenhouse gas emissions 17 percent below 2005 levels by 2020, and 83 percent by 2050. These reductions are consistent with historic bill passed by the U.S. the House of Representatives in the summer of 2009; if the U.S. Senate votes to approve climate legislation, these targets will become law. Although these targets are not as stringent as those already passed in Europe and elsewhere, they give environmentalists and climate scientists hope that a global agreement can soon be reached.

At the same time a global climate agreement is being negotiated, developing nations are leading a strong push to turn the Montreal Protocol into a climate change treaty by giving it authority to phase down HFCs. In 2009, Mauritius and the Federated States of Micronesia proposed an amendment to the Montreal Protocol allowing it to take control of HFCs. The United States, Mexico, and Canada quickly followed suit, submitting their own proposal in favor of this action. Advocates of moving HFCs to the Montreal Protocol argue that the ozone treaty is better equipped to handle HFCs: they are used in the same applications as ozone-depleting substances; they can be

phased down in a timely manner using existing Montreal Protocol infrastructure; and the costs are likely to be lower, since under the Montreal Protocol, only the incremental costs required to change technology are paid. Although no agreement was reached at the Meeting of the Parties to the Montreal Protocol in 2009, the proposals are still very active and are gaining support.

These policy developments are driven in part by new scientific findings on the future role of HFCs in atmospheric forcing. HFCs have long been overlooked as a source of greenhouse gas emissions: although they are potent greenhouse gases, they currently comprise less than 2% of global anthropogenic greenhouse gas emissions. However, as developing countries prepare to eliminate HCFCs, the demand for HFCs is growing. This, combined with increasing demand for refrigeration, air conditioning, and vehicles equipped with air conditioning, has the potential to drive HFC use and emissions to very high levels. According to a recent article that appeared in the US Proceedings of the National Academy of Science, HFC emissions could grow to 28-45% of anthropogenic CO<sub>2</sub> emissions by 2050 if current rates of consumption are maintained.<sup>2</sup>

The message is clear: alternatives to high-GWP HFCs are needed, and quickly. HFCs are no longer acceptable or desirable.

## **2. What's next? New Refrigerants Invented, Old Refrigerants Re-visited**

For many people involved in refrigeration and air conditioning, it feels like just yesterday the world was evaluating alternative refrigerants, trying to identify acceptable substitutes for CFCs. Until recently, most experts believed that all alternative refrigerants had already been identified. That is why it came as a surprise to some when chemical companies announced in 2006 that they had invented new refrigerants. These announcements came shortly after Europe issued the MAC Directive, requiring that vehicle air conditioning systems use refrigerants with a GWP less than 150 for new vehicle types sold in the EU after 2011.<sup>3</sup> Within weeks of the MAC Directive publication, Honeywell announced a new refrigerant, called "H" (ozone depletion potential >0; global warming potential <10). Just days later DuPont announced "DP-1" (ozone depletion potential = 0, global warming potential ~40); and Arkema and SinoChem announced candidates. In early 2007, Honeywell and DuPont announced they were combining forces to commercialize a new refrigerant, JDH. However, by November 2007, DuPont and Honey had abandoned fluid H, DP-1, and JDH. DP-1 and JDP were abandoned for being judged by DuPont and Honeywell as too toxic. Fluid "H" was abandoned because it had stability problems, and possibly because the Assessment Panels of the Montreal Protocol raised environmental and health concerns about the toxic and ozone-depleting ingredient CF3I.

DuPont and Honeywell revisited their options and identified 2,3,3,3-tetrafluoropropene as a possible option. 2,3,3,3-tetrafluoropropene is an olefin (CH<sub>2</sub>=CF-CF<sub>3</sub>) and is designated as HFC-1234yf. However, chemical manufacturers prefer to call this chemical a hydro-fluoro-olefin, or HFO. ("Olefin" is the historic name for unsaturated hydrocarbon.) This HFO nomenclature is intended to distinguish the climate-friendly low-GWP HFOs from the common high-GWP HFCs that are considered by environmental NGOs and many governments as unsustainable and targeted for phaseout. HFO-1234yf has a GWP of only 4, compared to HFC-134a, which has a global warming potential of 1,430. HFO-1234yf is slightly flammable, and is categorized as A2L (lowest toxicity, low flammability). Although HFO-1234yf is being developed specifically for the vehicle air conditioning market, it is possible that

this or other new HFOs can be developed or optimized for other refrigeration applications.

While new refrigerants will undoubtedly play an important role in future refrigeration and air conditioning equipment, older refrigerants are also taking on an important new role. Ammonia, carbon dioxide, water, and hydrocarbons are seeing increasing use and application (see table 1).

**Table 1: Low-GWP Refrigerants**

<b>CFC, HCFC or HFC Application</b>	<b>Low-GWP Alternatives</b>
Domestic Refrigerators and Freezers	HC-600a HC-600a & HC-290 blend Unsaturated HFCs (also called HFOs)
Commercial Refrigeration	HF-600a HC-290 CO <sub>2</sub>
Large (Industrial) Refrigeration Systems	Ammonia CO <sub>2</sub> Hydrocarbons
Unitary Air Conditioning	Hydrocarbons in systems with small refrigerant charge HFOs CO <sub>2</sub> HFC-152a HFC-32
Chillers	Ammonia Hydrocarbons CO <sub>2</sub> HFOs
Vehicle Air Conditioning	HFO-1234yf CO <sub>2</sub>

Source: TEAP Task Force Decision XX/8 Report, May 2009

The challenge for the refrigeration and air conditioning sector is to introduce new refrigerants and next-generation technologies where and when they are environmentally superior, while maintaining performance, safety, and customer satisfaction. The following sector descriptions are adapted from the latest reports of the Montreal Protocol Technology and Economic Panel.<sup>4</sup> They describe the low-GWP options being considered in each sector:

<p><b>Low-GWP Refrigerant Options</b></p> <p><i>From the Montreal Protocol Technology and Economics Assessment Panel's 2009 Assessment of Alternatives to HCFCs and HFCs</i></p> <p><u>Domestic Refrigerators</u></p> <p>About 63 percent of current new production of domestic refrigerators and freezers employ HFC-134a refrigerant and slightly more than 35 percent employ hydrocarbon refrigerants. HC-600a is the primary hydrocarbon refrigerant used. Blends of HC-600a</p>
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and HC-290 are used in some cases. These blends allow matching the volumetric capacity of previously used refrigerants to avoid capital investment to retool compressor manufacturing. These blends result in a small reduction in refrigerator energy efficiency. Either HFC-134a or HC-600a deliver comparable energy efficiency with design variation providing more difference than the refrigerant selection. Two issues of interest are (1) the partial second generation migration from HFC-134a to HC-600a and (2) current preliminary suggestions of the use of low GWP unsaturated HFCs to replace HFC-134a.

Migration of automatic defrost new production refrigerators from HFC-134a to HC-600a is motivated by global warming considerations. Conversions began in Japan and have progressed to include the majority of new refrigerator production in Japan. A major U.S. manufacturer recently announced an intent to introduce auto-defrost refrigerators using the HC-600a refrigerant. Codes and standards modifications and approvals are currently in process and commercial introduction is anticipated in 2009.

Chemical manufacturers developed low GWP unsaturated HFC compounds for automotive air conditioning use. The theoretical assessment is that HFC-1234yf has the potential for comparable energy efficiency to HFC-134a in domestic refrigerators. Long-term reliability expectations for domestic refrigeration use are significantly more demanding than for automotive applications. Numerous application criteria need to be assessed before this refrigerant can be established as a viable alternative candidate in this subsector.

### Commercial refrigeration

Refrigerant needs vary depending on commercial refrigeration application. The majority of stand-alone equipment is based on HFC-134a technology but for low-temperature equipment R-404A can also be used. When the GWP of HFC-134a is considered prohibitive, either (1) a very stringent policy for recovery at end of life has to be implemented or (2) a refrigerant such as HC-600a or HC-290 might be used as a replacement. The latter provided that the refrigerant charge can be kept low, at acceptable levels. Many equipment manufacturers have accepted the recommended limit of 150 grams. CO<sub>2</sub> is also being introduced, particularly in moderate climates, but there are issues with performance and operating costs.

In water fountains, some large beverage companies have switched from HFC-134a to isobutane (R-600a). For ice-cream freezers, a growing proportion of equipment has been converted from HFC-134a to propane (HC-290). For vending machines at the larger end of the scale, CO<sub>2</sub> has been chosen as the refrigerant, the main reason being the avoiding of large charges of flammable refrigerants; this at the cost of a lower performance at higher ambient temperatures.

Newly produced condensing commercial refrigeration units can HFC-134a, HCFC-22, R-404A, R-407C, R-507, other HFC and HCFC blends, and HC refrigerants. CO<sub>2</sub> is also starting to be offered as a possible option for this type of equipment. It should be noted that in Northern Europe, HC-290 or even HC-1270 are used as refrigerants.

In centralized systems, CO<sub>2</sub> is beginning to be introduced in direct expansion systems in Europe. In indirect (secondary loop) centralized systems, hydrocarbons are becoming a popular refrigerant choice. CO<sub>2</sub> can also be used as a heat transfer fluid and as a refrigerant in some low temperature indirect systems.

### Large (Industrial) refrigeration

In large refrigeration systems, particularly in the industrial sector, ammonia has been much more widely used than in other sectors. In the limited applications where ammonia is not suitable due to safety or other reasons, designers have adapted other “natural” refrigerants, in particular carbon dioxide (usually in cascade with a reduced charge HFC system, ammonia or a hydrocarbon).

#### Unitary Air-conditioning

Nearly all air-cooled stationary air conditioners and heat pumps manufactured prior to 2000 used HCFC-22 as their working fluid. In the developed countries, HFC refrigerants have been the dominant replacement for HCFC-22 in all categories of unitary air conditioners. Hydrocarbons have been used in some very low charge applications; including lower capacity portable room units and split system air conditioners.

Most developing countries are continuing to utilise HCFC-22 as the refrigerant in unitary air conditioning applications. There are several alternatives that are showing promise, including hydrocarbons, CO<sub>2</sub> and new low-GWP (unsaturated) HFCs. However, the development of products with these options is expected to require significant additional research and development.

#### Chillers

Chiller refrigerants proposed as alternatives to HFCs include R-717, hydrocarbons, carbon dioxide, and new unsaturated HFCs such as HFC-1234yf. R-744 (carbon dioxide) has rather poor energy efficiency for chiller applications in warmer and hot climates.

For chillers with reciprocating, screw, and scroll compressors, HCFC-22 is being replaced in newly-designed equipment by HFC-134a or R-410A. Some chillers are available with R-717 (ammonia) or hydrocarbon refrigerants (HC-290 or HC-1270). Such chillers require attention to safety codes and regulations because of flammability concerns and, in the case of R-717, toxicity concerns. For highly specialized chiller applications such as military shipboard and submarine use, unique requirements for toxicity and flammability limit the available options. In these cases, it may be necessary to continue using HFC-134a, HFC-236fa, HCFC-22 or CFC-114.

#### Vehicle Air Conditioning

HFC-1234yf is expected to replace HFC-134a in vehicle air conditioning. SAE International (formerly called the Society of Automotive Engineers) issued a press release in November 2009 finding that HFO-1234yf was the best replacement for HFC-134a.”<sup>5</sup> Some support also exists for using CO<sub>2</sub> in vehicle air conditioning, which was supported by the German-based automobile industry in the early to mid 2000’s.

### **3. The importance of Life Cycle Climate Performance**

In order to reduce greenhouse gas emissions, it is not enough to consider the GWP of the refrigerant alone. Indeed, it is possible to select a refrigerant with a low GWP, but

sill increase overall greenhouse gas emissions. This would occur if the low-GWP alternative resulted in higher energy use, and therefore larger indirect (fuel consumption) greenhouse gas emissions.

Life-cycle climate performance (LCCP) is a tool that was developed to take into account all potential greenhouse gas emissions arising from a technology or an activity. This analysis includes, among other things, the greenhouse gas emissions from direct emissions of operating fluids, CO<sub>2</sub> emissions from energy consumption, fugitive emissions arising from the manufacture of the operating fluids and equipment, CO<sub>2</sub> associated with embodied energy, and end-of-life disposal.

By promoting LCCP, policymakers and engineers can optimize climate and consumer benefits. Systems with high LCCP will have higher efficiency and lower refrigerant emissions than standard systems. This will lead to lower energy costs and reduced maintenance for the consumer, and fewer greenhouse gasses emitted to the atmosphere. One example where LCCP has been used extensively is vehicle air conditioning (see box 1). The following section gives an overview of global and U.S. actions that promote next-generation refrigeration and air conditioning technology with better LCCP, focusing on of refrigerant choice for mobile air conditioning as a case study.

**Box 1: GREEN MAC LCCP Model**

In order to help engineers and policy makers select the best MAC alternative, environmental and industry experts developed the GREEN-MAC-LCCP© model to compare refrigerants' life-cycle climate performance (LCCP). LCCP is the most comprehensive life cycle analytical technique for identifying environmentally superior technology to minimize greenhouse gas (GHG) emissions from refrigeration and air conditioning applications. It quantifies every aspect of greenhouse gas emissions, including materials, shipping, manufacturing, operation, servicing, recycling and destruction. This model was initially developed by Stella Papasavva and William Hill at General Motors in early 2000s, and it was later perfected by an industry-government partnership to pick the winner in the global competition to replace HFC-134a. It is now an SAE International Standard and is a completely transparent. A copy of the model is available on-line at: [www.epa.gov/cppd/mac](http://www.epa.gov/cppd/mac).

#### **4. Case Study: Promoting LCCP in Mobile Air Conditioning**

##### *4.1 Alternatives considered*

Alternative refrigerants that have been considered for mobile air conditioning include hydrocarbons, HFC-152a, CO<sub>2</sub>, and HFC-1234yf.

Although hydrocarbons are efficient refrigerants with zero ozone depletion potential (ODP) and low global warming potential (GWP~3 to 5), they are highly flammable, and vehicle manufacturers do not endorse their use, particularly because less flammable options like HFC-152a and HFC-1234yf are available.

HFC-152a is a more efficient refrigerant than HFC-134a, with no impact on ozone depletion and a low global warming potential (GWP 124). It has an ASHRAE6 refrigerant classification of A2 (lowest toxicity, moderate flammability). One possible way to mitigate flammability concerns is to use HFC-152a in a secondary loop system, keeping the refrigerant contained under the hood where it is completely separated from the passenger compartment. Secondary loop systems are an engineering challenge because they introduce additional weight, complexity, and maintenance issues to the

MAC system, however, when implemented correctly, they provide added safety and equal or better efficiency and cooling performance.

With a GWP of 1 by definition, CO<sub>2</sub> has the lowest direct global warming potential of all mobile air conditioning refrigerant alternatives. It has no impact on ozone depletion and is non-flammable. However, CO<sub>2</sub> systems operate at a much higher pressure. Additionally, although CO<sub>2</sub> is a natural refrigerant, it has acute toxicity risks; health and safety organizations such as the US Occupational Safety and Health Administration limit exposure to 3% averaged over 15 minutes, and some regulatory authorities such as the US Environmental Protection Agency have proposed additional exposure limits for CO<sub>2</sub> used in MAC, such as a ceiling of 4%. Additionally, although CO<sub>2</sub> systems perform well and have high energy efficiency in mild to moderate climates, cooling performance and efficiency degrades in hotter and more humid climates such as those found in the southern United States, India and China. CO<sub>2</sub> is also the most expensive alternative. The IPCC estimates that additional cost of a CO<sub>2</sub> air conditioning system is 48 to 180 US dollars.

HFC-1234yf (also called HFO-1234yf) is a mildly flammable, ozone-safe, low global warming potential refrigerant. It has a GWP of 4, and has properties similar to the current refrigerant, meaning that neither the air conditioning technology nor the production lines would need to undergo significant re-design. HFC-1234yf does not present the pressure or acute toxicity risks of CO<sub>2</sub>, nor does it present the flammability risks of hydrocarbons or HFC-152a (see table 2: flammability properties). For example, whereas propane has a lower flammability limit (LFL) of 2.2% and HFC-152a has a LFL of 3.9%, concentrations of HFC-1234yf have to reach 6.5% by volume in air before it can ignite. Additionally, whereas propane has a minimum ignition energy (MIE) of 0.25 mJ and HFC-152a has a MIE of 0.38 mJ, it would take much more energy—over 1,000 mJ—to ignite 1234yf. Practically, this means that flammability risks for HFC-1234yf are easier to contain. In the United States and in Europe, use of new chemicals such as HFC-1234yf requires regulatory approval. In Europe, chemicals must be registered in accordance with the regulation on Registration, Evaluation, Authorization and Restriction of Chemicals (REACH), and HFC-1234yf has been registered. In the United States, the Environmental Protection Agency’s Significant New Alternatives Program reviews alternative refrigerants for environmental acceptability. This program has proposed listing HFC-1234yf as acceptable for use in vehicle air conditioning with use conditions to mitigate risks associated with exposure to HFC-1234yf and its decomposition products.

Table 2. HFC-1234yf flammability properties (Minor, 2008).

	LFL <sup>a</sup> (vol%)	UFL <sup>a</sup> (vol%)	Δ (vol%)	MIE (mJ)	BV <sup>c</sup> (cm/s)
Propane	2.2	10.0	7.8	0.25	46
R152a	3.9	16.9	13.0	0.38	23
R32	14.4	29.3	14.9	30-100 <sup>b</sup>	6.7
Ammonia	15	28	13	100-300 <sup>b</sup>	7.2
1234yf	6.5	12.3	5.8%	>1,000 <sup>b</sup>	1.5

<sup>a</sup>Flame limits measured at 21 C, ASTM 681-01

<sup>b</sup>Tests conducted in 12 liter flask to minimize wall quenching effects

<sup>c</sup>Burning velocity ISO 817 (1234yf burning velocity measured by AIST, Japan)

## 4.2 Policies to Promote MAC LCCP in Europe and the USA

### 4.2.1 European Union

Starting the 1st of January, 2011, all new vehicle types sold in the EU must have an air conditioning refrigerant with a GWP equal to or less than 150. Starting the 1<sup>st</sup> of January, 2017, all vehicles sold in the EU must have a refrigerant with a GWP of 150 or less. Currently, the law only applies to the refrigerant and life-cycle climate

performance is not addressed. However, in 2008, the European Commission reported that they were considering complementary efforts to improve air conditioning efficiency. The Commission held a “public consultation on future regulations addressing reduction of CO<sub>2</sub> emissions of light-duty vehicles by more efficient MAC equipment” in the spring of 2008.<sup>7</sup> The consultation addressed several topics, including potential test procedures and safety regulations. As of October 2009, the Commission had analyzed the results and reported that a legislative proposal is forthcoming.

#### 4.2.2 The US State of California

The US State of California was the first authority to incorporate elements of life-cycle climate performance in their regulations. California’s vehicle greenhouse gas standards provide credit to manufacturers that use alternative refrigerants, reduce refrigerant leakage, and improve MAC energy efficiency. The California regulation limits the grams of CO<sub>2</sub>-equivalent that a vehicle emits per mile, and it applies to 2009 and subsequent model years. The formula they proposed to determine the CO<sub>2</sub> emissions per mile is:

$$\text{CO}_2 + \text{N}_2\text{O} * \text{GWP}_{\text{N}_2\text{O}} + \text{CH}_4 * \text{GWP}_{\text{CH}_4} - \text{AC allowances}$$

Where AC allowances = credit for reducing direct (leakage) and indirect (fuel use) emissions from MAC. The California proposal estimates that on average, vehicle air conditioning emits 6 grams carbon dioxide equivalent per mile (3.75 g/km) for AC-direct (refrigerant leakage) and 17 grams CO<sub>2</sub>e/mile (10.5 g/km) for AC-indirect (fuel use). Actions to reduce direct and indirect emissions that would receive credit are described in table 3.

Table 3. Credit for reducing MAC greenhouse gas emissions under California regulation. Source: California Air Resources Board.

Direct AC Emissions Maximum credit = 9 grams CO <sub>2</sub> e/mile for low GWP refrigerant option, 6 grams otherwise.	Indirect AC Emissions Maximum credit = 11 CO <sub>2</sub> e/mile
<ul style="list-style-type: none"> <li>• Qualified “Low-Leak AC System”*</li> <li>• Refrigerant with GWP of 150 or less</li> <li>• Alternative technologies if reductions are demonstrated to be equal or greater than measures listed above</li> </ul>	<ul style="list-style-type: none"> <li>• Qualified “AC system with reduced indirect emissions”</li> <li>• Refrigerant with GWP of 150 or less</li> <li>• Alternative technologies if reductions are demonstrated to be equal or greater than measures listed above</li> </ul>
<p>*Additional details available from California Air Resources Board:  <a href="http://www.arb.ca.gov">http://www.arb.ca.gov</a>. See also section 3.6.1, “Credit for reducing refrigerant GHG emissions.”</p>	

#### 4.3 United States

In May 2009, US President Obama announced new national auto standards that will accelerate increases in auto fuel economy and impose the first-ever national greenhouse gas emission standard on cars and trucks. Cars and light trucks will have to achieve a corporate average fuel economy (CAFE) standard of 35.5 miles per gallon (~16 km per liter) by 2016, and emit no more than an average of 250 grams of CO<sub>2</sub> per mile (~156 grams per kilometer). These controls include incentives for vehicle manufacturers to reduce GHG emissions associated with vehicle AC. In September 2009, the US EPA and the US Department of Transportation’s National Highway Traffic and Safety Administration (NHTSA) proposed new rules.<sup>8</sup> Like California’s regulation, the national rules give vehicle manufactures credit for MAC improvements, but there are



important differences. For example, the national rules would give more credit for reducing refrigerant-related GHG emissions and less credit for improving energy efficiency: cars can earn up to 13.8 grams CO<sub>2</sub>-eq per mile (8.6 g/km) for switching to a low-GWP refrigerant (the number increases to 17.2 grams of CO<sub>2</sub>-eq per mile for trucks), and up to 5.7 grams of CO<sub>2</sub>-eq per mile (~3.5 g/km) for improving AC energy efficiency.

## **5. Servicing Sector is Large Target for Emissions Reductions**

Much attention is paid to the design of future refrigeration and air conditioning systems. Although this is an important potential source of greenhouse gas emissions reductions, the current opportunities in the servicing sector should not be forgotten. HCFCs and HFCs will continue to be used by the servicing sector long after manufacturers have switched to low-GWP refrigerants in new equipment. Some countries, such as Japan, have implemented excellent policies and practices designed to maximize the collection and recycling of used refrigerant. Other countries have not come so far. Not all countries mandate refrigerant recovery and recycling, and those that do have often failed to enforce refrigerant recovery and recycling laws. Sometimes loopholes exist as well. In the United States, for example, although automotive servicing technicians are required to recover refrigerant for recycling, they are not required to fix refrigerant leaks before re-charging systems with HFC-134a. Without fixing leaks, refrigerant leaks back out to the atmosphere. Additionally, the law only applies to professional servicing technicians. Individuals who recharge their air conditioners themselves lack recovery and recycling equipment, and therefore vent refrigerant to the atmosphere.

Globally, service sector emissions can be decreased by:

- implementing strong laws and policies requiring refrigerant collection and recycling
- improving enforcement of these laws
- providing continuous education and training to servicing sector professionals in methods to reduce refrigerant emissions
- certifying or recognizing service sector companies that follow best practices for the environment
- restricting or banning non-professional (do-it-yourself) servicing, where appropriate
- employing other creative emissions reductions strategies, such as refrigerant deposits or fees used to pay for collection and destruction of contaminated or unwanted refrigerant

## **6. The way forward**

The transition to low-GWP refrigerants will be an engineering challenge, but it is necessary to avoid large emissions of HFCs in the future. In order to maximize the environmental benefits of next-generation air conditioning and refrigeration technology, it is important that new technologies have the highest achievable life-cycle climate performance. The challenge is to introduce new refrigerants and next-generation technologies where and when they are environmentally superior and to assure consumer safety and satisfaction.

By working together, government, industry, and nongovernment organizations worldwide can assure safety, customer satisfaction, and environmental protection at the same time. Governments and nongovernment organizations can help achieve this by implementing policies that promote LCCP and refrigerant containment; discouraging irresponsible and emissive refrigerant use; providing recognition for the most

environmentally-preferable products through eco labels and advice to consumers, and encouraging servicing best practices.

Innovative businesses can help guide successful refrigerant choices. It will be important for businesses to stay ahead of policy developments, and be ready for refrigerant change. Focusing on life-cycle analysis will help select optimal alternative refrigerants, and avoid problems in the future. Industry is best advised to be open and transparent about life-cycle calculations, however, to avoid conflicts that have arisen in the past due to lack of disclosure about assumptions. Industry can also play an important role by helping educate policymakers and regulators about the technical performance of refrigerant alternatives.

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<sup>1</sup> Views presented are those of the author and do not necessarily reflect the official views of the U.S. Environmental Protection Agency.

<sup>2</sup> Guus J. M. Velders, David W. Fahey, John S. Daniel, Mack McFarland, and Stephen O. Andersen. 7 July 2009. "The large contribution of projected HFC emissions to future climate forcing." *Proceedings of the National Academy of Science (PNAS)*. Vol. 106, No. 27, 10949-10954.

<sup>3</sup> Official Journal of the European Union. 14 June 2006. DIRECTIVE 2006/40/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL of 17 May 2006 relating to emissions from air-conditioning systems in motor vehicles and amending Council Directive 70/156/EEC. Retrieved 30 November 2009 from:

[http://www.fluorocarbons.org/documents/library/Legislation/JO\\_L161\\_12\\_2006\\_40\\_EC\\_Directive.pdf](http://www.fluorocarbons.org/documents/library/Legislation/JO_L161_12_2006_40_EC_Directive.pdf).

<sup>4</sup> United Nations Environment Programme Technology and Economic Assessment Panel. May 2009.

"Assessment of Alternatives to HCFCs and HFCs and Update of the TEAP 2005 Supplement Report Data." Task Force Decision XX/8 Report. United Nations Environment Programme: Nairobi, Kenya.

<sup>5</sup> SAE International. 20 November 2009. "SAE research group finds HFO-1234yf suitable as A/C refrigerant replacement." Retrieved 30 November 2009 from: <http://www.sae.org/mags/sve/NEWS/7203>

<sup>6</sup> ASHRAE = American Society of Heating, Refrigeration and Air Conditioning Engineers

<sup>7</sup> Results of the consultation were published on-line at: <http://ec.europa.eu/enterprise/automotive/environment/mac/consultation/contributions.htm>

<sup>8</sup> These rules are available on-line at: <http://edocket.access.gpo.gov/2009/pdf/E9-22516.pdf>.