CLIMATE AND CLEAN AIR COALITION
TO REDUCE SHORT-LIVED CLIMATE POLLUTANTS

Technology Forum on Climate-Friendly Alternatives in Commercial Refrigeration

Montreal, Canada
8 December 2012

Sponsored by the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC)

Meeting Summary

Technology Forum on Climate-Friendly Alternatives in Commercial Refrigeration

Background and Overview

As countries phase out hydrochlorofluorocarbons (HCFCs) under the Montreal Protocol, they often need to make choices between high-global warming potential (GWP) hydrofluorocarbon (HFC) alternatives and, when available, more climate-friendly alternatives. Depending on the alternatives selected, the increase in HFC emissions could partly offset the climate benefit achieved by the earlier reduction in ozone-depleting substance (ODS) emissions under the Montreal Protocol.

In order to assist countries, in particular developing countries, in planning and implementing HCFC transitions that minimize climate impacts, the Climate and Clean Air Coalition to Reduce Short-Lived Climate Pollutants (CCAC) sponsored this Technology Forum on Climate-Friendly Alternatives in Commercial Refrigeration. Given that the commercial refrigeration sector has a number of climate-friendly refrigerant alternatives that are already commercialized or near commercialization in some countries and regions, this forum fostered a dialogue between government representatives, industry, technology users and providers, and international organizations to discuss the latest technological developments, examples from end-users, and build confidence in and discuss pathways towards more climate-friendly commercial refrigeration.

The workshop took place immediately after the 68th meeting of the Executive Committee of the Multilateral Fund for the Implementation of the Montreal Protocol. Over 130 participants representing government, industry, non-governmental organizations, and environmental organizations attended the one-day technology forum. The forum met its goal of providing information on the technical, financial, and environmental aspects of some of the key low-GWP, energy-efficient alternative technologies that are available or emerging in commercial refrigeration. The day was structured to maximize discussions among panelists and to engage the audience on the state of the technology currently available. Panels shared perspectives from supermarket end-users of new technologies, manufacturers of commercial refrigeration systems and equipment, and government-industry partnership programs and regulations.

For example, panelists discussed carbon dioxide (CO_2) transcritical systems in various markets, including describing how that technology has significantly advanced in recent years. Barriers, such as constraints on operating efficiencies in high ambient temperatures, were covered. Other refrigerant options included both fluorinated and non-fluorinated options with innovative designs that reduce charge size and the potential for leaks. Participants observed that regardless of the specific technology selected, the transition from HCFCs offers the opportunity for upgrading installed systems and installing newly designed systems that decrease the impact on the ozone layer and climate change, and transitioning to climate-friendly refrigerants, using smaller refrigerant charge sizes, and reducing leaks are all options.

A site visit to a Sobeys/IGA Extra supermarket using a newly-designed CO_2 transcritical system completed the day's program.

AGENDA

Opening Session	
8.45 – 8.50	**Welcome and Introduction** *Philippe Chemouny - Environment Canada*
8.50 – 8.55	**Background on CCAC and HFC work** *John Thompson – United States Department of State*
8.55 – 9.15	**Overview of the Commercial Refrigeration Sector** *Dave Calabrese – Air-Conditioning, Heating, and Refrigeration Institute / International Council of Air-Conditioning, Refrigeration, and Heating Manufacturers' Associations (AHRI/ICARHMA)*
Session I: Needs on the Ground - End-User Perspectives	
9.15 – 10.30 *(75 minutes)*	Panel discussion on experience and knowledge-sharing on successful implementation of alternatives by supermarket owners and operators, perspectives on the drivers for technologies pertaining to costs, space, energy-use, safety issues, regulatory compliance, etc. and the related challenges and how they were overcome. **Moderator:** *Warren Heeley – Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI), Canada* **Panelists:** *Paul Anderson – Target, USA* *Carlos Arruda – Supermercados Verdemar Ltda., Brazil* *Joseph Gomez – Tesco, UK* *Harrison Horning – Hannaford Bros. and Delhaize Group, USA/Belgium* *Florian Schütze – Lidl, Germany*
10.30 – 10.45	Coffee Break
Session II: Technologies – System Manufacturing and Contracting	
10.45 – 12.45 *(120 minutes)*	Presentation and panel discussions on stand-alone/unitary systems, central systems, system design for supermarket refrigeration, availability of equipment with different alternatives, costs, challenges, and feasibility of use in developing countries. **Opening Presentation and Moderator:** *Denis Clodic, International Institute of Refrigeration (IIR) / Mines-ParisTech, France* **Panelists:** **a) Stand-alone systems (40 minutes)** *Masood Ali – Kysor/Warren, USA* *Charles Hon – True Manufacturing Company, USA* *Bruno Pussoli – Metalfrio Solutions SA, Brazil* *Drew Tombs – AHT, USA/Austria* *Yukio Yamaguchi – Sanden, Japan* **b) Centralized systems (55 minutes)** *Luigino Belloni – Zanotti, Italy* *Simon Bérubé – Carnot, Canada* *Iwan Chandra – PT. Sumo Elco Mandiri, Indonesia* *Takeshi Ishii – Panasonic Corporation, Japan* *Travis Lumpkin – Hussmann, USA* *Scott Martin – Hill Phoenix, USA*
12.45 –13.45	Lunch Break

Session III: Technologies – Compressors and Condensing Units	
13.45 – 14.45 *(60 minutes)*	Presentation and panel discussions on industry experiences and perspectives on availability and maturity of compressors/condensing units for various alternatives and applications (such as stand-alone equipment, centralized systems, cold rooms, etc.), costs and challenges and feasibility of use in developing countries. **Opening Presentation and Moderator:** *Walid Chakroun, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) / College of Engineering & Petroleum, Kuwait University, Kuwait* **Panelists:** *Torben Funder-Kristensen – Danfoss, Denmark* *Bernard Philippe – Johnson Controls, Inc., France/USA* *Giacomo Pisano – Dorin, Italy* *Rajan Rajendran – Emerson, USA*
Session IV: Initiatives and Partnerships to Encourage Transition and Reduce Emissions	
14.45 – 15.45 *(60 minutes)*	Panel discussion on regulatory drivers, voluntary initiatives and corporate/government partnerships to encourage transition to low-GWP and energy-efficient technologies and to reduce emissions through proper refrigerant management and best practices. **Moderator:** *Javier Carmago, Ministerio de Ambiente y Desarrollo Sostenible, Colombia* **Panelists:** *Arno Kaschl – European Commission* o EU actions targeting HFC emissions from commercial refrigeration *Cindy Newberg – United States Environmental Protection Agency* o Reducing emissions through public-private partnerships *Clare Perry – Environmental Investigation Agency (EIA)* o EIA's Chilling Facts and promoting HFC-free cooling from niche to mainstream *Dave Stirpe – The Alliance for Responsible Atmospheric Policy* o Responsible management of refrigerants
15:45 – 16:00	Coffee Break
Session V: Challenges and Opportunities	
16.00 – 17.20 *(80 minutes)*	Panel discussion on applicability and potential for adoption of climate-friendly alternatives in developing countries, key opportunities, barriers and challenges, cost consideration for various alternatives, revision of standards and regulations particularly for addressing safety issues, feasibility of various alternatives including the role of ambient temperature. **Moderator:** *Bitul Zulhasni – Ministry of Environment, Indonesia* **Panelists:** *Nandan Chirmulay – United Nations Development Programme (UNDP)* *Ayman Eltalouny – United Nations Environment Programme (UNEP)* *Ole Nielsen – United Nations Industrial Development Organization (UNIDO)* *Agustín Sánchez – Coordinador de la Unidad de Protección a la Capa de Ozono, Mexico* *Viraj Vithoontien – World Bank*
17.20 – 17.30	**Wrap-up and thanks**
Optional Field Visit	
18.00 – 20.00	Field visit to nearby supermarket which has converted to transcritical CO_2 technology *(Maximum 60 persons on basis of separate invitations)*

Forum Participation

International Organizations:	22% =	31 (including Multilateral Fund and Ozone Secretariats)
Government Representatives:	31% =	44 (23 Developing Countries, 21 Developed Countries)
Industry Representatives:	39% =	55
NGOs/Civil Society:	7% =	10
Total Number of Participants:	=	140

List of Refrigerants Referred to in this Report

Refrigerant	Composition	Global Warming Potential (GWP)
R-12	CFC-12	10,900
R-22	HCFC-22	1,810
R-134a	HFC-134a	1,430
R-404A	HFC blend	3,922
R-407A	HFC blend	2,107
R-407F	HFC blend	1,825
HFO-1234yf	HFO-1234yf	4
R-290	Propane	3.3
R-600a	Isobutane	3
R-717	Ammonia (NH_3)	0
R-744	Carbon Dioxide (CO_2)	1
R-1270	Propylene	1.8

Technology Forum – Climate-Friendly Alternatives in Commercial Refrigeration

Montreal, Canada – 8 December 2012

Welcome and Introduction: Philippe Chemouny, Environment Canada

Mr. Chemouny welcomed the participants to the technology forum and thanked the European Commission and the governments of Germany, Italy, Mexico, and the United States of America, as well as the United Nations Development Programme (UNDP) and the United Nations Environment Programme (UNEP) for their cooperation in organizing the forum. Many of the participants had attended the Bangkok Technology Conference, which had taken place during the summer, to discuss alternative substances to ODS and HFCs. He said that the present conference had been organized to focus on commercial refrigeration, one of the key sectors where those substances were being used, and where many alternatives were available, or becoming available.

The technology forum primarily focused on issues relevant to developing countries, but the discussion was also relevant for other countries. The forum encouraged participation and discussion between the panelists and the participants. It would start with a presentation by a representative of the International Council of Air-Conditioning, Refrigeration, and Heating Manufacturers' Associations (ICARHMA) on the key aspects of the applications in commercial refrigeration and would be followed by several technology-oriented panels which would discuss alternatives from the point-of-view of different industry segments. Following that, panelists would discuss how the technologies could be promoted, or incentivized, by the efforts of government, industry or non-governmental organizations, or their joint efforts, and would conclude with a panel of experts who would discuss the opportunities and challenges associated with adopting the technologies.

Background on CCAC: John Thompson, State Department, United States of America

Mr. Thompson provided background on the CCAC, a new, voluntary initiative aimed at achieving substantial progress in addressing near-term global warming. The CCAC was launched in February 2012, and brings together people from the private and public sector to address global warming, in an evolving effort that depends on the involvement of motivated partners. Structured around a working group and a high-level assembly, the CCAC covers three areas: black carbon, methane, and HFCs, the subject of this forum. In the effort to move toward lower global warming potential energy efficient alternatives to high-GWP HFCs, the CCAC is helping countries understand volumes of HFCs used and sectors of use, as well as working on establishing standards with the goal of enabling climate-friendly technologies. The CCAC is working with UNEP on case studies, some of which will build on this conference. It is sponsoring conferences, such as the one in Bangkok last July, and would like to get involved in technology demonstrations. In closing, Mr. Thompson urged anyone interested in joining the CCAC, and those particularly interested in the focal area of HFCs, to reach out to representatives of the United States or Canada.

Overview of the Commercial Refrigeration Sector: David B. Calabrese, General Counsel and Senior Vice-President, Air-Conditioning, Heating, and Refrigeration Institute and International Council of Air-Conditioning, Refrigeration, and Heating Manufacturers' Associations (AHRI/ICARHMA)

Mr. Calabrese reviewed the establishment and purpose of ICARHMA. There are similarities and differences between commercial refrigeration and the air-conditioning sector: both have health, environmental, and economic benefits, but refrigeration applications present additional challenges related to system architecture, charge size amounts, temperatures, and leak potential. He then reviewed the refrigerants currently in use and the different types of commercial systems: semi-vertical display cases; multi-deck, vertical display refrigerated merchandisers; chilled transparent vertical door display cabinets; multi-deck vertical display frozen food merchandisers; and frozen transparent vertical door display cabinets. The non-ozone-depleting alternative refrigerants in use are hydrocarbons (HCs), such as isobutane, propane, and propylene, as well as ammonia (NH_3), carbon dioxide (CO_2), HFCs, and unsaturated HFCs (which are also called hydrofluoroolefins (HFOs)), or blends of some of those chemicals.

Mr. Calabrese said that direct expansion systems are the most common type of refrigeration system design and typically involve long run lines from roofs to the interiors of stores. Centralized systems have lower levels of cost, but they also have efficiency issues and problems with leaks and pressure drops. Distributed systems can use an array of separate compressor racks which could lower the refrigerant charges by up to 50%. However, space constraints are associated with those systems, and indirect systems are gaining a significant market share. Indirect systems, which can lower refrigerant charges by up to 90%, are now normally used in Europe. They have a low leak potential of 5% or less and low pressure loss, but can involve fluid and efficiency losses especially when glycol is the heat exchanger. Cascade systems involve the addition of a secondary loop which allows for a more complex chiller with a secondary compressor. That meant that CO_2 could be used in the secondary loop and HCs or ammonia in the first loop, which could be located in a secure area to address the safety issues associated with those chemicals.

Although moving from high-GWP chemicals has the advantage of addressing the damage they cause to the climate, changing could impose indirect costs, such as increased energy costs. It is important to maintain choice in the use of refrigerants and so it is necessary to evaluate the characteristics of refrigerants to ensure that informed choices are made. He emphasized that the transition also has to be predictable and smooth to ensure that it is both safe and efficient. Safety is a key issue in the United States, but the choice of refrigerant cannot be based on any single factor and needs to consider safety, energy efficiency, and economics as well as availability. This choice is different in different applications, and he reviewed the benefits and drawbacks of ammonia, HCs and CO_2.

He said that most economic sectors are inter-connected and that policy makers need to ensure that policies do not reduce emissions in one sector while increasing them in another; low emissions should not be sought at the expense of overall efficiency. Business needs predictability and research is being done by the Low GWP Alternative Refrigerants Evaluation

Program at AHRI to determine the positives and negatives of the new generation of refrigerants. A recent study summarizes the technical and regulatory barriers to their use in different regions, and a cooperative research program has been established to identify suitable alternatives to high-GWP refrigerants. Thirty-eight low-GWP refrigerant candidates are being tested globally in twenty-one entities in a number of applications. The final report from this study will be available in 2013. In closing, he said that the refrigeration industry is committed to moving forward to address the challenges of alternatives in the most efficient way.

SESSION I: NEEDS ON THE GROUND – END-USER PERSPECTIVES

moderated by Warren Heeley, Heating, Refrigeration and Air Conditioning Institute of Canada (HRAI)

Session I was a panel discussion on experience and knowledge-sharing on successful implementation of alternatives by supermarket owners and operators, perspectives on the drivers for technologies pertaining to costs, space, energy-use, safety issues, regulatory compliance, etc. and the related challenges and how they were overcome.

Panelists:

Paul Anderson, Target, USA

Target is a grocery and general merchandise retailer with stores located in the United States and Canada. Target aims for all new Canadian stores opening in 2013 to meet LEED standards, and has experience with CO_2 cascade refrigeration systems.

Carlos Arruda, Supermercados Verdemar Ltda., Brazil

Verdemar is a small chain of six gourmet stores in Brazil. In 2010 they became the first company in South America to use a CO_2 cascade refrigeration system. In a high ambient temperature climate, their CO_2 stores are energy efficient.

Joseph Gomez, Tesco, UK

Tesco is a global grocery and general merchandise retailer. In Europe, Tesco is focused on meeting European Union fluorinated gas commitments and has set a goal of zero carbon emissions by 2050. They are moving towards an HFC-free business. In the United Kingdom, they have experience with various types of CO_2 refrigeration systems.

Harrison Horning, Hannaford Bros. and Delhaize Group, USA/Belgium

Hannaford is a supermarket chain in the northeast United States, and their parent company Delhaize Group uses all types of refrigeration systems in their grocery stores around the world, including CO_2 in cascade systems, transcritical CO_2 systems, HC stand-alone systems, and NH_3 or NH_3/CO_2 hybrid systems.

Florian Schütze, Lidl, Germany
Lidl is a grocery chain with stores throughout Europe. They have recently opened 150 new concept stores with an “integral plant” which uses hydrocarbons (e.g. propane) as the primary refrigerant to transfer heat to a secondary refrigerant such as a brine solution, which is circulated through the store.

DISCUSSION

There was substantial discussion on ambient temperature and its effect on the selection of alternative refrigerants. Ambient temperature was repeatedly confirmed to be a very important factor in compressor efficiency. Currently, transcritical CO_2 systems work better in cooler climates, because stores already invest more in expensive heat recovery, so the base case is already expensive. The technology is improving for use farther south, but is not yet in place. A member of the audience informed the forum that the tipping point for compressor efficiency was approximately 50°F or 10°C, below which CO_2 transcritical compressors were more efficient than HFC compressors. Lidl uses primarily propane systems because propane is more stable in higher ambient conditions than CO_2.

Maintenance and servicing: This is a major consideration with the introduction of new technologies, notably CO_2 systems which function at high pressure. Skills and capability need to be embedded in the local community.

Cost benefits and energy usage: Mr. Horning noted the high cost of equipment and installation means that companies need to justify a move to “natural refrigerants” to shareholders, but that transcritical CO_2 systems are cost effective to operate in cool climates. Verdemar also uses the use of green solutions as a marketing tool to help with payback.

Use of R-407A or other: R-407A is the current standard refrigerant used at Hannaford, partly because at one time it was the best choice to support the phase-out of R-22; R-407F may now be worth considering, to replace R-404A in the future. The GWP of R-407F is less than half of R-404A. At Verdemar, R-134a was chosen over R-404A or R-407A as it has a much lower GWP.

Constraints to implementation of alternatives: Lidl noted certification of materials, which they overcame by working with a long-standing supplier. Target noted capital investment for equipment and installation, and costs associated with higher energy consumption.

SESSION II: TECHNOLOGIES – SYSTEM MANUFACTURING AND CONTRACTING

moderated by Denis Clodic, International Institute of Refrigeration (IIR) / Mines-ParisTech, France

Session II consisted of a presentation and two panel discussions on stand-alone/unitary systems, central systems, and system design for commercial refrigeration and the availability of equipment with different alternatives and the costs, challenges, and feasibility of their use in developing countries.

Opening presentation: Denis Clodic

Mr. Clodic reviewed three types of systems: stand-alone equipment, condensing units, and centralized systems. Stand-alone equipment includes vending machines, ice cream freezers and dispensers, and stand-alone display cases. Units are simple to install, have a wide variety of cooling capacity (from 100 watts to three kilowatts (kW)), and current models can use the full spectrum of refrigerants: chlorofluorocarbons (CFCs), HCFCs, HFCs, CO_2, and HCs. Often, the equipment is owned by the producers of the items being sold. Several global companies have moved towards using "natural refrigerants." Many small- and medium-sized enterprises offer a wide variety of stand-alone equipment using different types of technology. There has been a significant development of CO_2 systems capable of operating under even high ambient temperature, while HC options are preferable in low-capacity stand-alone equipment. HFO-1234yf and low-GWP blends are also beginning to compete with "natural refrigerants."

In small- and medium-sized commercial refrigeration installations, condensing units have one or more compressors connected to an air condenser which are then sold to be connected to evaporators installed in cold rooms and display cases. Condensing units offer a wide variety of cooling capacity and commonly use R-134a and R-404A as refrigerants, although more recently CO_2 and HCs are also being used, and Mr. Clodic noted that Lidl has been using HCs for twelve years. The refrigerant charge size of condensing units requires safety precautions when using flammable substances, in which case a second loop could be installed. While HFCs are still dominant, CO_2 condensing units give new opportunities to contractors, and low-GWP HFCs, CO_2, and HCs will likely replace high-GWP HFCs in Europe during the next few years.

Centralized systems consist of direct expansion, indirect, CO_2 cascade, and CO_2 transcritical systems. In centralized systems, low- temperature and medium-temperature refrigeration applications may require the use of different refrigerants. Many Northern European operations choose CO_2 transcritical designs for environmental and climatic reasons, and CO_2 cascade systems at low-temperature levels are an effective option for all climates. In medium-temperature level applications which require larger refrigerant charges, a wider variety of refrigerants are being used.

The efficient use of CO_2 transcritical depends on the number of hours the ambient temperature is lower than 25°C. Greater energy efficiency and energy consumption are key drivers for future equipment design. For example, many companies have committed to putting doors on all display cases, which for medium-temperature display cases can lead to a 20 to 30% reduction in energy consumption. The Ecolabel of the European Union (EU) is also establishing targets for energy efficiency.

With the exception of CO_2, all refrigerants are to some extent flammable and consequently there is a need to have risk assessments and establish categories of flammability. A safety management system needs to cover the entire lifetime of the equipment being used, especially the most dangerous stages when flammable refrigerants are charged or recovered. The safety management system also requires training and awareness-raising, and regulations are needed to enforce refrigerant containment and the qualifications of the personnel manipulating all refrigerants. Leaks are always possible, even with the best of intentions. It is also better to have

recovery of the refrigerants at the end of the lifetime of the equipment, although that is also related to the quality and training of the personnel involved.

a) Stand-alone systems

Panelists:

Masood Ali, Kysor/Warren, USA

Kysor/Warren's parent company, Heatcraft RPD, is part of Lenox International which has a presence on five continents. Their products include centralized racks and distributed systems for food retailers. The company is looking at upcoming technologies, such as the use of CO_2, HFCs, propane, and ammonia, because there's no one-size-fits-all solution.

Charles Hon, True Manufacturing, USA

True Manufacturing is the largest self-contained refrigerator manufacturer in the United States with equipment that uses R-134a, CO_2, and propane. True's equipment is 69% more efficient than U.S. government ENERGY STAR standards.

Bruno Pussoli, Metalfrio Solutions SA, Brazil

Metalfrio has been in the light commercial plug-in appliance business for fifteen years. They sell 1.5 million products a year, including equipment using propane and, to a lesser extent, CO_2, with manufacturing conducted on four continents.

Drew Tombs, AHT, USA/Austria

AHT is a global supplier of deep-freeze and chilling cabinet equipment that uses propane refrigerant. Currently they have 530,000 propane cabinets in the field, and they also operate the Cool Point System, a network of fully-trained service and removal providers.

Yukio Yamaguchi, Sanden, Japan

Sanden is a global producer of products ranging from motor vehicle air-conditioning compressors and heat exchangers to vending machines and product display showcases. In stand-alone equipment, they use CO_2. Sanden operates a green and sustainable plant in Japan.

DISCUSSION

In response to a question about how to address the safety and flammability issues associated with stand-alone systems, Mr. Hon said that manufacturers need to address the fans, lighting circuits, and associated wiring. For example, the fans and fluorescent lighting should be sealed to protect against explosion or fire in the case of leaked refrigerant. Alternatively, a different lighting system, such as light-emitting diodes, could be used, and the amount of wiring minimized to reduce the risk of sparks. Mr. Tombs agreed that the process started at the design level and also emphasized product testing and labeling. For example, color-coding compressors by refrigerant type can help alert technicians that a different refrigerant is being used. Both

panelists stressed that care should be taken during the design, manufacturing, inspection, and certification stages.

One participant asked how CO_2 compared in terms of efficiency with other refrigerants. Mr. Yamaguchi said that Sanden had compared CO_2 with R-134a across the 5 to 40°C range, and found that CO_2 was as efficient at ambient temperatures of less than 40°C, and had a higher efficiency when compared using the annual average temperature. Mr. Hon agreed, and said that True sells some units that use CO_2. Test results showed that at temperatures lower than 25°C, CO_2 would be at least as efficient as R-134a. Mr. Clodic asked whether that comparison had entailed the use of different heat exchangers. Mr. Yamaguchi said that the CO_2 had been compared with R-134a using the same refrigeration circuit. However, Mr. Pussoli said that at 40°C, CO_2 and R-134a required different compressor capacities. At that temperature, the issue was really the highest efficiency that could be achieved, and that depends on the heat exchanger being used.

In response to a question about the number of systems being produced using a 150 gram charge of HCs, Mr. Hon said larger equipment was used in the United States and smaller equipment in Europe and that HCs were used in 80% of single circuit systems. Multiple circuits could run those circuits through the same box, each with a charge of 150 grams. Mr. Clodic asked about the market share of stand-alone systems other than CO_2 and HCs and observed that HFCs represented 50% of systems globally. Mr. Hon said that in North America the market share of HCs was still low and that it was almost impossible to sell stand-alone systems in Canada except when they were installed in the open air due to Canadian safety standards. However, exports to Europe were growing and although R-134a was losing market share, R-290 (propane) was growing. Mr. Pussoli said that his market was composed of 70% HFCs and 30% propane, and that CO_2 systems were only just being introduced. Mr. Yamaguchi said that in Japan, 25% of vending machines use CO_2 while 70% use R-134a, and a small number of vending machines use HFO-1234yf. In refrigerated showcases, the use of CO_2 had just started and its share was low thus far.

In response to questions about the use of HFO-1234yf, Mr. Hon said that there was a limited supply of the chemical and as little research had been done on it there was only cursory information available. It is less flammable than HCs, but he did not know the costs. Mr. Ali said that HFOs worked, but it is important to look at blends with CO_2. There are design problems with R-744 (CO_2) operating processes.

In response to a question about the 150 gram charge size limit in the United States, Mr. Hon said that the limit had been chosen for safety reasons and that safety had to be proved before that could be changed. The U.S. Environmental Protection Agency has a process in place for reviewing the size limit and safety guidelines called the Significant New Alternatives Policy (SNAP) program. He said that 150 grams is a viable charge size for self-contained units. Mr. Clodic said that in the European Union, safety standards allow up to a one kilo charge, but that there are different rules for air-conditioning and refrigeration, and indirect systems were different. There could be a 150 gram charge in stand-alone equipment, but 100 such stand-alone devices, each with a 150 gram charge, could be linked together. Mr. Tombs added that modularity gives flexibility, and he said the largest installation in Korea had 190 smaller units linked together.

b) Centralized systems

Panelists:

Luigino Belloni, Zanotti, Italy

Zanotti has been in business for 50 years and produces small, medium, and large cold room units using a variety of refrigerants, including propane and propylene.

Simon Bérubé, Carnot, Canada

Carnot, established in 2008, manufactures and refurbishes industrial and commercial refrigeration equipment using refrigerants such as CO_2 and ammonia. They have installed and retrofitted a number of Canadian supermarkets with CO_2-based systems.

Iwan Chandra, PT. Sumo Elco Mandiri, Indonesia

PT. Sumo Elco Mandiri manufacturers refrigeration and air-conditioning units, mostly using R-22, but they are now building systems using R-404A and are looking into propane and CO_2-based systems as well.

Takeshi Ishii, Panasonic Corporation, Japan

Panasonic recently acquired Sanyo and is now expanding into the development of CO_2-based commercial refrigeration systems, for supermarkets and convenience stores.

Travis Lumpkin, Hussmann, USA

Hussmann sells refrigerated merchandise display cases, as well as installation and maintenance services. Recently they have been transitioning away from HFCs and are also focused on improving product efficiency.

Scott Martin, Hill Phoenix, USA

A recent Hill Phoenix project installed an ammonia/CO_2 refrigeration system in a supermarket. It might not always be possible to be HFC-free, but it is possible to reduce HFC use by using CO_2 or water-based cooling, or designing systems with smaller charge size.

DISCUSSION

Regarding the potential for charge size reductions, a participant observed that a switch from HFCs to HCs alone could generate a 40 to 50% charge reduction because of the density of HCs, and asked what charge reduction could be achieved through system design. He was told that using HCs, a complete system re-design achieved a 40 to 50% charge reduction, and a reduction of 15 to 20% was achieved by verifying the possibility of using HCs in the same machine design. It was also important to check the possibility of reducing the refrigerant charge in case of leakages.

Regarding the efficiency of transcritical CO_2 systems, the panel members remarked that any time CO_2 is taken to ambient temperature to condense it, the ambient conditions affect system efficiency. However, the system can be optimized, for example by improving the valves and

other components. Mr. Martin stated that while the industry has had over 50 years of experience with traditional systems, there has only been about six years of experience with transcritical systems. Over time, with more experience, costs and efficiency will improve. In addition, other new low-GWP refrigerants and blends are being developed. Given the breadth of refrigerants, the answer for every operating condition does not lie in any single refrigerant, and never has. Many different technologies should be considered.

When choosing a refrigerant and predicting loads and leakage rates, Mr. Lumpkin noted that location, safety concerns such as the proximity to residents and users, and servicing needs all have to be taken into consideration. There are many options, including ammonia, low-charge ammonia, and low-GWP HFCs.

A participant asked whether the technology as it exists now should be adopted, or should countries wait, and if so, for how long. The panel responded that it was better not to wait – there are existing technologies and we need to change the way of thinking about refrigeration and how it interacts with buildings, lighting, and other design elements. That process will take time, as the whole industry, including its education system, needs to change. Participants were advised to engage in a store test first, to gain some experience, and learn the pros and cons of the systems and develop their technicians, after which they would be in a position to make a more informed decision on how to move forward. They would never be able to appreciate the advantages of a system without testing it first.

In closing it was observed that one solution is to reduce the charge size as much as possible, and that the pros and cons of indirect systems should be evaluated. It is clear that when temperatures are high, industrial systems are the better option, and that the size of each subsystem has to be determined on a case-by-case basis. However, the advisability of a large centralized system was not clear and is still under evaluation.

SESSION III: TECHNOLOGIES – COMPRESSORS AND CONDENSING UNITS

moderated by Walid Chakroun, American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE) / College of Engineering & Petroleum, Kuwait University, Kuwait

Session III consisted of a presentation followed by a panel discussion on industry experiences and perspectives on the availability and maturity of compressors/condensing units for various alternatives and applications, and the costs, challenges, and feasibility of their use in developing countries.

Opening presentation: Walid Chakroun

Mr. Chakroun said that in refrigeration, different compressors are needed depending on the cooling capacity required. He reviewed the different types of passive and dynamic compressors available. The compressor choice is driven, in part, by the refrigerant being used. He reviewed the history of refrigerants, from the earliest uses of ammonia to CFCs and HCFCs, and the subsequent move back to “natural refrigerants” and HFOs. He also reviewed the different types of commercial refrigeration systems.

Stand-alone units are used extensively in many countries operating under Article 5 of the Montreal Protocol. An estimated 32 million stand-alone units are in use worldwide, together with an additional 20.5 million vending machines, and constitute 7% of global commercial refrigeration stocks.

Condensing units consist of one or two compressors, one condenser, and one receiver, assembled into the condensing unit system. They are linked to one or more display cases in the sales area through a piping network and are typically installed in specialty shops such as bakeries, butcher shops, and convenience stores. They are also extensively used in Article 5 countries. Refrigerant charges range from 0.5 to 20 kilograms (1 to 20 kW). Condensing units constitute 33% of global commercial refrigeration stocks.

Centralized systems consist of racks of compressors installed in a machine room. Centralized direct systems circulate refrigerant from the central machine room into the sales area, while indirect systems chill an intermediate fluid, which circulates from the refrigerant-containing equipment to the display cases or other cooling medium. The charge size ranges from 300 to 3,000 kilograms, depending on the size of the supermarket. Centralized systems constitute 60% of global commercial refrigeration stocks.

He also stressed the difficulties of countries with high ambient temperatures, such as Kuwait, where temperatures can reach 50°C. High ambient temperatures mean high condensing temperatures and pressures and, as a consequence, the coefficient of performance (COP) can drop 20 to 25%. Liquid injection is used for R-22 in low-temperature applications, but economizers, or sub-coolers, are not popular in commercial refrigeration because of their high costs and the preference for customary design. Constraints caused by high discharge temperature and pressure led to the choice of “medium pressure” refrigerants such as R-134a or HFO-1234yf for single-stage systems. There is also a lack of low-GWP refrigerants with a large refrigeration capacity in order to replace R-404A or R-22 in single-stage refrigeration systems.

Most commercialized HFCs are potent greenhouse gases. In some applications, the “indirect” effect of producing energy is much greater than the GWP effect of the refrigerant itself. The process of switching to low-GWP options is moving at different speeds around the world. The challenge for high ambient temperature countries is that their refrigerant selection and their operating systems are still not based on a holistic analysis of multiple criteria such as energy efficiency, system performance, potential impact on community safety, risk to personal safety, cost, and minimization of direct and indirect environmental impacts. Some HFOs are available in limited quantities, but are not yet fully tested in all applications. Some HFOs and lower-GWP HFCs also have mild flammability and their cost is high. There is as yet no ideal refrigerant, and so refrigerants and blends will continue to be used.

With alternative technologies, the question of which refrigerant to use is size and application dependent. Selection of the correct refrigerant requires consideration of capital costs, operating cost (including energy and maintenance), equipment size and location, operating temperatures/pressures, facility staff capability, and local, national, and international regulations. Mr. Chakroun reviewed several different alternative technologies. In CO_2 technology systems, the pressures are approximately ten times higher than systems using ammonia. Special

equipment designs and different manufacturing processes have led to high pressures which result in high gas density, allowing far greater refrigerating effects to be achieved from a given compressor. It is cost effective for smaller products that require high pressure ratings, and at low temperatures (−30 to −50°C) CO_2 produced very small reductions in saturation temperature for a given pressure drop, allowing higher mass flux in evaporators and suction pipes without efficiency penalties. It performs exceptionally well in low-temperature applications.

Hydrocarbon refrigerants have excellent environmental, thermodynamic, and thermo-physical properties; however, they are highly flammable. Hydrocarbon refrigerants provide a range of boiling points with applicability from cryogenics to air-conditioning. They are mostly used in European and Asian countries, and are used in smaller commercial refrigeration systems including beverage and ice-cream machines, transport refrigeration systems for trucks, and chillers in the range 0.3 to 40 tons of refrigeration.

Ammonia is readily available, inexpensive, operates at pressures comparable with other refrigerants, absorbs large amounts of heat when it evaporates, and has no ozone-depleting potential (ODP), no GWP, and a low total equivalent warming impact (TEWI). Ammonia has a low boiling point (−28°F at 0 pounds per square inch) and high latent heat of vaporization (nine times greater than R-12). However, ammonia has toxic effects at higher concentrations (above 300 parts per million), but has a self-alarming odor. It is easy to repair leaks and it is lighter than air. Ammonia use should expand as regulatory officials become informed of its relative safety. The barriers to expanding the use of ammonia that have to be addressed are generally related to human health, environmental safety, and system installation. Continued research is required on topics such as handling, application, operation, control of emissions, and new technology. There is also a need to maintain and develop standards and guidelines for practical and safe application of ammonia in refrigeration systems.

In closing, Mr. Chakroun said that there was concern with the high-GWP of some HFCs as well as calls to reduce their use. Research is required to extend lower-GWP HFCs into new applications and to develop new refrigerants that minimize environmental impacts and safety concerns. The issues with “natural refrigerants” are flammability, toxicity, high pressures, their behavior in operating systems and, in some cases, their lower operating efficiencies. There is a need to balance the safety, energy efficiency, cost, and the environmental impact of refrigerants using a consistent and comprehensive methodology across all refrigerants and system types by using benchmarks such as TEWI or life cycle climate performance (LCCP). Advancing the design of equipment that facilitates reduced refrigerant emissions is also needed, as are methodologies and practices to minimize or prevent refrigerant loss during installation, operation, maintenance, decommissioning and end-of-life disposal.

Panelists:

Torben Funder-Kristensen, Danfoss, Denmark

Danfoss manufactures energy efficient products and controls for the food retail, heating, and air-conditioning sectors. They have experience with lower-GWP refrigerants, including CO_2.

Bernard Philippe, Johnson Controls Inc., France/USA
Johnson Controls manufactures equipment, controls, and services for heating, ventilating, air-conditioning, refrigeration and security systems. Their compressor products use CFCs, HFCs, HCs including CO_2, and ammonia.

Giacomo Pisano, Dorin, Italy
Dorin manufactures semi-hermetic refrigeration compressors. With their focus on green technology, they have developed CO_2-based compressors from 3 to 90 horsepower.

Rajan Rajendran, Emerson, USA
Emerson is a global manufacturer of heating, ventilation, air-conditioning and refrigeration solutions for residential, industrial, and commercial applications. They have experience with manufacturing and servicing propane, CO_2, ammonia, HFC, and HCFC applications.

DISCUSSION

One participant asked whether those responsible for certification, such as Underwriters Laboratories (UL), had been caught off-guard by all the new technologies and whether that was the reason for the delays in the implementation of new technologies. Mr. Pisano said that there was no similar system body to UL in Europe, but that in the United States and Canada it had not been necessarily onerous and it was possible to get an exemption to run an evaluation of a system. However, if a larger number of units were being installed, they might be delayed while that testing took place. Mr. Funder-Kristensen said that in Europe it was up to the manufacturer to prove the technology, although there is also a notification requirement under the Pressure Equipment Directive (97/23/EC) of the European Union that established a safety level, and manufactures have to prove they are within it. Mr. Rajendran said that if the International Organization for Standardization (ISO) does not have a standard, then UL is at a loss and has to rely on the expertise of industry; but UL could react faster when industry did its work.

One participant observed that compressor manufactures and gas manufacturers were each waiting for the other. Mr. Rajendran said that compressors are available for blends such as R-404A and also for R-407A and R-407F too, with half the GWP for the same efficiency. He also pointed out that for A2L (mildly flammable) fluids, standards need to be established, but that when they are published the manufacturers will be ready. It was also pointed out that R-407A was the first in a series, of which R-407F was the latest example. Once the controls are ready, there should be no issue with the compressors as they are in the same range.

One participant said that A2L flammability standards are needed and asked when they could be expected. By not adopting standards, developing countries had been placed in a difficult position. They had taken on obligations to reduce R-22 use and had completed projects but could not go forward with them as no standards are in place. Mr. Philippe said that the delay in standards was not an excuse as it is possible to train people now. However, it was pointed out that UL standards had been voted down by the ISO technical committee in April and nothing is expected in the near future.

SESSION IV: INITIATIVES AND PARTNERSHIPS TO ENCOURAGE TRANSITION AND REDUCE EMISSIONS

moderated by Javier Carmago, Ministerio de Ambiente y Desarrollo Sostenible, Colombia

Session IV consisted of a series of four presentations made by the panelists. The topic was regulatory drivers, voluntary initiatives, and corporate/government partnerships to encourage transition to low-GWP and energy-efficient technologies and to reduce emissions through proper refrigerant management and best practices.

Panelists:

Arno Kaschl, European Commission

Mr. Kaschl made a presentation on EU legislative actions targeting HFC emissions from commercial refrigeration. The existing Fluorinated-Gas Regulation from 2006 focuses mostly on prevention of emissions during the use phase of equipment and end-of-life treatment. There are requirements for operators on leak checking, record keeping, and assuring proper recovery, as well as certification requirements for service personnel. As suitable alternatives are available in most areas and abatement costs are generally modest, a new law was proposed in November 2012 by the European Commission to greatly reduce the use of HFCs in new equipment. This phasedown will reduce HFCs placed on the market in the EU to 21% of today's levels by 2030. In addition, some bans are foreseen that will directly affect the supermarket sector, namely on hermetically-sealed equipment and on servicing refrigeration equipment with very high-GWP HFCs. This proposal is currently being debated by the European Council and the Parliament.

Cindy Newberg, United States Environmental Protection Agency (EPA)

Ms. Newberg's presentation was on the role of public-private partnerships in addressing emissions. After noting that retail food is an incredibly important sector, accounting for over 40% of 2010 HFC consumption, she described an approach taken in the United States, where partnerships provided opportunities to go beyond regulatory requirements. She focused on GreenChill, an EPA partnership with food retailers, describing its programs, philosophy, and results. She presented tools such as a Financial Impact Calculator that allows retailers to calculate how much product they need to sell to pay the replacement cost of leaked refrigerant, and a Climate Impact Calculator that compares the CO_2 effect of reducing refrigerant leaks to the more familiar measure of reducing electricity consumption. She closed by reviewing lessons learned and suggesting that one possible way forward is to consider how partnership programs can be more broadly used.

Clare Perry, Environmental Investigation Agency (EIA)

Ms. Perry presented the EIA's Chilling Facts campaign to promote HFC-free cooling. Her talk covered the background of the EIA and the campaign itself, the main findings as contained in the EIA's reports from 2009 to 2012, and lessons learned. She described how EIA's approach has changed over time – seeking a more cooperative relationship with industry to achieve climate

goals. She also described the agency's information sharing activities and proposed activities and challenges that lie ahead.

Dave Stirpe, The Alliance for Responsible Atmospheric Policy
Mr. Stirpe spoke on responsible management of refrigerants. He provided some background on the makeup and membership of the Alliance. The Alliance is a leading industry group that coordinates industry participation in the development of international and U.S. domestic government policies regarding ozone protection and climate change. The Alliance was organized in 1980 and is presently composed of about 100 manufacturers and businesses – many of which are multinational companies that rely on HCFCs and HFCs. The Alliance supports the orderly global phasedown of high-GWP HFCs. Mr. Stirpe reviewed their responsible-use principles and best practices, in particular equipment and fluid requirements. These practices reduce emissions of CFCs, HCFCs, and HFCs.

The moderator closed the session by saying that the presentations contained useful information, and that challenges still remained for small- and medium-sized enterprises. He also remarked that ministers might attempt to develop national policy in association with other, more influential departments, such as mines and energy. Because of a shortage of time, the questions and answers for this session were taken together with those in Session V.

SESSION V: OPPORTUNITES AND CHALLENGES

moderated by Ms. Bitul Zulhansi, Ministry of Environment, Indonesia

Session V consisted of brief statements by the panelists on what they perceived to be the key opportunities and challenges for the adoption of climate-friendly alternatives in developing countries, followed by a discussion period. The panel members were Nandan Chirmulay (United Nations Development Programme), Ayman Eltalouny (United Nations Environment Programme), Ole Nielsen (United Nations Industrial Development Organization), Agustín Sánchez (Coordinador de la Unidad de Protección a la Capa de Ozono, Mexico) and Viraj Vithoontien (World Bank).

Introduction

In her introduction Ms. Zulhansi said that the discussion would address the opportunities and challenges and potential for adoption of climate-friendly alternatives, revision of standards and regulations particularly for addressing safety issues, and the feasibility of various alternatives, including the role of ambient temperature in developing countries as they prepare for subsequent phases of the HCFC phase-out. She asked the panelists what were the key challenges and opportunities for transferring and adopting climate-friendly technologies for commercial refrigeration in developing countries and identified several key themes relevant to the issue of technology transfer: how to facilitate the adoption of climate-friendly technologies; how domestic and international standards could be addressed to remove barriers for the introduction of such technologies; the relative advantages of "natural refrigerants" as compared

to low-GWP HFCs; the key cost considerations involved in the adoption of various alternatives; and whether future HCFC phase out management plan (HPMP) stages could be structured to maximize the adoption of climate-friendly technologies in the commercial refrigeration sector and so avoid high-GWP HFCs.

Mr. Chirmulay said that the issue presented both opportunities and challenges. Through the course of the day there had been a general discussion of the technologies that could be developed. However, there are challenges in both manufacturing and servicing. One challenge for manufacturing is that standards rely on industry to proceed with technological updates for the standards for new alternatives. Another major challenge is the introduction of new alternatives. With respect to servicing, he asked how to reduce the use of CFCs and HCFCs. There has been containment and a partial freeze, but unless equipment is no longer based on those chemicals, they will still be used. There has also been a great deal invested in training technicians, but there is also a need to keep technicians sustainably in the trade, which is also a challenge.

Mr. Eltalouny noted that there is a great deal of overlap between air-conditioning and refrigeration but also that specific considerations apply to each sub-sector. For example, each sector has different policy-related technical instruments, stakeholders, and decision makers. He also reviewed the experience of United Nations agencies, and challenges from the field. These include a lack of interest by end-users, with high-GWP refrigerants not on their “radar,” and some believe that zero-ODP and high-GWP refrigerants are climate-friendly. Stating the need to change that culture, he gave the example of the Montreal Protocol facing similar problems in its early days: Article 5 countries did not have sufficient information for refrigeration, and were therefore advised by the suppliers. That did not promote innovation, but instead business as usual. There was also a high price for alternatives and limited technical capacity to use them. Although there were interesting examples from Brazil and Indonesia, there was a lack of technology transfer to small- and medium-enterprises in the sector. It is also important to make them aware of climate benefits. In closing, he said that there are opportunities in at least two areas: low-GWP alternatives could be promoted in two directions and not just top down; not just by government but by industry as well. Joint ventures could also be set up. The problem is that the new alternatives in the developed world are not being transferred to partners in the developing world.

Mr. Nielsen said he had the same concerns. The Montreal Protocol could not be a substitute for barriers in technology for different types of refrigeration. He said that it is good to know about the mature technologies in stand-alone, self-contained units, but the barrier was small- and medium-enterprises in developing countries. Funds for them were limited through the Montreal Protocol. The availability of components is also a priority issue, as is the lack of standards for flammable refrigerants. However, if there are no standards it should be possible to look to the European Union, the United States and Japan and follow their procedures. He urged that developing countries not be made a playground for experimentation. Replacement grade alternatives do not just involve retrofitting but also a number of flammable refrigerants for stand-alone equipment. Although they technically work, there are safety concerns. Centralized systems present a number of technical options, some being used in the United States and the EU. The main barrier is cost, and support is limited, as are servicing centers. CO_2, cascade systems, and HCs require

training. It is important to remember the energy efficiency of any system and if the refrigerant was marginally higher in GWP, but improved energy efficiency, or if other things would have to be done to address energy efficiency. It is important to keep costs low.

Mr. Sánchez said that all the alternatives worked well in some countries. However, in the tropics, where most Article 5 countries are located, climate conditions are different. While some developed countries say it is possible to use CO_2 transcritical systems, the difficulty is how to use it and how to adapt that process when there are restrictions with respect to: availability; costs; safety; applicability; energy consumption; and external limits, such as international market conditions, as well as internal use changes to consider, for example, the education of users and environmental considerations. There is also the problem of the cost of adaptation. A country could be interested in adopting alternatives but find there are market barriers due to the cost of the chemical. It is important to keep the conditions right for growth into new technologies. He also reviewed different policy measures and said that if investment was not ready there could be a risk of setbacks in development. Taxation gives advantages to high capital companies instead of smaller ones; smaller companies do well with subsidies, and distribution could be managed affordably to allow energy efficient use. Compliance measures have to be devised with investment and support services in mind, and consumer behavior has to be changed. However, there are other important changes that could reduce refrigerant emissions such as modifying the existing technologies, such as adding closed doors on freezers. In that example, consumers had less easy access to products and so it was important to educate them to accept the new technologies.

Mr. Vithoontien said that there are opportunities with lower-GWP alternatives in stand-alone units which are extensively located in developing countries. For larger units, based on what he had heard, commercial refrigeration depends on location. Developed countries were still fine-tuning the systems and there is an opportunity for developing countries to learn from that process. There have been no clear cut developments, although a number of companies have taken the lead and are getting out of R-22 and hoped that as the technology matures, the price will go down. The need for energy efficiency is generally understood but the issue for refrigerants is how to translate that to language a lay person could understand. The EIA and the private sector had shown leadership and its project could be expanded into developing countries, but there has to also be a consideration of profit and loss. The challenge for so many is the limited capacity for advancing technology transfer. Investment is a challenge for developed and developing countries and the key question is what the return on investment will be. The servicing sector will also be faced with multiple refrigerants in the developing world and training is needed to address that; standards are important and needed, but the capacity within the countries to enforce those standards is needed too.

DISCUSSION

In response to a question on high ambient temperatures, Mr. Chirmulay said that in developing countries, stand-alone equipment dominates, and most of it is located indoors in places that are already climate-controlled. With respect to centralized systems, high ambient temperatures

affect all refrigerants equally. Mr. Sánchez gave the example of Mexicali, which was similar to Arizona in the United States. In Mexicali, new technology based on solar power is planned for installation, and it is hoped to be in operation next year. The temperature in Mexicali reaches 45 to 50°C at certain times of the year, similar to other developing countries. He said that when more information was available on that new technology he would share it.

One participant thanked the panelists for their instructive presentations, which were most significant for low-volume and very low-volume consuming countries. However, he said that they had not been complete as there were other challenges as well. One of them is financing for the transition from HCFCs, and he asked how that would be financed. There is also the problem of refrigerant and equipment disposal and the availability of HFC equipment. Low-volume consuming countries are dependent on developed world support for that and have no control over it. They have no options and it is a huge challenge for them. They want to move into those alternatives but they have no choice in the matter.

Mr. Eltalouny said that he could not agree more with the point that had been made. Financial considerations for the transfer of technology have not been captured properly in the projects of the Multilateral Fund. However, climate benefits are part of the strategy of the Multilateral Fund and that will continue in stages II and III, at which point costs would be discussed. The present concern is with existing refrigeration. Mr. Chirmulay said that he was not sure what was meant by financing alternatives. Financing by the Multilateral Fund could leverage other financing sources. The disposal of ODS is important, but is an overarching issue for all sectors and not just commercial refrigeration. For commercial refrigeration, the percentage of HCFCs was low, even if trending higher. Disposal should occur when timely, and destruction should take place only when recycling is not possible. One of the biggest drivers is when the price differential of alternatives becomes cost-effective. Some technologies are already in use and have good paybacks.

One participant congratulated the organizers and said that during the course of the day he had a good opportunity to explore the technologies available in commercial refrigeration. It is a very simple segment of the air-conditioning/refrigeration sector and in developing countries the majority of units are stand-alone. It is similar to domestic refrigeration with 80 to 85% being stand-alone units, while 15% are larger systems. The walk-in cooler situation in developed countries is different. The majority of R-12 has been converted to R-134a. He therefore suggested that developing countries could focus on adopting alternatives for stand-alone units now, where low-GWP alternatives are available. One example is that alternatives to R-134a are HCs such as propane, which has been in use since 1994. The main barrier is the global end-user's willingness to use HC technology. Global beverage companies have put out stand-alone units but they have not taken off. That was the driver for HFC manufacturers, the end user. Servicing agent training on flammable refrigerants is also an issue but the servicing challenge was the end user's willingness to use HCs.

Another participant said that from his point-of-view, the barrier is the number of changes required whenever selecting or adopting new technologies. He had learned from previous experience that it was better to wait until the technologies had been tested before they were taken on. For example, in his region the leakage standard was different from those in Article 2

countries. His region had learned that it had to wait for HFCs and HFOs, as each time a low-GWP alternative was adopted they found that later they had to go to yet another standard involving yet a lower GWP.

Another participant expressed her concern at the fact that the Multilateral Fund treated small enterprises assembling and charging commercial refrigeration equipment as part of the refrigeration servicing sector, and that the eligible funding for the servicing sector was insufficient. While the Multilateral Fund will provide some funding to small- and medium-sized enterprises, the problem previously experienced in the solvent sector was that the amounts were so low that enterprises were not interested in converting. She said that the challenge for the Multilateral Fund would be to address that.

Mr. Eltalouny said that he could not agree more. He said that he had mentioned the low-hanging fruit in stand-alone applications and the need to create the willingness to address that and do the cost accounting work which has to be done at the technical level to change capacity. For the rest, the commercial applications still need to get technology; but patience is required as that needs time. Mr. Vithoontien said that based on presentations he felt that there were opportunities for lower-GWP energy efficiency which was a win-win for the private sector, and not just the owners of units, but in the bigger picture at national level as well. Growth in energy efficiency in developing countries allows governments to redirect national resources to things other than power plants.

Closing remarks: Mr. Philippe Chemouny, Environment Canada

Mr. Chemouny thanked the presenters and the participants for an interesting discussion and said that there was a lot of interest in opportunities for low-GWP energy efficient technologies for developing countries. Important challenges had been mentioned, including ones related to financing, which could not be addressed only by the Multilateral Fund. He suggested that countries interested in further work on low-GWP alternatives could explore opportunities within the CCAC. He said that through perseverance and working together, the acceptance of climate-friendly technologies would come.

Following the Forum, some of the participants paid a field visit to a supermarket which had converted to transcritical CO_2 technology.