Technical Meeting on HCFC Phase-Out
5-6 April 2008, Montreal, Canada

OVERVIEW OF ADVANTAGES AND DISADVANTAGES OF ALTERNATIVES

This document provides a summary of the alternatives to HCFCs that were described in presentations made at the Technical Meeting on HCFC Phase-Out, held in Montreal, Canada from 5-6 April 2008. Only those advantages and disadvantages addressed during presentations at the Technical Meeting are including in this summary table, and it should also be noted that certain considerations like health and safety concerns may need to be evaluated on a case-by-case basis. All presentations are available in full as part of the Technical Meeting proceedings.

ALTERNATIVE AND PRESENTER	ADVANTAGES	DISADVANTAGES	COMMERCIALIZATION	COMMENTS
Commercial Refrigeration				
R-422D retrofit of HCFC-22 supermarket systems (Epta)	• Retrofits done quickly without business interruption or additional investment • Energy advantages • Lower discharge temperature (for longer compressor and components lifespan)	• Direct GWP climate impact • No other disadvantages specifically addressed in presentation	• Pilot retrofit project in Edeka Market in Fuldabrück	
R-417A retrofit of HCFC-22 medium temp. ref. and stationary AC **R-422A retrofit** of HCFC-22 and R-502 medium/low temp. ref. **R-422D retrofit** of HCFC-22 ref. and stationary AC **R-437A retrofit** of CFC-12 medium temp. ref. and mobile AC (DuPont)	• Safety classification of A1 • Typically no-oil-change retrofit • Comparable energy efficiency compared to HCFC-22 for R-417A, R-422A, and R-422D, and compared to CFC-12 or HFC-134a for R-437A • Comparable capacity compared to HCFC-22 or R-417A, R-422A, and R-422D, and compared to CFC-12 or HFC-134a for R-437A	• Direct GWP climate impact • No other disadvantages specifically addressed in presentation	• Commercialization not specifically addressed in presentation	• Retrofits may be required to avoid premature obsolescence of equipment • R-417A (ISCEON® MO59) • R-422A (ISCEON® MO79) • R-422D (ISCEON® MO29) • R-437A (ISCEON® MO49), pending ASHRAE approval
R-744 (CO_2) new transcritical and cascade supermarket refrigeration systems (Green Cooling Council)	• No climate impact • Low toxicity and no flammability • Potential for low power consumption in cool/moderate climates • Theoretical higher efficiency than HFC-134a up to 30°C • Low cost and widely available refrigerant	• Lack of systems knowledge/familiarity • Potential for high power consumption in hot climates • Remote location servicing challenge • Installation costs currently 20% higher than conventional system	• Around 30 cascade systems installed in commercial refrigeration and food processing facilities in Australia (since 2005) and transcritical system in Adelaide, Australia • In Europe, over 100 supermarkets running on transcritical CO_2 cycle	

ALTERNATIVE AND PRESENTER	ADVANTAGES	DISADVANTAGES	COMMERCIALIZATION	COMMENTS
R-290 (propane) commercial refrigeration equipment, including bottle coolers, glass door merchandisers, ice cream/chest freezers, commercial refrigerators and freezers (Danfoss)	• Low cost and widely available refrigerant • In running production • Good thermodynamic performance compared to HCFC-22, especially in low countries • Low climate impact (GWP of 3) • Comparable pressure, capacity loss, and COP performance compared to HCFC-22 • Improved pressure ratio LBP, discharge temperature, and volumetric capacity compared to HCFC-22	• Safety concerns (flammability); may mean slightly increased cost depending on base design • Costs for factory investments in leak test, charging, and safety installments • Change of system parts for larger appliances	• In running production	
Small/Medium AC & Heat Pumps				
R-410A scroll and rotary compressors (Mitsubishi)	• Performance with R-410A is better compared to HCFC-22 in room AC units • Comparable running costs (e.g., electricity)	• Increased manufacturing cost of compressor when changing from HCFC-22 to R-410A (including refrigerant cost, switch from mineral oil to synthetic oils, etc.)	• Commercialization not specifically address in presentation	• Prevent refrigerant oil from deteriorating by reducing quantity of water in refrigeration oil • Prevent sludge generation by preventing contaminants being mixed into the compressor
R-410A and R-407C scroll and rotary compressors and heat pumps in small and medium air conditioning equipment (Hitachi)	• High efficiency and reliability in scroll and rotary compressors with new design technology • High efficiency in heat exchangers by increasing heat transfer rate, reducing pressure loss, and increasing amount of subcooling • Increased coefficient of performance • More compact component dimensions means material cost ratio decreased for R-407C and R-410A compared to HCFC-22	• Direct GWP climate impact • No other disadvantages specifically addressed in presentation	• Commercialization not specifically addressed in presentation	• Oil charger and refrigerant charger must be changed at assembly line facilities • Several specification changes, conversion of facilities, and preparation of tools is required
CO_2 heat pump high temperature water heater (Daikin)	• Lower GWP than HFC alternatives • Emissions about 2/3 to ½ of a gas water heater • Efficient system of CO_2 water heater and thermal storage • Safe (heats water up to 90°C without flame) • Energy efficient against conventional resistive heater Lower running cost (since heats water at night when electricity rates is lower) • Higher operating pressure compared to R-410A so enhances a swing compressor for higher reliability and lower leakage • Performance of water heat exchanger improved	• No disadvantages specifically addressed in presentation	• Commercialization of residential CO2 heat pump water heater started in 2001; cumulative sales exceeded 1 million units in 2007	• CO_2 not suitable for reversible air source heat pump, but good potential for high temperature heat pump and water heaters and other once-pass heating applications with large temperature differences • This type of thermal storage system may be useful for developing countries where nuclear or wind power is utilized

ALTERNATIVE AND PRESENTER	ADVANTAGES	DISADVANTAGES	COMMERCIALIZATION	COMMENTS
Other Refrigeration/AC				
Ammonia commercial/ industrial applications (Jaeggi/Guntner)	• No climate impact • Favorable in large systems	• No simple replacement in new systems; all refrigerants need adjustments (e.g., different refrigerant-carrying tubes)	• Used in commercial/industrial applications in Europe	
Propane commercial/ industrial applications (Jaeggi/Guntner)	• Low climate impact • Comparable thermodynamic data to HCFC-22	• No simple replacement in new systems; all refrigerants need adjustments	• Commercialization not specifically addressed in presentation	
CO_2 low temp. and supermarket refrigeration (Jaeggi/Guntner)	• Lower GWP than HFC alternatives • High cost reduction potential	• No simple replacement in new systems; all refrigerants need adjustments	• Used in low temperature and supermarket refrigeration in Europe	
CO_2 compressors in vending machines (Sanyo)	• CO_2 is widely available • High volumetric cooling capacity and heat transfer • Heat pump ability at low temperature ambient • Low climate impact (GWP of 1) • Nonflammable • Energy consumption is 10% less than an HFC-134a system at 32°C (17% less in field test during summer) • Parts and materials are comparable cost to conventional HFC or HCFC rotary compressor for AC	• No disadvantages specifically addressed in presentation	• 30,000 systems installed in Japanese vending machine market currently	• Design challenges include system efficiency (lower theoretical efficiency with normal refrigeration system) and high working pressure • Reduce discharge gas temperature and compression load for a big improvement of cooling effect and efficiency
Hydrocarbons retrofit of large chillers (Energy Resources Group)	• Energy savings • Low climate impact	• Technician training to understand hydrocarbon characteristics • Some projects, sites, and chillers are not suitable for hydrocarbons because of location, serviceability, ventilation	• Conversions successfully carried out in Singapore, Malaysia, Thailand, Indonesia, Philippines, etc	• Challenges include distribution, availability, quality, and training • Safety survey/audit must be carried out before conversion, and safety devices needed

ALTERNATIVE AND PRESENTER	ADVANTAGES	DISADVANTAGES	COMMERCIALIZATION	COMMENTS
Large AC				
R-410A scroll chillers (McQuay)	• Comparable to higher efficiency compared to HFC-134a and R-407C • Improved capacity and suction and cond. pressure compared to HFC-134a (and higher than R-407C) • Safety classification of A1 • Proven performance and reliability over 11 years • No fractionation/glide (service) • Cost optimization (less copper and less charge)	• 10 to 15% more costly (higher operating pressure means equipment redesign, thicker compressor shell, heavier wall tubing, superior control and protection, better welds required)	• Commercialization not specifically addressed in presentation	• R-410A has higher operating pressure, requiring new system design, but more robust equipment means less leaks • Polyolester lubricant absorbs moisture from the air; technicians need training for new lubricant and refrigerant
R-407C scroll chillers (McQuay)	• Comparable to higher efficiency compared to HFC-134a • Improved capacity and suction and cond. pressure compared to HFC-134a • R-407C is drop-in replacement for HCFC-22 with an oil change (no need for redesign) • Safety classification of A1	• Direct GWP climate impact • No other disadvantages specifically addressed in presentation	• Commercialization not specifically addressed in presentation	• Polyolester lubricant absorbs moisture from the air; technicians need training for new lubricant and refrigerant
Ammonia new screw packaged chillers (Johnson Controls)	• Inexpensive on mass basis, compared to HCFC-22, HFC-134a and other HFC blends • Ammonia leaks are self-alarming (pungent odor) • Comparable to improved cycle efficiencies compared to HCFC-22, HFC-134a, R-507, and R-404A, and thus lower operating costs	• Not compatible with copper • Low concentrations ruled toxic • Considered flammable • Some regulatory barriers (at least in United States)	• European chiller market is heavily ammonia based	
HFC-134a helical rotary air-cooled and water-cooled chillers (Trane)	• Energy efficiency impact is greater than direct GWP impact • HFC-134a has a higher coefficient of performance than CO_2, comparable to HCFC-22 and HFC-410A • Performance/cost penalty from moving from HCFCs to HFCs can be offset by non-refrigerant technology to minimize the cost increase	• Refrigerant has higher GWP (see advantages) • No other disadvantages specifically addressed in presentation	• 45,000 units in place, with over 40% in A5 countries	• Capacity, supply chain, and service infrastructure development is important • Non-HFC fluid technologies increase indirect emissions due to poor energy efficiency or raise safety concerns
Foams				
HFC-245fa and hydrocarbons replacement of HCFC-141b in PU rigid foams in appliances (Dow Brazil)	• HFC-245fa favored for energy efficiency and non-flammability • HFC-245fa requires a low machinery investment • Hydrocarbons favored for low environmental impact and low cost blowing agent	• HFC-245fa is a higher cost blowing agent with a climate impact (high GWP) • Hydrocarbons require high machinery and plant processing cost	• HCFC replacement by HFC-245fa successfully implemented in China and the U.S.	• Challenges are density, cost, and processing

ALTERNATIVE AND PRESENTER	ADVANTAGES	DISADVANTAGES	COMMERCIALIZATION	COMMENTS
Hydrocarbons, HFCs, and water replacement of HCFC-141b in PU rigid foams (Huntsman)	• Hydrocarbons widely used in China in appliances	• High capital investment for hydrocarbons • Potential safety concerns with hydrocarbons • CO_2/water has poor thermal insulation and adhesion • HFC is more expensive than HCFC-141b	• Pentane is 50% of total PU rigid foam in China; hydrocarbons commercialized in appliances and pipes, and in reefer containers and sandwich panels, to a lesser extent • Water commercialized in sandwich panels, pipes, and structural foam, and in spray to lesser extent • HFCs partially commercialized in appliances and reefer containers	• Conversion cost from HCFC-14b to c-pentane is approximately €870,000
HFC-365mfc/227ea and HFC-365mfc/245fa in PU foam (Solvay Fluor)	• HFC-365mfc/227ea in spray foam is cost-effective, high-performance alternative, provides for easy processing in most climates, and saves energy • HFC-365mfc/227ea offers non-flammable systems for other markets, as well as easy handling and best thermal conductivity; minimal system modification required to switch from HCFC-141b • HFC-365mfc/227ea leads to improved operation with lower foam density possible in panel laminates • HFC-465mfc offers good dimensional stability, compressive strengths, lower foam density, and enhanced insulating performance in insulation panels, sandwich panels, and appliances • Substituting pentane in a formulation by HFC-265mfc can lower cost, GWP, and improve overall performance • Excellent fire resistance • Converting foaming machines from HCFC-141b is simple and cost-effective	• Cost of HFC blowing agent is higher than HCFC-141b, but increased water content, decreasing densities, and less energy utilization will promote savings • Climate impact from direct GWP (but reducing emission reductions and better insulation means less CO_2 emissions and environmental competitiveness is LCA and eco-efficiency studies)	• Commercialization not specifically addressed in presentation	• In converting production facilities, some precautions recommended to account for potential flammable mixtures in air
Pentane in rigid foam manufacturing equipment (Hennecke, KraussMaffei)	• Low climate impact • Low cost blowing agent • Reasonable availability • Improved ageing characteristics and thermal insulation	• Pentane with form with air an explosive mixture; safety measures must be taken when processing	• Retrofits have been undertaken in Chile and other countries	• Cost for pentane upgrade in A5 countries of small to mid-size plants is US$120,000 to $520,000 • In processing plant for pentane as a foam blowing agent, required elements: pentane/polyol storage, premixing unit, metering unit, and working and foaming area