HCFCs IN REFRIGERATION
AND AIR CONDITIONING*
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Outline

- HCFC Phase-out Management Plan (HPMP) of MLF
- Summary of UNEP RTOC Report 2006
- HCFCs and HCFC-22 (R-22)
- Replacement refrigerants and blends
- Availability
- Aspects of replacing HCFC-22 and different options
- Decision XI X/6
- Concluding remarks
HPMP - Recommendations to MLF

- Although the current guidelines are based on ODP, the HPMPs should also address climate change by using alternatives with lower GWP taking into account energy efficiencies, equipment, and climate circumstances.
- Conversion policy would consider discouraging the use of HCFC alternatives with high GWP.
- Strategic activities be identified between now and the establishment of the baseline (at the end of 2010). These might include, demonstration projects with no or very low GWP technology and effective energy conservation measures.
- The choice of technologies should also ensure that environmentally-safe substitutes and related technologies are transferred to Article 5 countries under fair and most favourable conditions.
HCFCs & RAC Sector

- Currently, HCFC-141b, HCFC-142b and HCFC-22 account for more than 99% of the total consumption of all HCFCs in A5 countries. These are mainly used in the manufacturing of foam products (32.5%) and refrigeration equipment, including servicing sector (66.2%).
- HCFC-22 is likely to be used in all A5 countries as a refrigerant for servicing of air conditioning and in commercial refrigeration.
- The refrigeration servicing sector will play an important role in achieving the phase-out, particularly in those countries without HCFC manufacturing enterprises.
- There are a number of other HCFCs used in the RAC, particularly HCFC-123 in centrifugal chillers as an alternative to CFC-11 and HCFC-124 and HCFC-142b (in blends) as alternatives to CFC-12. Mostly these refrigerants and products are imported into A5 countries.
- Both HFCs as well as a low GWP refrigerants are likely to have the same or better energy efficiency compared to HCFC-22 equipment, in some cases, requiring significant redesign or use of an optimized compressor, with some cost increases.
HCFC-22 in RAC Sector

- HCFC-22 was mainly (only) applied in AC before 1990; no other HCFC was applied in both Refrigeration & AC sectors before mid-1990s.
- HCFC-22 is the only HCFC that is applied in large quantities in R&AC; larger size products show considerable emissions during operation.
- HCFC-22 (transitionally) replaced R-502 in commercial refrigeration in 1990s (due to the CFC phase-out in the developed countries in 1995/96).
- HCFC-22 is by far the predominant HCFCs in RAC sector, with an estimated share of more than 97.2 per cent of the total HCFCs consumption (metric tonnes) in the refrigeration sector.
- Air-cooled air conditioners, from 2.0 to 700 kW, are used in residential and commercial applications for cooling or heating, representing probably the largest sub-sector of HCFC-22 consumption in Article 5 countries.
The service sector is a HCFC-22 consumer in all or most Article 5 countries.
Wherever air conditioning equipment is being used, HCFC-22 is likely to be used for servicing. AC unit population is very large and rapidly increasing. This will lead to an overall high service demand.
The use of HCFC-22 in commercial refrigeration is further boosting service demand. The structure of the service sector and phase-out are known from the phase-out of CFC-12.
Global phase-out of CFCs and also HCFCs, coupled with steps to reduce global warming, continues to drive transitions away from ODS refrigerants.

The technology options may be universal, but regional choices are influenced by local laws, regulations, standards, and economics.

More than 20 new refrigerants were commercialized for use either in new equipment or as service refrigerants since the publication of the 2002 RTOC report.

Additional refrigerants still are being developed, and research continues to increase and improve the physical, safety, and environmental data.
Domestic refrigeration: More than 96% of new production uses non-ODS refrigerants, primarily HFC-134a and isobutane (HC-600a).

Commercial refrigeration: Most stand-alone equipment use HFCs, but HC; CO2 (R-744) use is growing, especially in Europe and Japan. Use of HCFC-22 (USA and Article 5 countries) and R-404A (Europe) dominate in new supermarket systems. CO2, HCs, and ammonia (R-717) are predominantly used in Northern European countries.

Industrial refrigeration: R-717 and HCFC-22 are the most common refrigerants for new equipment; costs have driven HFC-use in small systems. CO2 use is gaining in low-temperature, cascaded systems.

Transport refrigeration: New production has shifted to non-ODS options, such as HFC-134a, R-404A and R-507A, with recent increases also for R-410A. Nearly all CFC-containing systems will be retired by 2010.

Air conditioners and heat pumps: HFC blends, primarily R-410A, but also R-407C, are the most common near-term substitutes for HCFC-22 in air-cooled systems. HCs are an option for low charge systems and limited consideration of CO2 continues. HCFC-22 recovery and containment are necessary to ensure adequate refrigerant supply for service.

Water-heating heat pumps: This small but rapidly growing application area is driven by energy efficiency. HFCs, primarily HFC-134a and R-410A, are replacing HCFC-22. CO2 systems have been introduced in Japan and Europe.

Chillers: HCFC-22 continues to be used in small chillers; the use of HFC-134a, R-407C, and R-410A is increasing here. HCFC-123 and HFC-134a are used in larger centrifugal chillers. Ammonia or HC use is limited.

Vehicle air conditioning: HFC-134a has been used almost exclusively since 1994 in new systems in non-Article 5 countries, and now also globally. Environmental pressure such as recently adopted EU MAC directive is driving possible future replacement of HFC-134a in vehicle air conditioning by low GWP alternatives. CO2 and also HFC-152a are currently among important candidates. Few ODS-containing systems will remain in service after 2012.
CFC bank is approximately 450,000 MT, 70% of which can be found in A5 countries. The annual global CFC demand of approximately 50,000 MT per year is decreasing slowly.

HCFCs form the dominant refrigerant bank, estimated as more than 1,500,000 MT, representing 60% of the total amount of refrigerants in use. Two thirds of this bank can be found in non-Article 5 countries. Current service needs are estimated at 200,000 MT per year.

Efficient R&R and retrofit to non-ODS service refrigerants are essential to avoid HCFC shortages in Article 5 countries. The critical years could be 2009 and 2010 in Europe and later on in the USA and other countries.

Refrigerant recovery is required in the USA and EU upon equipment decommissioning or retirement; it is receiving increasing attention in other non-A5 countries.

The countries, with successful R&R, have achieved with training and comprehensive regulations.

The technological options for RAC are expected to be much the same in the next four years as they are today.

In applications with high emission rates e.g. commercial refrigeration, designs with lower emissions, and conversion to low-GWP refrigerants, such as CO2, are expected.
Research will continue to develop additional refrigerant options. These are likely to drive further innovations in RAC equipment, with lower refrigerant charges.

- Use of indirect systems (applying heat transfer fluids in secondary loops) is increasing to reduce charge sizes, to enable use of sealed systems, and to facilitate application of flammable ODS alternatives.

- Owing to EU regulations on HFCs, the industry will be forced to make a second refrigerant change in MAC from HFC-134a. Several candidates continue to be evaluated, including CO2 and HFC-152a as well as new low-GWP refrigerants, some of which may have low ODPs.

- The use of HCs and CO2 in stand-alone commercial refrigeration equipment is expected to grow, mainly in Europe. HFC blends are the most likely near-term refrigerants to replace HCFC-22 in several applications.

- The dominant HCFC-22 bank is expected to continue to grow for a number of years, and the HFC bank is expected to increase rapidly, at least during the next decade.

- Contrary to non-Article 5 countries, the demand for service refrigerants in most Article 5 countries will consist of CFCs and HCFCs. One of the main concerns will be maintaining adequate supplies of HCFCs. Refrigerant conservation programs to be established for CFCs in Article 5 countries will mostly be government sponsored and regulatory in nature.

- As in many non-Article 5 countries, Article 5 countries may include restrictions on the sale, use, and end-of-life disposal requirements that mandate recovery and recycling of refrigerants.
HCFC-22 in refrigeration

- Commercialized since 1936
- HCFC-22 (R-22) was (is) applied in
  - commercial refrigeration (also in R-502: CFC-115/HCFC-22)
  - small window AC and largest AC units, chillers, heat pumps
- HCFC-22 was (is) used in equipment with
  - reciprocating, and rotary, rolling compressors
  - scroll, screw, and centrifugal compressors
Substitutes for HCFC-22

- In 90s, the US Alternative Refrigerant Evaluation Program (AREP) investigated 14 blends and pure refrigerants as HCFC-22 replacements
- Investigations mainly dealt capacity and energy efficiency
- Certain blend compositions have been reformulated (e.g. different compositions of HFC-32 and HFC-125, including R-410A)
- Blends were/are normally patented by manufacturers
Substitutes for HCFC-22

- Four blends are mainly applied (R-404A, R-407C, R-410A, R-507A), with R-404A and R-507A in commercial refrigeration equipment (these are the replacements for the former R-502)
- Pure refrigerants HFC-134a (with GWP < HCFC-22), HFC-152a, ammonia, CO2, and hydrocarbons, some blends of HCs are also applied in HCFC-22 applications, though the use is so far small
- Ammonia has been historically used in large size refrigeration systems (e.g. cold storage, chillers)
## Substitutes for HCFC-22: Pure refrigerants & blends

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<th>Refrigerant</th>
<th>Type and/or name</th>
<th>GWP (100a)²</th>
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Global availability of HCFC-22 substitutes

- Virtually all refrigerants are globally available
- The important F-chemicals: HFC-32, HFC-125 and HFC-134a
- Logistics and price differences
- With limited production capacity, availability of blends for all HCFC-22 replacement uses worldwide is questionable
- HFC-blends normally have patented composition, which has certain impacts on global use
- HFC-134a, HCs, NH3 and CO2 are more widely available, but replacement use limited
Substitute for HCFC-22: R-407C

- Different compressor lubricant from HCFC-22
- Low(er) energy efficiency
- Heat exchanger design different for higher energy efficiency; manufacturing process same
- Originally applied for AC, use has become less; R-407C can be applied in commercial refrigeration
- Retrofit possible, but difficult lubricant exchange
- No GWP advantage
Substitute for HCFC-22: R-410A

- Different compressor lubricant from HCFC-22
- Critical temperature is 25 K lower than HCFC-22
- Lower to comparable energy efficiency
- Heat exchanger design different for high pressure refrigerant; manufacturing process different
- Main application in small and larger AC
- Retrofit not possible (only for new systems)
- No GWP advantage
Substitute for HCFC-22: R-417A, R-422 (A-D)

- Similar compressor lubricant as for HCFC-22
- Critical temperature for R-422D (R-417A) is 16 K (9 K) lower than for HCFC-22
- Slightly lower energy efficiency
- Applications can be in commercial refrigeration and AC
- Retrofit from HCFC-22 easily possible
- No GWP advantage
Substitute for HCFC-22: HFC-32/ HC-600 and HFC-32/ HC-600a

- Same compressor lubricant as for HCFC-22
- Critical temperature is 18 K lower than for HCFC-22
- Lower to comparable energy efficiency (wrt R-410A)
- HX design different for high pressure refrigerant; manufacturing process different
- Retrofit not possible (only for new systems)
- Certain GWP advantage (650 versus 1780)
- Issues of using a flammable refrigerant
Substitute for HCFC-22: HFC-134a

- Different compressor lubricant as for HCFC-22
- Critical temperature higher than HCFC-22
- Slightly lower energy efficiency
- Different compressor, HX and circuit designs for refrigeration and AC uses, manufacturing processes not different
- Retrofit not possible (only for new systems)
- No GWP advantage
Substitute for HCFC-22: R-717 (Ammonia)

- Major changes in compressor lubricant, design, as well as HX design
- Comparable to higher energy efficiency
- Retrofit not possible (only for new systems)
- Low GWP solution
- Ammonia possible in certain cases but requires complete new design and construction (costs)
Substitute for HCFC-22: R-744 (carbon dioxide)

- Major changes in compressor lubricant, HX and total circuit-system design
- Manufacturing processes different
- Energy efficiency dependent on application
- Low GWP solution
- Can be applied in certain cases (so far many demonstrations limited to MACs), and is used in cascaded systems together with ammonia in commercial equipment
Substitute for HCFC-22: R-290 (propane)

- No changes in compressor lubricant
- No changes in compressor and HX designs
- Comparable energy efficiency
- Critical temperature same as for HCFC-22
- HCFC-22 retrofit easily possible (concept OK for HCs?)
- Low GWP solution
- Flammability concerns in case of larger quantities
Energy efficiency

- Efficiency standards cannot be set in MP operations (also very dependent on use and climatic conditions)
- Compared to HCFC-22, energy efficiency (slightly) lower for HFC & blends, similar for propane and ammonia
- Energy efficiency can be increased by design (with impacts on costs/operating costs) and by choosing different product concepts (e.g. smaller distributed systems Vs large commercial refrigeration units)

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Low GWP and climate aspects

- Low GWP options are available for a number of cases
- Application implies dealing with flammability in manufacturing and operation of equipment and/or the use of different product designs and concepts
- Climate aspects are a combination of low emissions (in case of HFC/blends), low GWP of the refrigerant, and energy efficiency related (CO2) emissions
- All choices have pros and cons in general, and certain aspects are more important for certain types of equipment than for others

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Summary

- Use of some F-blends has implications in new equipment and for retrofits; other major issues are their global availability and their costs
- One or two HFC blends seem good retrofit candidates
- Ammonia and carbon dioxide can be applied in certain cases; require major manufacturing changes, in new applications; further developments can change this for carbon dioxide (energy efficiency?)
- Propane is an “easy” replacement but flammable refrigerant
Conclusions (1)

- There is currently no single route for the conversion from HCFC-22; not expected in the near future.

- Issues related to energy efficiency combined with product re-design, low emissions, flammability, standards for use of flammable refrigerants in certain types of equipment, etc., are all interrelated; they are difficult to quantify on a scale with all variables applied.

- Issues of market availability of refrigerants (as for HFC blends) or availability of good product designs (e.g. for CO2) complicate matters.
Conclusions (2)

- To reduce HCFC-22 consumption, the following may be considered:
  - Conversion of part of the product manufacturing to low GWP (i.e. flammable) refrigerants, part to HFC/blends
  - Limit (ban) the increase of installed product base operating on HCFC-22. This will depend on where and when manufacturing capacities are converted, on imports from developed and developing country manufacturers
  - Good practice in reducing emissions from servicing operations and retrofits of certain products to non HCFC-22 solutions

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Conclusions (3)

- Circumstances and possibilities are likely to change significantly during the next five-ten years.
- Choices MUST be made between now and five years from now, if a significant decrease in the consumption of HCFC-22 by developing country is needed.
- The challenge is how can all issues surrounding HCFC (and in particular HCFC-22) conversions/replacements be put in a decision tree?

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