World tendancies and priorities in development of low-temperature engineering

International Academy of Refrigeration

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International Institute of Refrigeration

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PLAN

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The International Institute of Refrigeration (IIR) is an independent intergovernmental science and technology based organization which promotes knowledge of refrigeration and associated technologies that improve quality of life in a cost-effective and environmentally sustainable manner including:

- Food quality and safety from farm to consumer
- Comfort in homes and commercial buildings
- Health products and services
- Low temperature technology and liquefied gas technology
- Energy efficiency
- Use of non-ozone-depleting and low global warming refrigerants in a safe manner

- 60 member countries (both developed and developing)
- 500 experts
- 600 corporate and private members: private companies (refrigeration equipment, public services, food and pharmaceutical sectors…), consultants, academics, students…
- Founded in 1908
- Head office in Paris, staff of 12
- Refrigeration portal: 90 000 references
- Journals
- Books
- Conferences
- Informatory Notes
- Statements
- Working Parties

1. Increasing needs of Refrigeration

1.1. Refrigeration is necessary to mankind

Why?

- Temperature is a magnitude and a key variable in physics, chemistry and biology.
- It characterizes the state of matter and liquid, solid and gaseous phases.
  → materials applications
- It is vital to all living beings and each living being (bacteria, plant, animal) has a temperature range within which it can live (more or less optimally: metabolism slowdown – or even arrest, hibernation…).

Consequence: exerting an effect on temperatures equals exerting an effect on nature

Man wants to tame nature and has to tame refrigeration

- The temperature governs whether a living being can survive or not.
- And whether pathogens can develop, survive or not.
  - To ensure that foodstuffs are healthy, to prevent the growth of pathogens, foodstuffs are chilled or frozen.

- Refrigeration is everywhere:
  - Cryogenics (petrochemical refining, steel industry, space industry, nuclear fusion…)
  - Medicine and health products (cryosurgery, anaesthesia, scanners, vaccines…)
  - Air conditioning (buildings, data centres…)
  - Food industry and the cold chain
  - Energy sector (including heat pumps, LNG, hydrogen…)
  - Environment (including carbon capture and storage), public works, leisure activities…

1.2. The increasing needs in developing and emerging countries

- 1600 deaths/year in the USA due to pathogens, at least partly associated with temperature control; many more in « developing » countries:
  WHO report (2008) : refrigeration and improved hygiene have reduced stomach cancer by 89 % in men and 92% in women since 1930 in the USA.
  Another estimation: about 3 millions deaths/year related to refrigeration worldwide
- Increase in the global population, particularly in Africa and South Asia (9-10 billion in 2050, 8 in developing countries)
- 70% (50% now) will be in urban areas (x2 in developing countries): increasing the need for cold chains, increasingly westernized models
- 1 billion people are undernourished; 23% of food losses are caused by a lack of refrigeration (vs 9% in developed countries)
- Needs for better health everywhere (good cold chain, air conditioning), ageing population…

⇒ This increase in emerging and developing countries will increase the impact on the environment

2. Energy and environmental challenges

2.1. Refrigeration is a major energy consumer

Refrigeration including air conditioning represents 15% of global electricity consumption. And it will increase (The Netherlands: 18%...)

- Global warming because of CO_2 emissions (electricity production depending on fossil fuels):

  TEWI, LCCP (IIR Working Party)
- The price of electricity will increase (new sources of energy have higher costs)
- Lack of power infrastructures
- Overall system solutions (district cooling…)
- Heat Pumps
- New regulations on energy, on buildings in Europe, the USA: constraints on energy → constraints on refrigeration systems
- Changing a system because of refrigerant issues must take into account potential reductions in energy consumption

2.2. The impact of refrigerants on the environment

- Vapour-compression systems will remain predominant in the short and medium term ⇨ more refrigerants.

- Impact on the stratospheric ozone layer:
  CFCs, HCFCs ⇨ the Montreal Protocol
  Phase-out plans for non article 5 countries/for article 5 countries
  The banks issue

- Alternative refrigerants:

  - HFCs, including HFOs: no impact on the ozone layer but an impact on global warming (included in the Rio Convention)

  - Natural refrigerants (ammonia, CO_2, hydrocarbons, water, air): have a very low impact on global warming.

  - Mixtures, combinations (cascades, secondary fluids)

Family of refrigerants	Main refrigerants	ODP	GWP
CFCs	CFC 11 CFC 12 Others	1 1 0.4 -> 1	4 750 10 900 6 000 -> 15 000
HCFCs	HCFC 22 Others	0,05 0.020 -> 0.070	1 810 70 -> 2 400
HFCs	HFC 134a HFC 404A HFC 407C HFC 410A HFC 32 HFC 1234yf Others	0 0 0 0 0 0 0	1 430 3 900 1 800 2 100 720 4 4 -> 4 500 (except HFC 23 = 14 800)
Natural Refrigerants	HC 290 HC 600a HC 1270 R717 (ammonia) R744 (Carbon dioxide) Air, water	0 0 0 0 0 0	20 20 20 ~ 0 1 ~ 0

CFCs and HCFCs are mainly replaced by HFCs, which generally have a high GWP

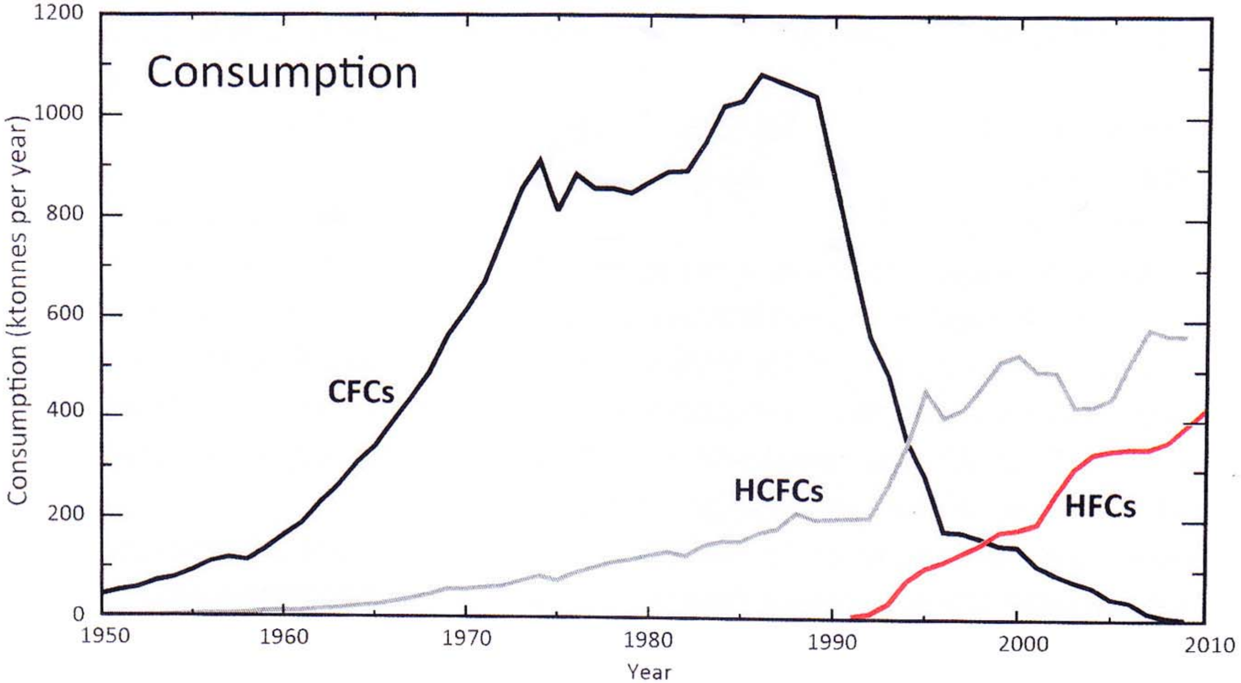

Figure ES 1. Global consumption (in kilotonnes per year) of ozone depleting CFCs and HCFCs. The phasing in of HFCs as replacements for CFCs is evident from the decrease in CFC usage concomitant with the increasing usage of HFCs. Use of HCFCs also increased with the decreasing use of CFCs. HCFCs are being replaced in part by HFCs as the 2007 Adjustment to the Montreal Protocol on HCFCs continues to be implemented. Thus, HFCs are increasing primarily because they are replacing CFCs and HCFCs.

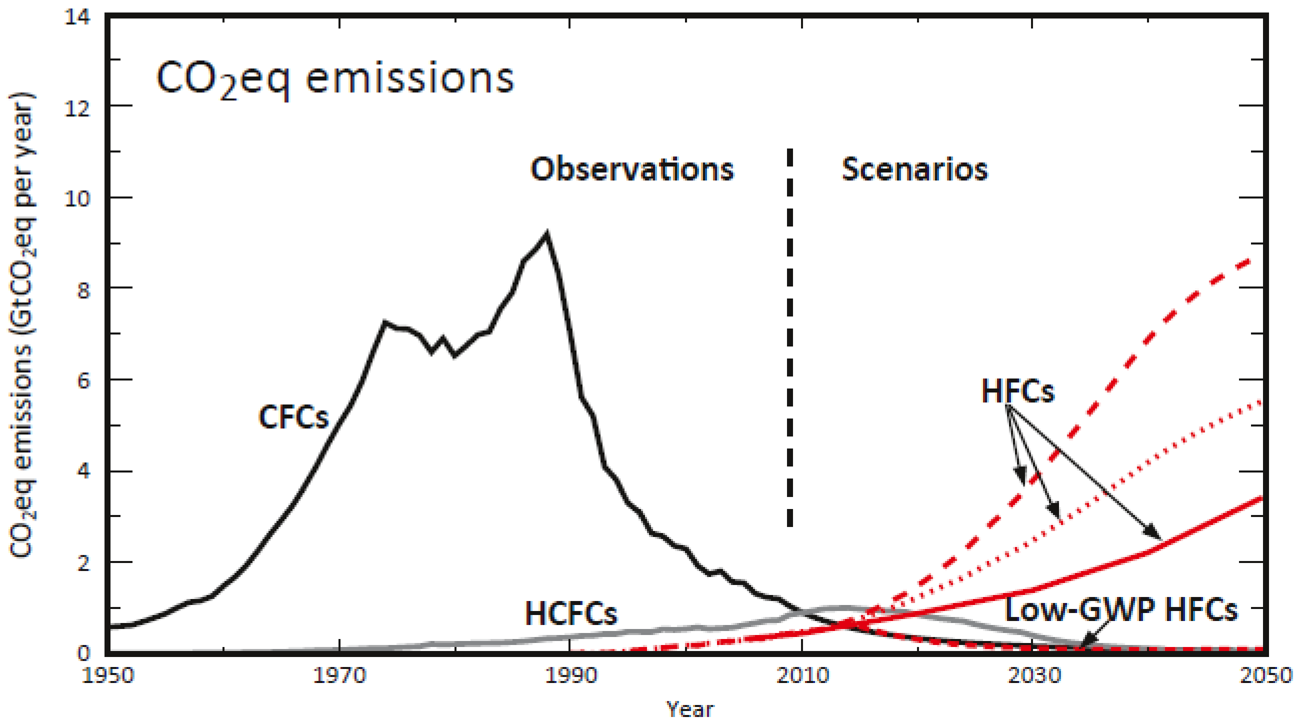

Figure ES 2. Trends in CO_2eq emissions of CFCs, HCFCs, and HFCs since 1950 and projected to 2050. The HFC emissions scenarios are from Velders et al. (2009) and Gschrey et al. (2011). The low-GWP HFC line represents the equivalent HFC emissions for a scenario where the current mix of emissions (with an average lifetime of HFCs of 15 years and an average GWP of 1600) was replaced by a mix of low GWP HFCs (with an average lifetime of less than 2 months or GWPs less than 20).

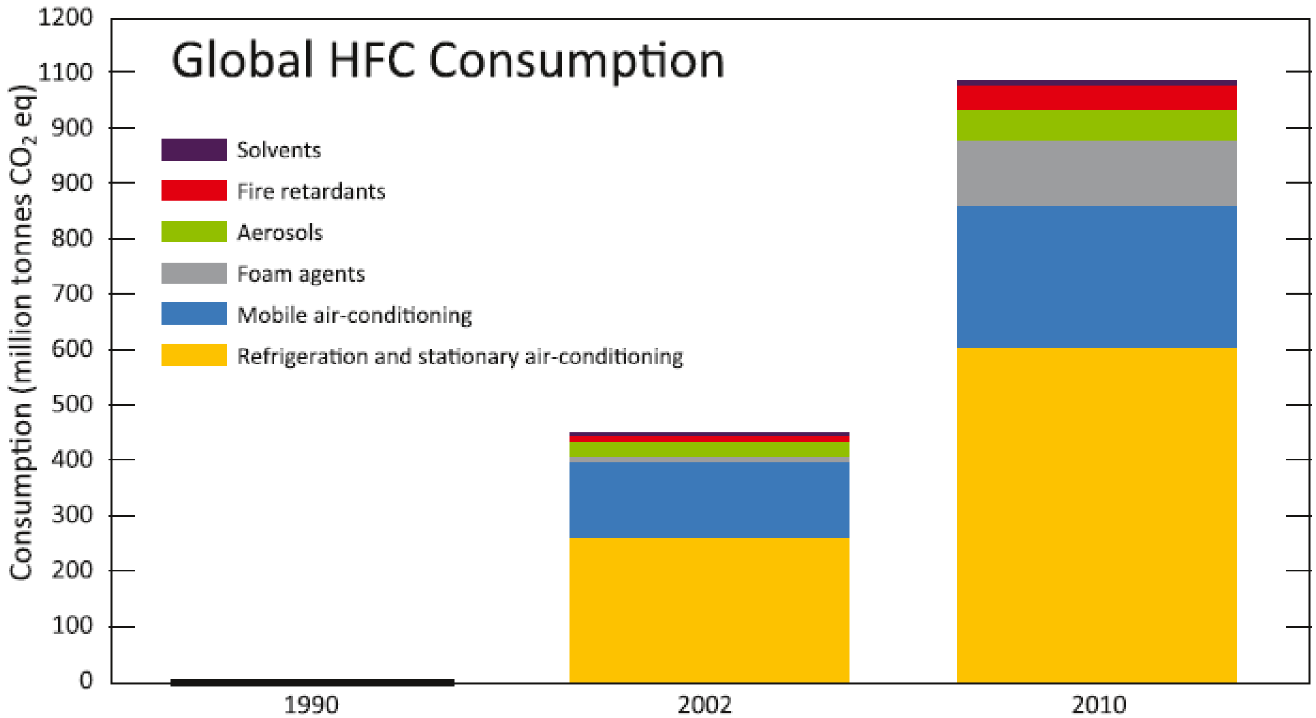

Figure 1.4. Estimated global consumption of HFCs by various sectors, expressed in CO_2equivalent, for 1990, 2002 and 2010 (TEAP 2005, EPA 2010a). HFCs are predominantly used for the same industrial uses as the CFCs and HCFCs which are subject to phase-out under the Montreal Protocol. The rapid growth in HFCs after 1990 is also clearly evident.

HFCs: currently less than 1% of CO_2 eq emissions. In 2050, 7% to 45% (more likely 7%) of CO_2 eq emissions.

HFCs emissions in 2050 could offset the achievements of the Montreal Protocol related to the phase-out of CFCs.

Hence, discussions held at an international level (Montreal Protocol and Kyoto Protocol meetings) on the future of HFCs: replacing HCFCs with HFCs could be a real threat to climate.

At the contrary, HFCs are short-living substances compared to CO_2 → phasing down HFCs would have short-time results (USA, Canada, Mexico, Sweden, Ghana, Bangladesh initiative)

North American and Mauritius-Micronesia proposals to gradually phase down (15% of previous emissions in 2033 and 2043 for developed vs developing countries) the consumption and production of HFCs, in all countries. The amounts are weighted according to their Global Warming Potential.

- Opposition of India, China, Brazil and Gulf countries
- Other initiatives:
  - ✓ The European F-gas regulation and the MAC directive
  - ✓ Taxes and bans on HFCs

This decision is linked to other decisions regarding global warming

(time schedule: 2015 for a new agreement on this issue)

3. How to reduce the impact on global warming?

3.1. Various solutions

- Other technologies: absorption, adsorption, solar refrigeration, magnetic refrigeration, thermoelectric cooling, cryogenics (nitrogen, CO_2)

  Still require technological improvements (cost, energy efficiency, capacity)

  → today, niche technologies

- Reducing leakage

  Variability → margins for progress

  Example in the EU (30% in the 1980s → 5% and less)

  Review of the F-gas regulation

  The difficulty: training

  Advantages: savings, better safety

- Reducing the refrigerant charge

  Issue of safety + GHG emissions

  Research and development for all refrigerants

  Secondary refrigerants

  Microchannels…

- Choosing a low-GWP refrigerant:

  What is a low-GWP refrigerant?

  A sector-by-sector approach, including high ambient-temperature conditions.

  « Low » or « moderate » GWP HFCs can be used, but only as a possible intermediate step. Moving directly to « very low » GWP HFCs (<150, cf MAC directive in Europe…, such as HFOs) and of course to natural refrigerants are a better option where possible (efficiency…)

3.2. Key elements to take into account when choosing a low-GWP refrigerant

- No very low-GWP refrigerant is perfect:

  They all present safety risks and drawbacks:

  flammability, toxicity, corrosion, pressure

  ⇨ all need adaptation of the equipment even if HFOs and to a lesser extent HCs are more similar to HFCs than others.

- Fair comparisons (outdoor temperature, type of equipment, suitable oils…) concerning efficiency are rare.

  Many technical developments in recent years on CO_2, on HCs and even on ammonia; thus improvements in the future…

  No real experience with very low-GWP HFCs: they are still not on the market, except in mobile air conditioning in Europe since the end of 2011 and experimental studies on supermarkets…

  First results published: generally show relatively similar efficiency.

- Safety regulations:
  - A barrier to ammonia; but ammonia is still recognized as the most efficient refrigerant; regulations can change (e.g. in France) but trained technicians are needed.
  - A barrier to hydrocarbons; but HCs are a really good solution for low charges; regulations can change (e.g. USA) and barriers could be relatively similar for very low-GWP HFCs (flammability, even if very low).

- Adaptation to warm climates

Still few recent examples: HFOs are not commercialized and natural refrigerant technical development is mostly in Europe and Eastern Asia.

However, CO_2 seems to be less efficient than current HFCs.

HCs are a real and potential solution (e.g. Australia, India, China) for many applications in the future.

Experiments with ammonia-CO_2 cascades are underway. However, a market needs to be developed.

- Industrial strategies:
  - Refrigerant manufacturers would like only one worldwide market (lobbying for the Montreal Protocol)

    E.g.: for mobile air conditioning → a European, then a worldwide market for HFO 1234yf?

    Refrigerant manufacturers are developing similar products for other uses: foams, commercial refrigeration, stationary air conditioning.

    But they need time to produce and commercialize them.
  - Equipment manufacturers: producing an increasing amount of equipment running on natural refrigerants because of huge demand in Europe and Eastern Asia.

    → Prices of equipment will decrease (currently, 10-20% higher than current equipment, but lower running costs)
  - Installers: resist change, because of a lack of expertise and training.

    → Working with them and funding training when implementing an HCFC phase-out plan is necessary.

- Refrigerant prices:

There will be shortages:

- Shortage of HCFCs because of phase out in developed countries (already in force) and because of manufacturer's forecasts.
- Shortage of HFCs produced by very-low-GWP HFC manufacturers because they need to convert their plants.

⇒ their price will increase.

The development of very-low-GWP HFCs was expensive: their price will be higher than those of HCFCs and HFCs + less current competition within refrigerant manufacturers.

Natural refrigerants: very cheap; higher investment costs but lower running costs.

- Types of equipment

  - <u>For relatively new equipment</u>: drop-in solutions with HFCs are the best option. Reducing leakage thanks to a better maintenance and training.

  - <u>For old equipment</u>: replacement solutions, taking into account energy consumption + solutions with natural refrigerants where possible (safety constraints, regulations, quality of maintenance) and low charge, even if the investment cost is higher.

  - <u>No universal solution</u>: refrigerant properties are different.

Conclusion: What should the future be?

- Current HFC consumption and production will decrease in the medium term: international regulations, the example of the European Union, worldwide strategies of refrigerant manufacturers.
- Very-low-GWP HFCs will be developed, but progressively (currently not on the market), and at higher prices at least at the beginning.
- Natural refrigerants are already a solution for various applications, including in warm climates. Countries like China are more and more interested and ready to manufacture equipment.
- A sectorial approach is needed in a strategic national plan.
- Numerous current technical developments on very-low-GWP refrigerants, on more efficient equipment and on new technologies.

⇒ need for updated information in administrations, in companies, and in universities.

The International Academy of Refrigeration shall be a tool for that

The IIR can help you

- Thanks to its new portal,
- Through its database Fridoc (the most complete refrigeration database)
- Through its publications (the International Journal of Refrigeration, the best impact factor in its field; the Newsletter, books, guides….)
- Through its reference documents (eg the International Dictionary of Refrigeration including russian…).
- Through its network of experts.
- Through its participation in international decisions.
- Through its conferences, congresses, research projects and working parties on these issues.

➡ See our Website: www.iifiir.org

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Thank you.