COLD CHAIN STEPS AND CHALLENGES

DIDIER COULOMB - IIR

I. INTRODUCTION

To maintain food or health products (medicines, vaccines) at an adequate temperature is an absolute necessity for human health in order to avoid bacterial illnesses and deaths. To have adequate refrigeration equipment and to be able to control real temperatures is necessary however this isn't always the case, even in developed countries let alone in developing countries. In these countries which have warehousing, transport and commercial and domestic equipment capabilities numbering up to 10 times less than developed countries, the loss of food is nearly 3 times higher than developed countries, equaling 19% of the food quantity available.

Several actions are being led by the IIR in this domain:

- National and international conferences. The next IIR conference on sustainability and the cold chain will be taking place at Nantes, France in April 2020.
- Joint publications with the FAO on sub-Saharan Africa
- Ongoing work with the Global Food Cold Chain Council and relevant UN agencies to update the 2009 IIR Informatory Note on the role of refrigeration in food worldwide
- The publication of "Cold Chain Briefs", conjointly with the UN Environment in 2018, a summary of which is presented below. The set of publications is available for free on the IIR and UN Environment websites.

II. THE COLD CHAIN BRIEFS

We have divided the cold chain in five different steps, and thus we have split the publications into five separate documents:

1. Food production and processing

   Compared to other sectors, industrial refrigeration presents some specificities:

   - A quite low leakage rate (5-12% per year)
   - A quite high refrigeration capacity per unit *15-20 kW_{ref} could be considered as a "small unit", 200-500 kW_{ref} is a "standard" unit, and 1-5 MW_{ref} (possibly more) could be considered as "big" facilities*
   - A quite high energy bill*{800 MWh-4 GWh/year is common, it is 60 k€-350 k€/year)*
     - ⇨ The energy performance (architecture of the refrigeration loop and choice of the primary refrigerant) has to be a major concern.

- The organization (architecture) of the refrigeration equipment used in this sector depends on:
  - ➢ The required temperature (cooling, freezing)
  - ➢ The nature of the processed product
  - ➢ (fruit & vegetables, meat products, eggs and dairy products, raw materials and processed food)
  - ➢ The size of the industrial site (some kg h-1 up to some tons h-1)

  ⇨ *A wide variety of configurations exist making generalization difficult*

Challenges

1. Develop high energy performance architectures
   Industrial refrigeration in food production and processing is energy intensive
   - ➢Energy consumption has to be one of the major concerns for this sector
   - ➢Work on smart cycles (desuperheaters, variable pressures, IHX, cascades, valorization of expansion work, heat recovery, ...)
2. Learn to manage the glide of low GWP blends, especially for “small” facilities
3. Trust in the sustainability of natural refrigerants, and especially with ammonia for “large” facilities.
4. Keeping an open mind, and observing the re-engineering of “old” solutions which have shown their advantages and limits (absorption-adsorption), or the development of new technologies (magnetic cooling, electric field cooling, thermoelastic cooling,...), but according to the present development of these technologies, their implementation in food production and processing will not be anytime soon…

Conclusion

Thanks to their performance, compactness and reliability, compression expansion systems with phase-change refrigerants have been used for more than a century, and they will probably continue to be used for a long time.

For “small” industrial units, alternative refrigerants could be low GWP blend of HFCs or HFCs-HFOs, and possibly HCs for very low refrigerant charges (less than 1.5 kg, which remains exceptional for industrial refrigeration).

For HFOs, the concern of their low flammability and of their long-term environmental impact has to be carefully studied (and not eluded).

For “large” industrial units, ammonia remains the best choice, despite safety concerns (which can be managed with a certain rigor).

$C0_2$ appears to be an interesting alternative, as far as heat recovery is envisaged and valued somewhere else in the process (otherwise, it is difficult to justify).

2. <u>Transport refrigeration</u>

Transport refrigeration types

- Refrigerated Vehicles
  - Vans
  - Trucks
  - Semitrailers

- Refrigerated Air Cargo
- Refrigerated Containers
- Refrigerated Trains
- Refrigerated Ships

Refrigerant Options

Transport Refrigeration		
Types of transport	**Current higher WP refrigerants (GWP kg. CO_2)**	**Alternative lower GWP refrigerants (GWP kg. CO_2)**
Refrigerated containers, road transport, trains	HFC-134a (1360) HFC-404A (3920) HCFC-22 (1810)	R-744 (1) J HFC-452A (1950) HFC-513A (573) HC-290 (5) **R-717 (O)**

A few comments:

- Particular constraints for containers (months at sea travelling around the globe)
- Particular constraints for fishing vessels (another cold chain technology brief)
- Aerospace industry = minimal charges up until now
- Propane and CO2 still rare in the world
- Cost and safety considerations are major
- National/international issues for transport regulations

3. <u>Fishing vessel application</u>

New systems

- Technically, there are satisfactory solutions to avoid R-22 and R-404A for most applications in new systems.
- For centralized systems, these rely mostly on the wider use of CO_2 and NH_3.
- Related safety issues are generally well controlled on board ships, and on land in most developed countries.

- Some developing countries are not ready to use NH_3 and CO_2 safely. Technical solutions exist, but **training is critical for implementation**.

Conversions from R-22 / 404A

- There are suitable blends with glide for small D-X systems in most cases.
- There is no clear solution for large systems. Retrofits may lead to drastic performance deterioration. Major overhaul or replacement of system may be needed.

4. Cold storage and refrigerated warehouses

Cold storage warehouse issues

Direct emissions

- Refrigerants - generally low GWP refrigerants such as ammonia (R717) in large plants
- Some evidence supports move to other refrigerants in Article 5 countries due to safety concerns
- Smaller plant HFC, HFO refrigerants
- Leakage about 8%/year
- Indications that may be 2x as high in developing countries

Indirect emissions

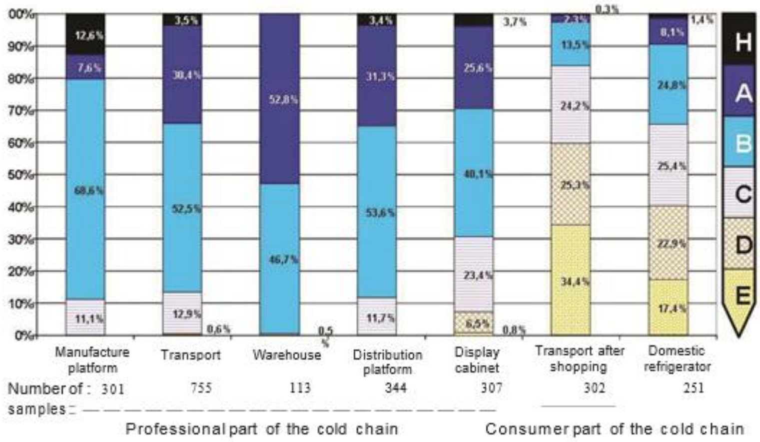
- Energy use
- 60-70% of electrical energy in cold storage facility can be used for refrigeration
- Wide range in energy use
- Energy savings of 30-40% typically can be achieved

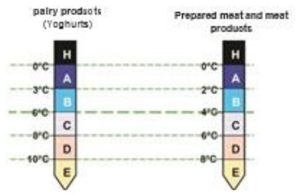
Perspectives and challenges

- Many options to reduce emissions (especially indirect)
- Direct emissions traditionally low, care needed to ensure new systems have low GWP refrigerants
- Training, maintenance often an issue (plus safety)
- Low potential for novel refrigeration systems in large systems
- But potential for CHP, poly/tri-generation
- Potential for better integration to reclaim heat and integrate with renewable energy resources

5. <u>Commercial, professional and domestic refrigeration</u>

First, the quality of the cold chain, especially at the consumer level, must be improved:





Derens, E., Palagol, B., Cornu, M., Guilpart J., 2007. The food cold chain In France and its impact of food safety. IIR JCR2007, Beijing, China.

Developments and perspectives regarding environmental issues:

- Opportunities to reduce energy usage
  - Often prevented by cost (emphasis on initial cost rather than lifetime)
  - Large number of options available
  - Loss in sales (e.g. doors on commercial cabinets)
  - Energy labelling may have impact (has already reduced energy used by domestic refrigerators by about 50%)
- Opportunities to reduce direct emissions
  - Safety of HC and A2L refrigerants
- Number of novel systems (magnetocaloric, electrocaloric, acoustic) under development or close to market, suitable for plug-in units

<u>CONCLUSION</u>

There are many different types of applications and thus many different solutions with a lower Global Warming Potential than the current one. It is difficult to thus recommend a simple solution. However, people should keep in mind that:

- the energy issue is more important than the refrigerant issue in a general climate change impact perspective,
- the control of temperature is still an issue and thus health and food losses remain even more important,
- refrigerant leakage is sometimes very important and it can often be reduced, which is a simple way to avoid greenhouse gas emissions,
- not in kind technologies can appear, even if vapour-compression systems will still be predominant in the near future,
- technologies are fast moving. Having constantly updated information, thanks to conferences, scientific journals, any kind of publication is necessary.

It is the IIR mission.