Status Quo and Perspectives for Green Cooling in Supermarket Refrigeration

Roberto Peixoto - Instituto Maua de Tecnologia – IMT - 13/09/2022

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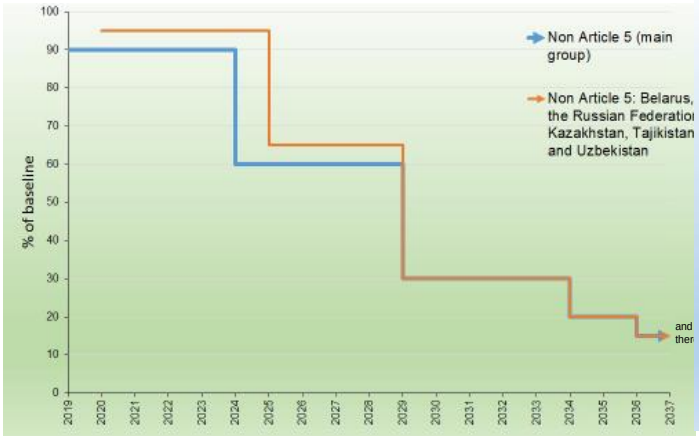
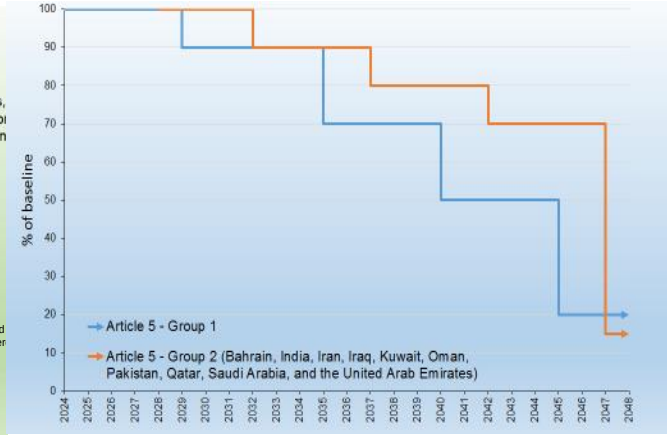
Global policy environment

Kigali Amendment

	N-A5 Parties: Group 1		N-A5 Parties: Group 2	
Baseline Years	2011, 2012 & 2013		2011, 2012 & 2013	
Baseline Calculation	Average consumption of HFCs in 2011, 2012, and 2013 Plus 15% of 1989 HCFC baseline consumption		Average consumption of HFCs in 2011, 2012, and 2013 Plus 25% of 1989 HCFC baseline consumption	
Reduction steps				
Step 1	2019	10%	2019	5%
Step 2	2024	40%	2024	35%
Step 3	2029	70%	2029	70%
Step 4	2034	80%	2034	80%
Step 5	2036	85%	2036	85%

	Article 5 Parties Group 1		Article 5 Parties Group 2	
Baseline Years	2020, 2021 & 2022		2024, 2025 & 2026	
Baseline Calculation	Average production/consumption of HFCs in 2020, 2021, and 2022 plus 65% of HCFC baseline production/consumption		Average production/consumption of HFCs in 2024, 2025, and 2026 plus 65% of HCFC baseline production/consumption	
Freeze	2024		2028	
Reduction steps				
Step 1	2029	10%	2032	10%
Step 2	2035	30%	2037	20%
Step 3	2040	50%	2042	30%
Step 4	2045	80%	2047	85%





Impact of the Montreal Protocol and the Kigali Amendment on the use of Refrigerants

- The complete elimination of HCFCs under the Montreal Protocol in is planned for 2030.
- The Kigali Amendment entered into force on 1 January 2019
- HFCs became controlled substances under the Montreal Protocol
- HFC control schedules adopted for developing and developed countries (parties).
- Developed (n-A5) countries started to phase down HFCs by 2019. Developing countries (A5) will follow with a freeze of HFC consumption levels in 2024, with some countries freezing consumption in 2028.

The Paris Agreement

- The Paris Agreement central aim is to strengthen the global response to the threat of climate change
- Keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels
- To pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius. ↔ ***Kigali Amendment***

HFC Phase Down Schedule
Current EU F-Gas Regulation

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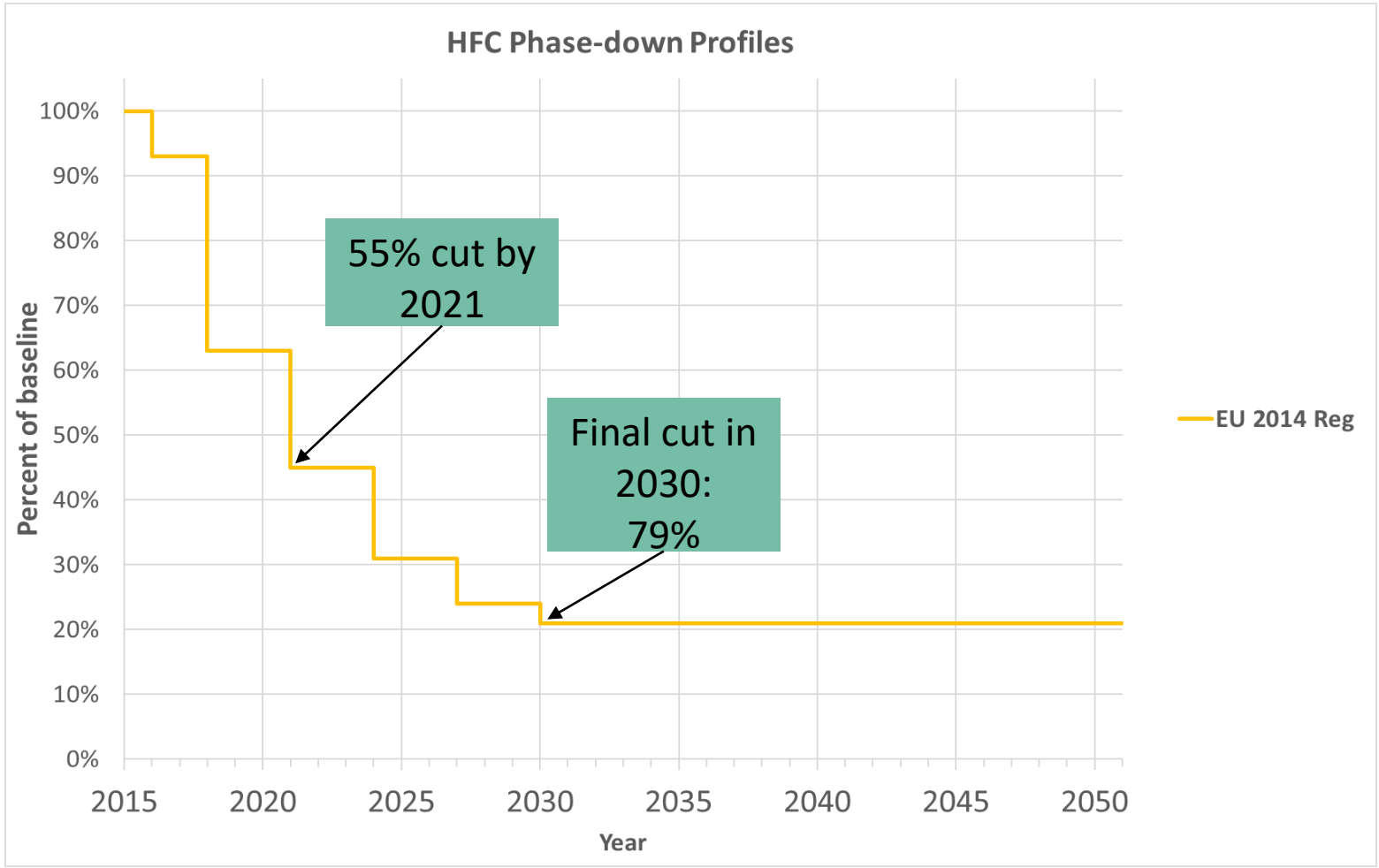
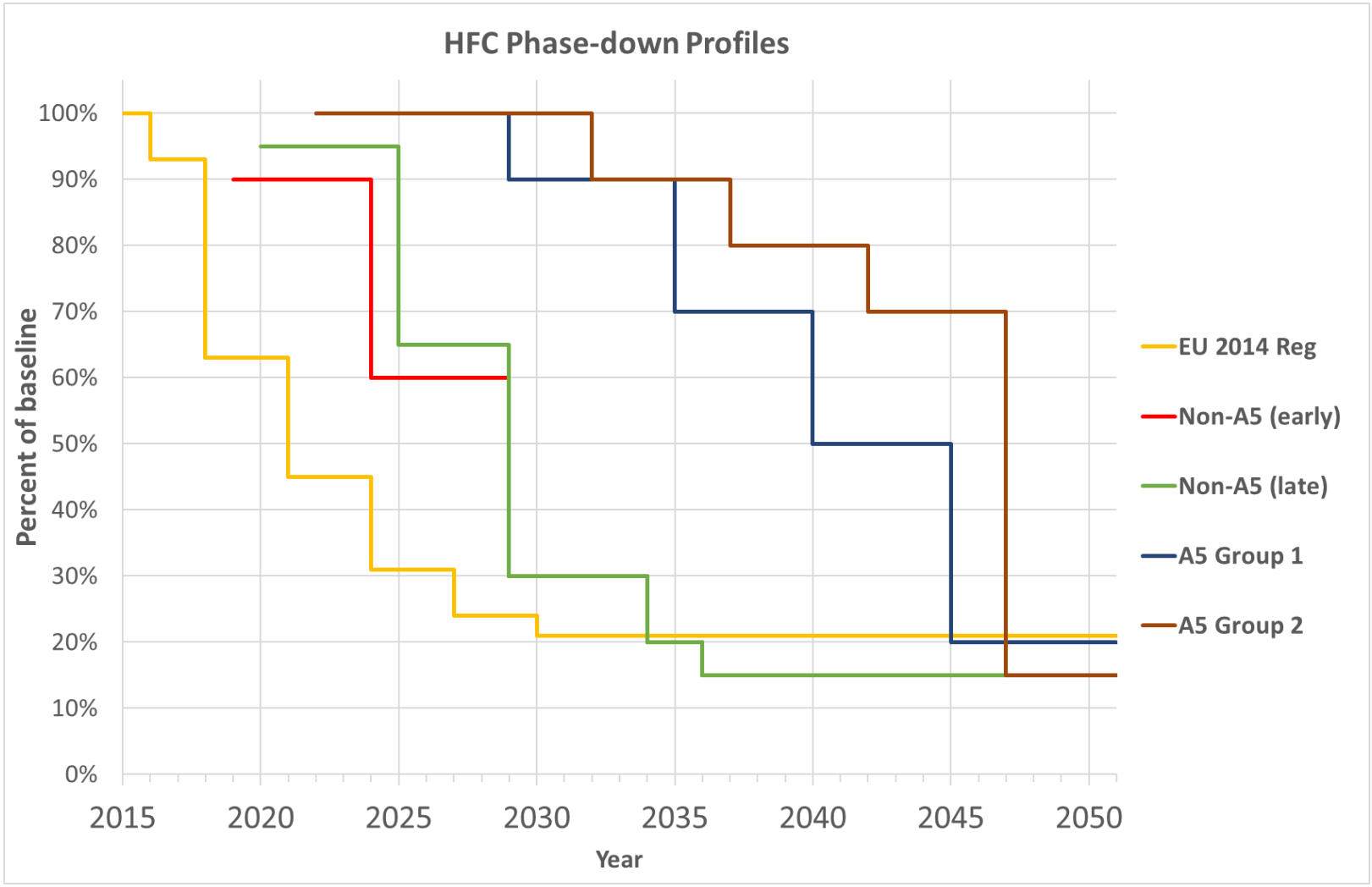
Baseline 2009-2012



Source: Gluckman Consulting

Current EU Regulation compared to Kigali



Source: Gluckman Consulting

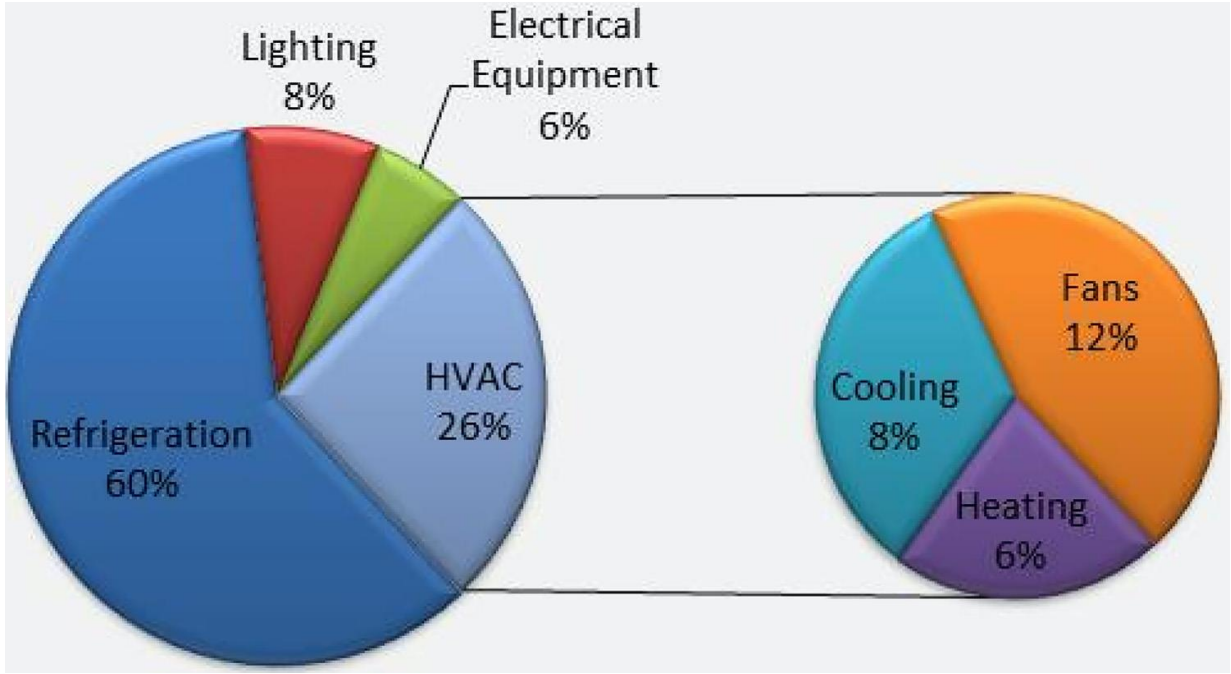
Market Trends

- Urbanization, electrification, development of cold chain for food and medicines, domestic air conditioning are expected to drive the growth of the RAC applications
- Energy (electricity) consumption for RAC has been increasing over the last years all over the world, due to the great growth in equipment numbers especially in developing countries
- Developing countries have approximately 10 per cent the refrigerated storage capacity (in m3/1,000 inhabitants) of developed countries
- Data about supermarket market size
  - Europe ranges between 110,000 –115,000 stores
  - USA the number ranges between 38,000 – 40,000 stores
  - Brazilian market :38,000 stores
  - China:65,000 – 70,000 stores.

(EIA-SHECCO 2018)

Energy consumption Supermarket

- In a supermarket, ~60% of electricity consumption is related to the refrigeration and air conditioning system



Source: Frozen food retail: Measuring and modelling energy use and space environmental systems in an operational supermarket", Energy and Buildings, 2017

Table 3. Product categories defined in regional standards

Australia	EU	U.S.[a]	China[c]
- Display cabinets (integral/remote, horizontal/vertical, refrigerator/freezer) - Drinks cabinets - Ice cream freezers - Scooping cabinets - Storage cabinets (integral, horizontal/vertical)	- Display cabinets (vertical/horizontal, refrigerator/freezer, roll-in) - Beverage coolers - Ice cream freezers - Gelato ice cream freezers - Vending machines (can & bottle/spiral) - Professional cabinets[b]	- Vertical open - Semi-vertical open - Horizontal open - Vertical closed transparent - Vertical closed solid - Horizontal closed transparent - Horizontal closed solid - Service over counter - Pull-down	- Display cabinets (integral/remote, horizontal/vertical/ combined, refrigerator/freezer) - Beverage display cabinets - Ice cream freezer display cabinets - Solid door commercial cabinets - Refrigerated beverage vending machines

a. Listed types in the U.S. are further divided by condensing unit type and operating temperature, e.g., vertical open types with remote condensing units for medium temperature (VOP.RC.M).

b. In Europe, "commercial" generally refers to cabinets for retail applications, i.e., with a direct sale function. "Professional" is a term used in Europe to describe cabinets and other refrigeration equipment designed for use and access by staff of the food service facility and not for access by customers/shoppers. EU "professional cabinets" are a subset of those referred to elsewhere as "commercial cabinets" or "storage cabinets." The term "professional" does not appear to be used in this way outside of Europe and so is not generally used within the Guidelines [15].

c. China set minimum energy performance standards (MEPS) for remote condensing RDCs in 2011 and for integral condensing refrigerated cabinets in 2015. The product categories are consistent with those used in the previous

https://united4efficiency.org/wp-content/uploads/2021/11/U4E_CommercialRefrig_Supporting-Info_20211109.pdf

Natural refrigerant options for supermarket refrigeration

- There are three types of refrigeration systems typically used in supermarkets:

Plug-in unit

Condensing unit

Compressor rack–centralised supermarket system

Isource: adapted from Gluckman consulting

Natural Refrigerants for Condensing Units

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R-717

- It is not commonly used in these systems for cost and safety reasons.

- However, it is used in systems cascaded with R-744 in the low stage of the equipment, especially in larger commercial application needs.

- Research is ongoing on low charge systems that could make this refrigerant more attractive in these applications.

Natural Refrigerants for Condensing Units

R-744

- R-744 condensing units are now commercially available in Europe and Asia. Market penetration is currently low, but is expected to increase in the near future.
- R-744 condensing units require a dual-stage design if high ambient temperatures occur frequently. Single stage systems are designed for cold climates.
- Cost remains the main barrier for these R-744 condensing units in certain regions, but with increased production capacity and financial incentives, this barrier is expected to be overcome soon.

Natural Refrigerants for Condensing Units

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Hydrocarbons

- Direct expansion condensing units using HC-600a or HC-290 or HC-1270 from 100 W to 10 kW (up to 1.4 kg load) are commercially available for temperatures ranging from -40 °C to 0 °C .
- Costs for these HC-based systems can be up to 15% higher than HFC systems due to the safety measures required to mitigate risks.
- Due to flammability concerns, indirect system condensing units using HC-290 or HC-1270 with typical refrigerant charges ranging from 1 to 20 kg are coming into use in Europe.
- HC systems can achieve up to 30% increases in energy efficiency

Natural Refrigerants for Centralized Systems

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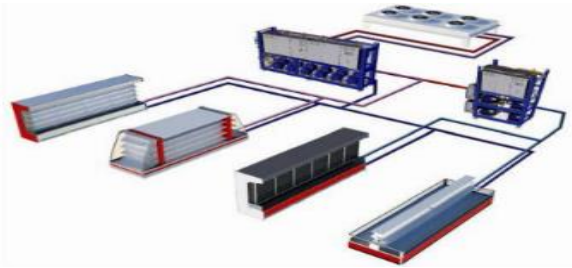
R717

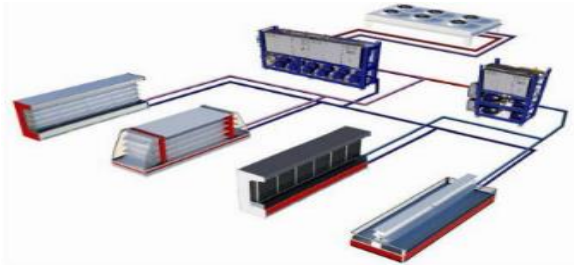
- Due to its toxicity, R-717 is confined to a ventilated engine room and R-717 systems are always designed with secondary circuits at each temperature level.
- Cascade systems R744 (CO_2) - R717 (ammonia). This system has been used in all parts of the world for a variety of applications.



Natural Refrigerants for Centralized Systems

Hydrocarbons

- HC-290 and HC-1270: introduced in supermarkets through a secondary circuit. HC-290 is now the preferred choice. The number of these HC systems is limited. Charge reduction technologies can support increasing the number of systems with these refrigerants.

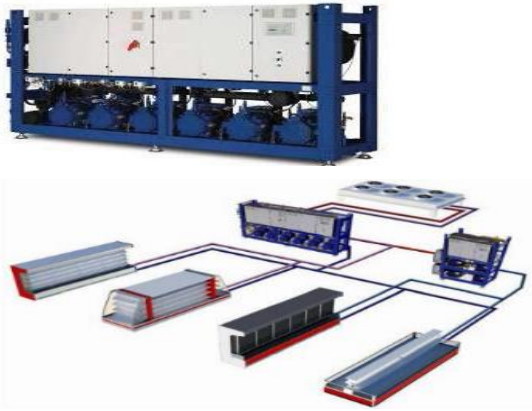


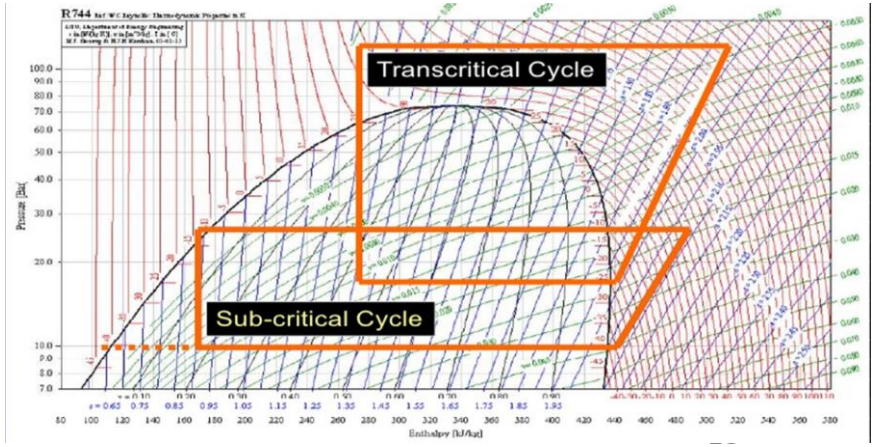
- HC-290 is generally similar in performance to HCFC-22 and R-717 in terms of operating temperatures and pressures, and requires similar sized compressors.

Natural Refrigerants for Centralized Systems

R-744

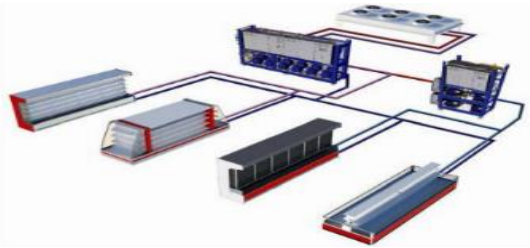
- 2005 two important new options: R-744 as the only refrigerant in booster systems and R-744 in cascade with HFCs and other refrigerants.
- R-744 cascade systems have found significant acceptance in centralized systems in Europe and have been implemented in many developing countries (A5)
- Configuration with HFC-134a and R-744.
- HCs and ammonia can be used as replacements for HFC-134a



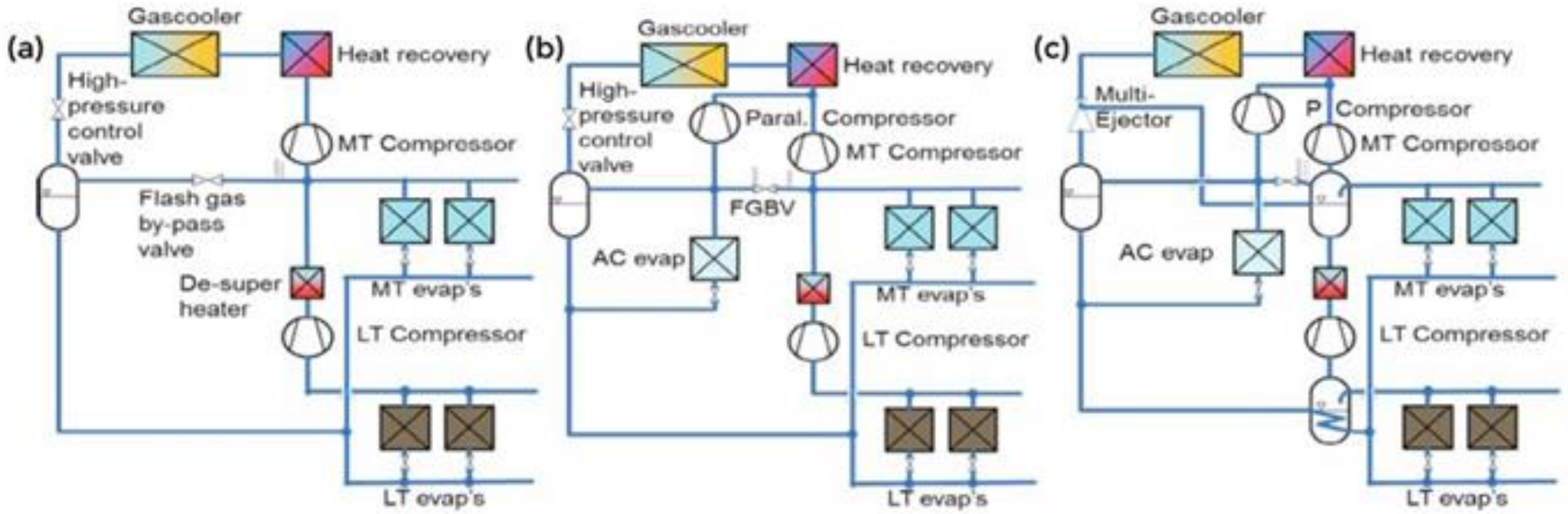


Natural Refrigerants for Centralized Systems

- R-744 as the only refrigerant in supermarkets: transcritical systems
- The cost of the systems has been reduced significantly
- R-744 basic transcriptional systems are less efficient than HFC systems for T> 26 °C,
- Methods such as mechanical subcooling, ejectors, steam injection, and parallel compression have been developed to improve performance.
- These concepts allow energy efficient operation also in higher ambient temperature conditions and several systems have recently been implemented in warmer climates.
- Transcritical systems in developing countries: South Africa, China, Indonesia, Colombia, Chile, Argentina, Brazil, Jordan, Malaysia



Technological evolution of the transcritical system



1st, 2nd and 3rd generation CO2 central refrigeration systems for supermarkets.

1st generation: booster system
2nd generation: booster system with parallel compression
3rd generation: booster system with parallel compression Y with ejectors

EIA-SHECCO - Technical report on energy efficiency in HFC-free supermarket refrigeration

Challenges in the Global South

- Development of technical capacity, involving: R&D, manufacturing lines conversion, adaptation of plant infrastructure to safe handling of high pressure, toxicity and flammable refrigerants
- Need to develop efforts for the capacity building of the servicing personnel, involving training and the provision of appropriate servicing tools
- Many countries have standards for refrigeration systems, but do not have updated standards on safe use of refrigerants.
- There is no specific standard for flammable refrigerants.

https://doverdlc.blogspot.com/2014/10/the-3rd-barrier-of-tech-integration.html

Final Remarks

- The European Union is much more advanced than the Kigali amendment. Its legislation (F-gas Regulation) is more restrictive in terms of HFC phase-out than Kigali.
- Challenges of the RAC sector include the change of HCFC, the phase down of high high-GWP HFC refrigerants and the reduction of energy consumption. Natural refrigerants are an important alternative
- Local manufacturers, contractors and technicians need support to absorb the technology, and countries need to build qualification and training certification programs for technicians to work safely with natural refrigerants

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