ENGINEERING TOMORROW

Components for Low GWP refrigerants

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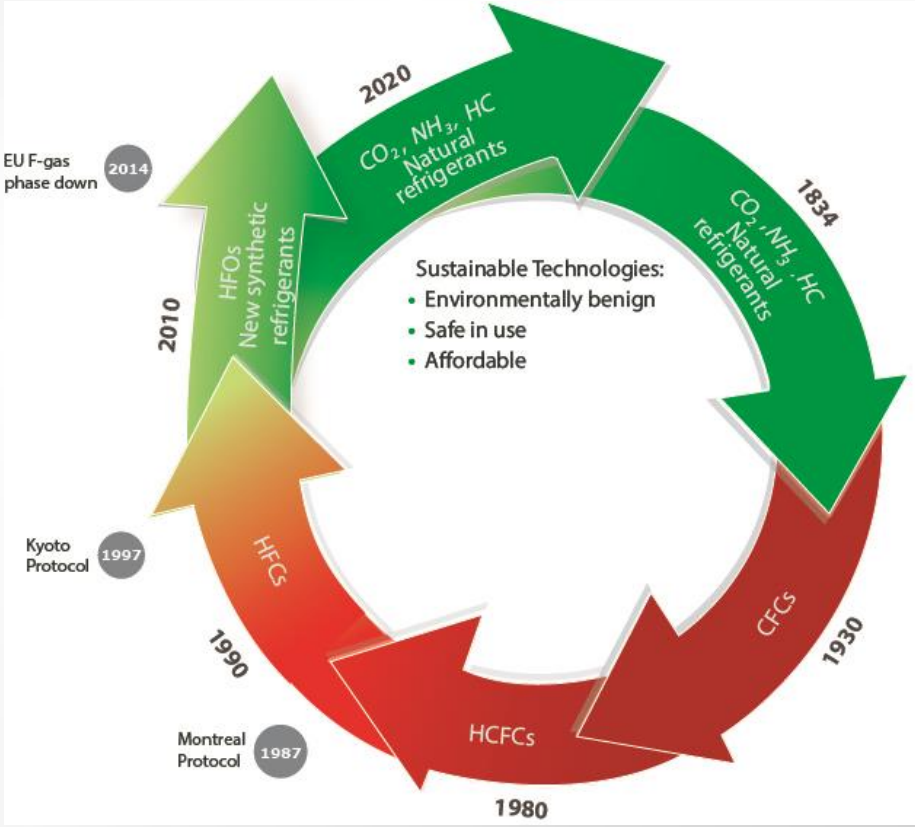
Content

Perspectives of main types of refrigerants :

- components
- safety
- system
- energy efficiency

Availability of components

- Influencing factors
- Present component map
- Predictions

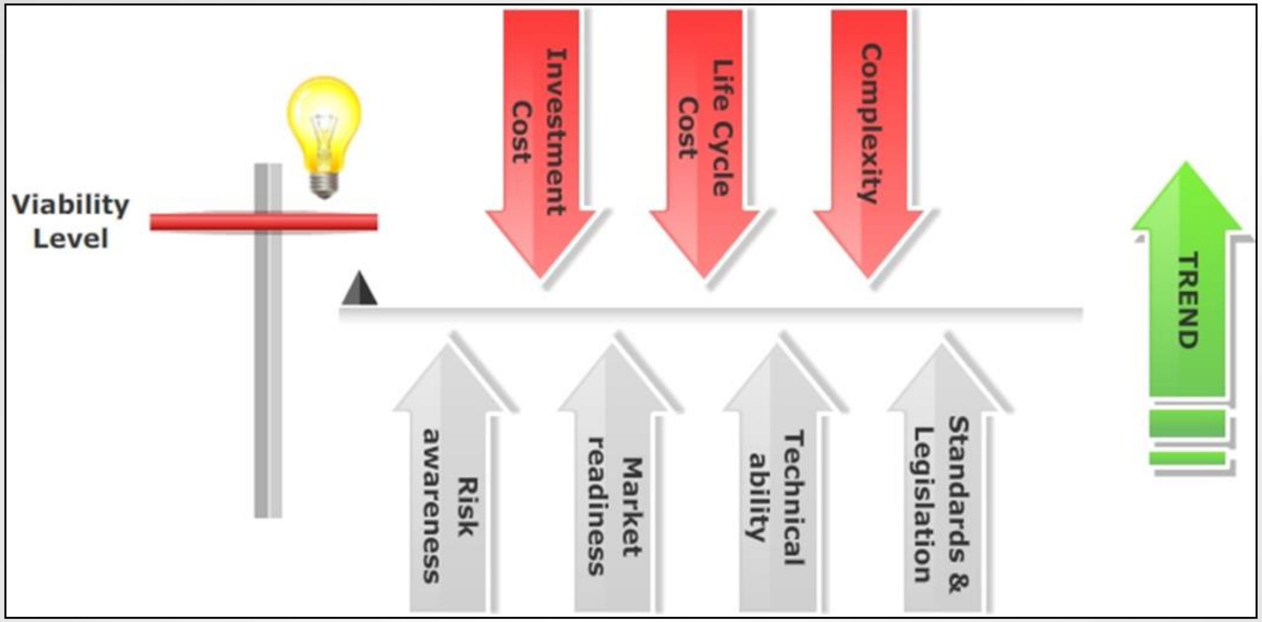


Perspectives of main types of refrigerants

- **Carbon chain based**
  - HFC and HFO
    - Low to medium pressures
    - Low to medium condensing temperatures
    - **High complexity**
  - Hydrocarbons
    - Low pressures
    - Low condensing temp
    - **Charge limitations**
    - **Flammability**

- **Unique single type**
- CO_2
  - High pressures
  - High condensing temp
  - **Efficiency challenges in warm climates**
  - **Still potential – not mature**
- NH_3
  - Low pressures
  - Low condensing temp
  - **Smaller capacity systems are not mature**
  - **Toxicity**

Factors influencing the availability of components



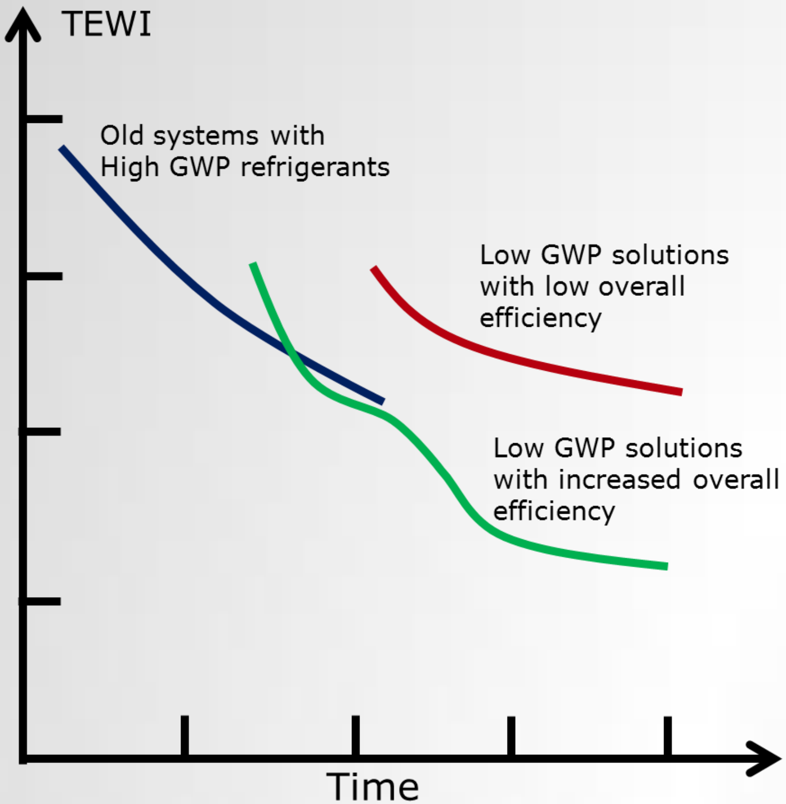
- Legislative certainty for Low GWP refrigerants increases
- Risk decreases - Safety standards are being updated
- Technical ability increases at manufactures – more suppliers of low GWP components
- Market readiness is scattered – but the awareness of educational need is there
- Investment cost on pair with tradional systems - Public investments and incentives supports low GWP refrigerants
- Life cycle cost decrease while Energy Efficiency of low GWP systems increases and exceeds expectations
- Complexity still exceeds traditional systems – but this is a challenge that can be handled

	Description - present	Component availabilty	Outlook
Household	Mature applications for **hydro carbons** with highest penetration in the EU	Good – many suppliers	Will eventually become global – the lowest hanging fruit
Light commercial	Mature applications for **hydro carbons** stretching from Household below 150 g of charge	Good – Carbon chain based A2L refrigerants can relatively easy be adapted	Hydro Carbons will dominate below 150 g charge as will A2L refrigerants above 150 g
Commercial	Still in transition for **CO2** in larger systems and **hydrocarbons** for stand alone units. Some smaller applications based on condensing units will still need **HFC/HFO**	Medium/good - CO2 components will align to system development - has increased significantly. Condensing units already adapted to GWP levels below 2000 and potentially lower	CO2 will be used in warmer climates than perceived today. Heat recovery will increase viability even more in colder climates
Transport	Difficult application as systems travel across borders and are placed in different locations. **CO2** is a candidate and systems developing. Also new **HFC/HFO** types with low to medium GWP are coming	Medium/good. Many components are the same or alike in Commercial refrigeration.	If CO2 to play a role where efficincy is sufficient. Due to safety HFC will be used whreever charge sizes becomes to big.
Industrial	Mature **ammonia** (NH3) applications but new improvements are developing due to various safety aspects. **CO2** is being more used in combination with ammonia	Good , for NH3 components Medium – CO2 components systems have increased significantly.	Charge reduction of pure NH3 systems. Combination of NH3 and CO2 will be an effective solution

Back up slides

Supermarkets

Moving to low GWP refrigerants may reduce Energy Efficiency



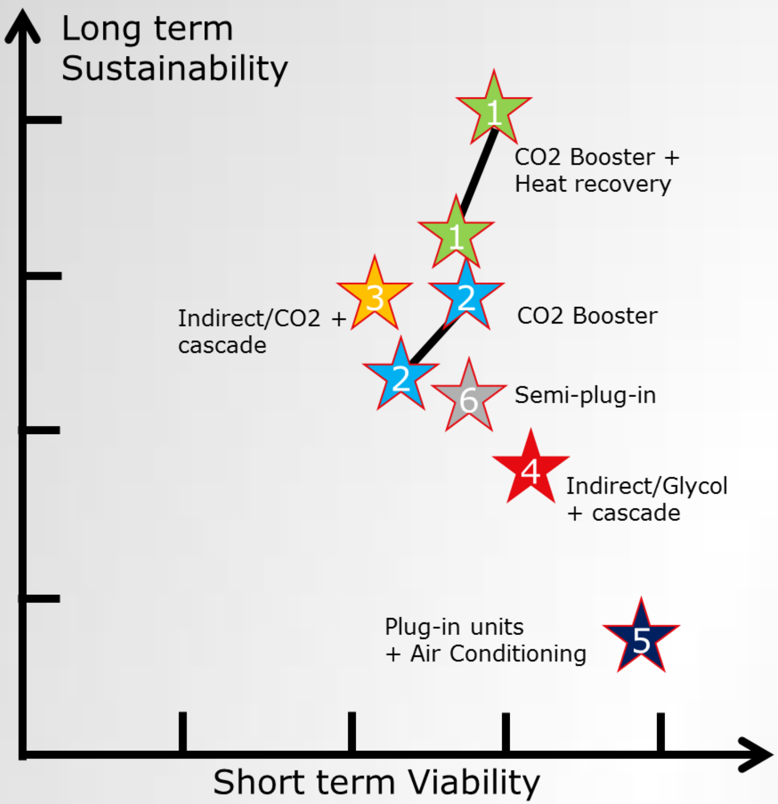
- Low GWP refrigerants need to be selected properly to ensure the system efficiency
- Low GWP solutions are not necessarily recognising energy challenges and opportunities
- Future energy systems will address accessible sources for energy efficiency and also demand response
- Lack of education and market readiness can result in short term rather than long term solutions

Evaluation of low GWP solutions for supermarkets

	COST Competi-tiveness	System complexity	Market readiness	Technical maturity	LCC Energy Efficiency	Smart Grid
CO2 Booster + Heat recovery Colder climate	☺☺☺☺☺	☺☺	☺☺☺☺	☺☺☺☺	☺☺☺☺☺	☺☺☺☺☺
CO2 Booster Colder Climate	☺☺☺	☺☺☺	☺☺☺☺	☺☺☺☺	☺☺☺☺	☺☺☺
Indirect/CO2 + cascade	☺☺	☺☺	☺☺☺	☺☺☺☺	☺☺☺☺	☺☺☺
Indirect/Glycol + cascade	☺☺☺	☺☺☺☺	☺☺☺☺	☺☺☺☺☺	☺☺	☺☺☺
Plug-in units + A/C	☺☺☺☺	☺☺☺☺☺	☺☺☺☺☺	☺☺☺☺☺	☺	☺
Semi-plug-in	☺☺☺☺	☺☺☺☺	☺☺☺	☺☺☺	☺☺☺	☺☺☺

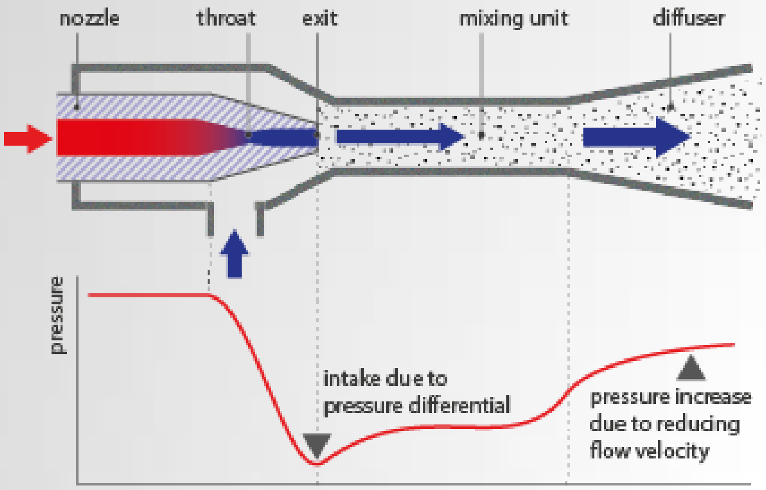
Viability : Cost + Complexity + Market readiness + Technical maturity
Sustainability : Life cycle cost (LCC) + Flexibility (Smart grid)

Solutions addressing the F-gas regulation



- High viability may result in lower sustainability
- Heat recovery has best overall score but relates mostly to Northern climates
- CO_2 booster systems score higher than indirect systems only in colder climates
- CO_2 booster success still depends to much on ambient temperature

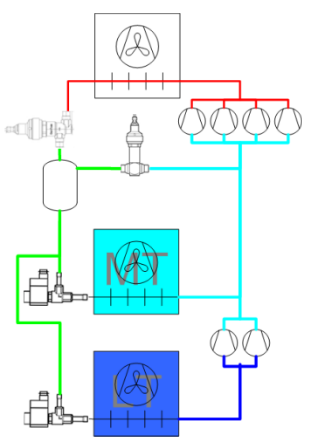
CO_2 with Ejector Technology



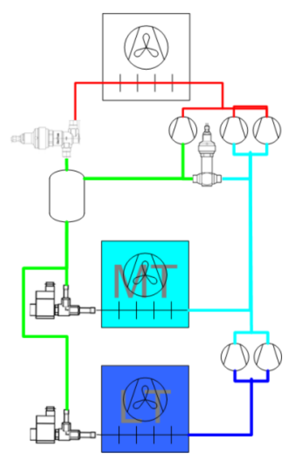
- Concept known for a 100 years
- Capacity adaption is key for success
- Especially suited for CO_2 due to high expansion work recovery potential
- Several University projects
- Running test sites show results as expected

CO_2 technology summary **@ 44 °C**

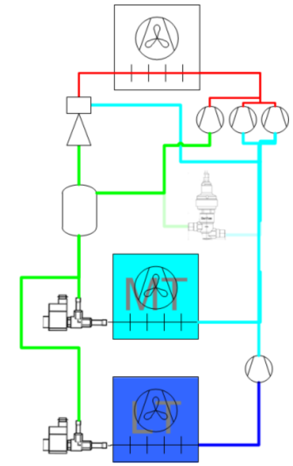
System	Energy saving VS. R404a	Compressor saving VS. Booster
Booster	-25%	0%
Parallel compression	3%	19%
Gas ejector	7%	28%
Liquid & gas ejector	16%	35%



Traditional transcritical booster system

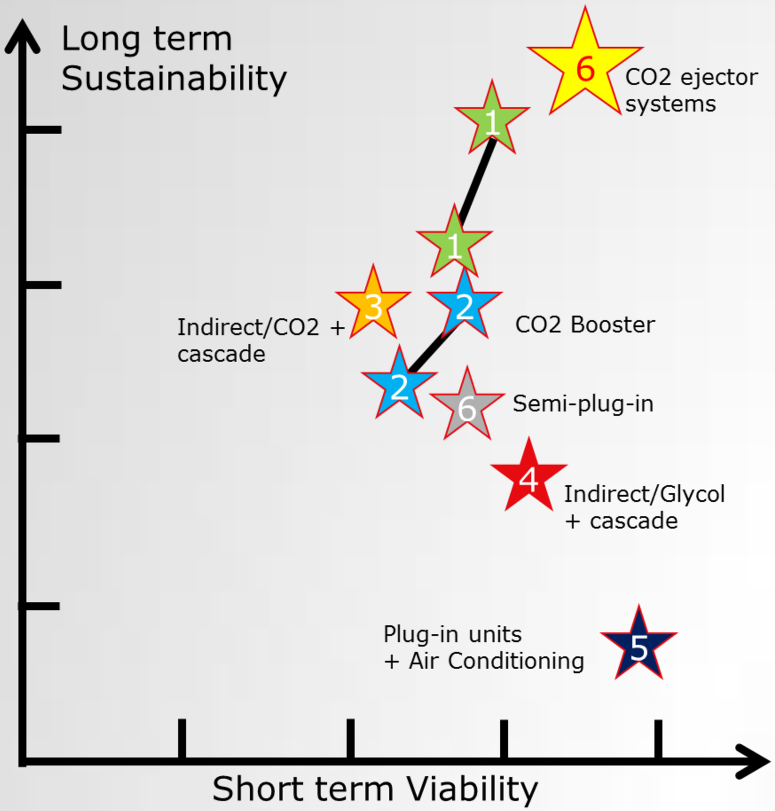


System with parallel compression



System with ejector and parallel compression

Main prospects



- A technology shift is under way in the commercial refrigeration segment and already happening in the EU
- Mature and efficient solutions evolve as a result of market uptake and a need for simple operation of systems
- To utilise the best long term solutions a focus on the ease of use as well as education is needed
- CO_2 technologies have the potential to become viable even in high ambient locations in the near future

Back up slides
Generics

Refrigerants for the future

Carbon Chain Base Refrigerants