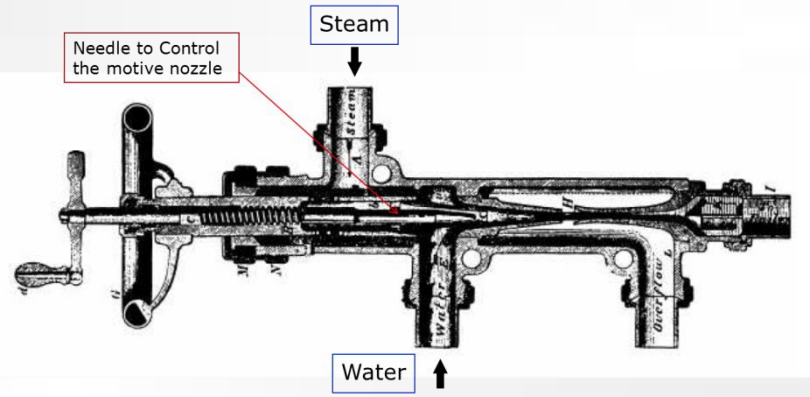
ENGINEERING
TOMORROW

Barriers and opportunities for selection of best low GWP technologies

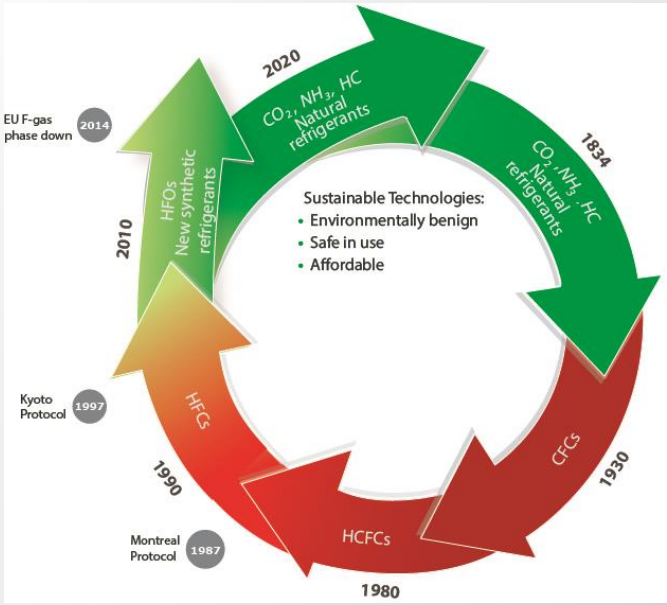
Torben Funder-Kristensen; TFK@DANFOSS.COM

Agenda

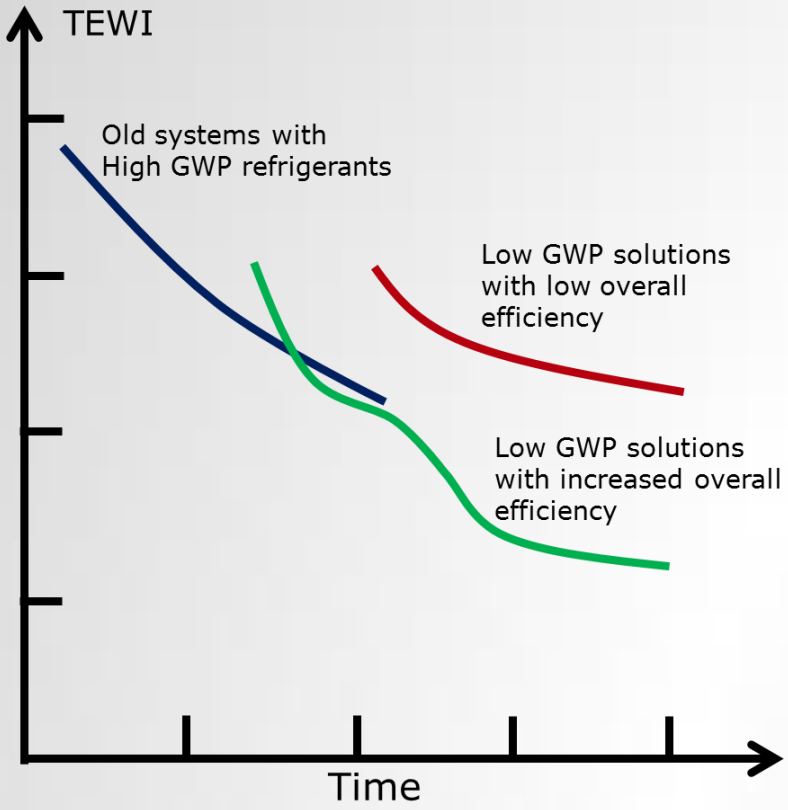
- Potential pitfalls of the F-gas regulation
- Comparison between low GWP solutions for supermarkets
- Technologies that will position CO2 as a warm climate candidate
- Conclusion



Ejector from Henri Griffard (1864), with integrated spindle valve for control of motive flow rate



Potential pitfalls of the F-gas regulation



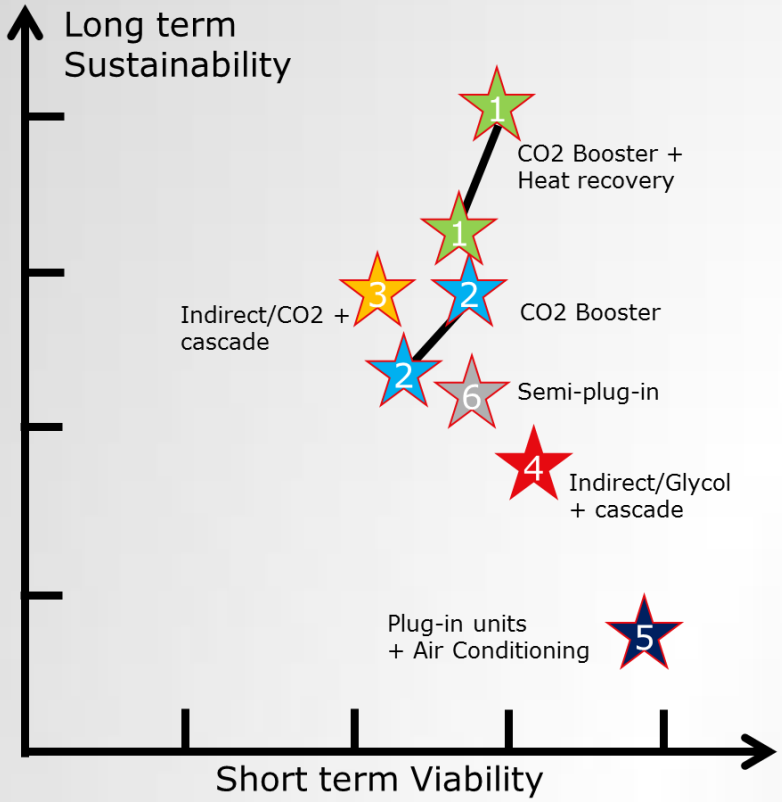
- The F-gas regulation does not account for the system efficiency
- Low GWP solutions are not necessarily recognising energy challenges and opportunities
- The EU energy union will address accessible sources for energy efficiency and also demand response
- Lack of education and market readiness can result in short term rather than long term solutions

Qualitative evaluation of low GWP solutions

	COST Competi-tiveness	System complexity	Market readiness	Technical maturity	LCC Energy Efficiency	Smart Grid
CO2 Booster + Heat recovery North EU						
CO2 Booster North EU						
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)

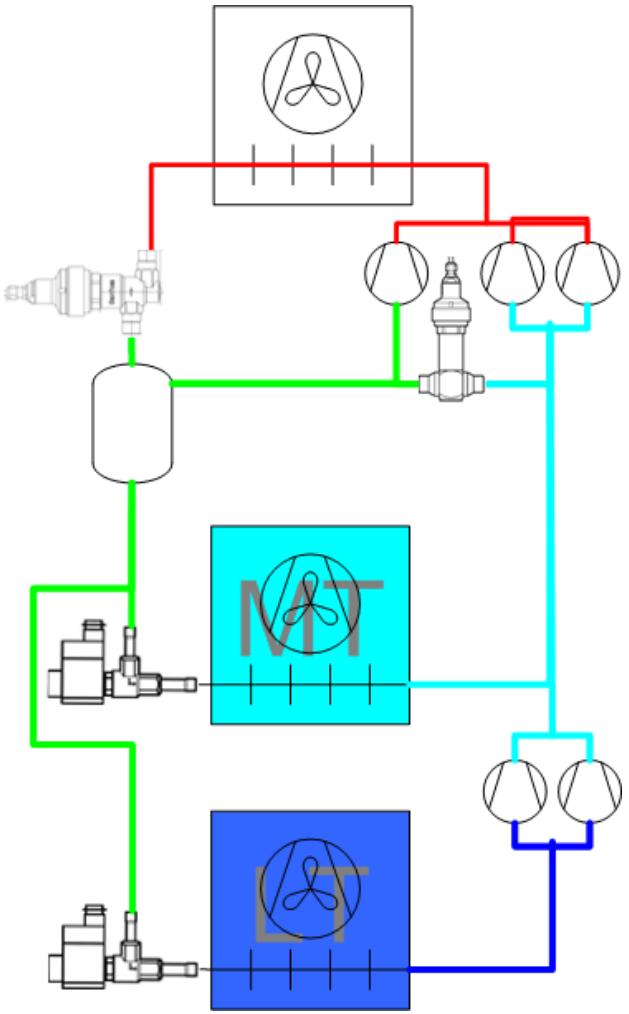
Solutions addressing the F-gas regulation



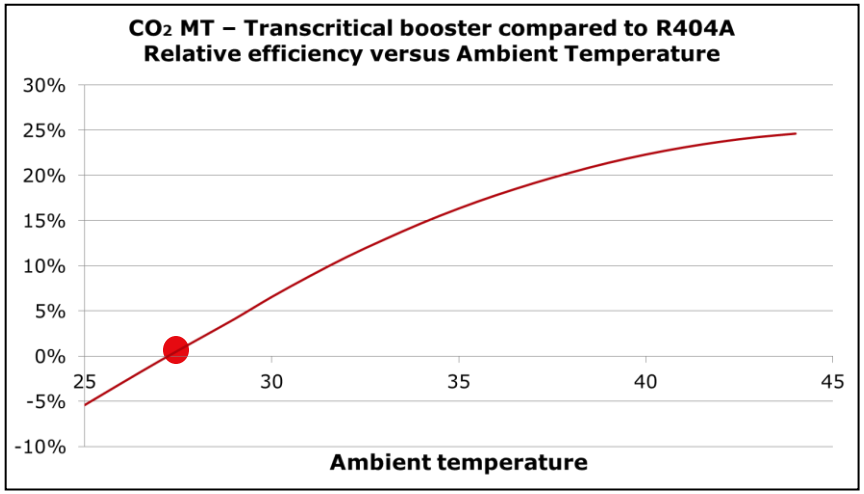
- High viability may result in lower sustainability
- Heat recovery has best overall score but relates mostly to Northern Europe
- CO_2 booster systems score higher than indirect systems only in colder climates
- CO_2 booster success still depends to much on ambient temperature

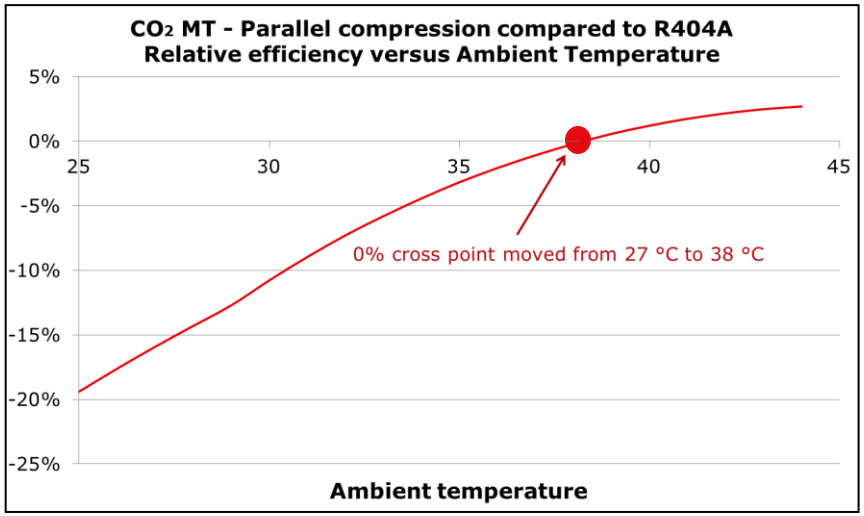
From Booster to Parallel Compression

- The CO_2 transcritical booster system is the most common system (> 5.000 systems)
- Parallel compression (+ 50 systems) is the first step towards using CO_2 in warmer climates.
- Parallel compression
  - improves COP in warm climates
  - reduces the swept volume of the compressors



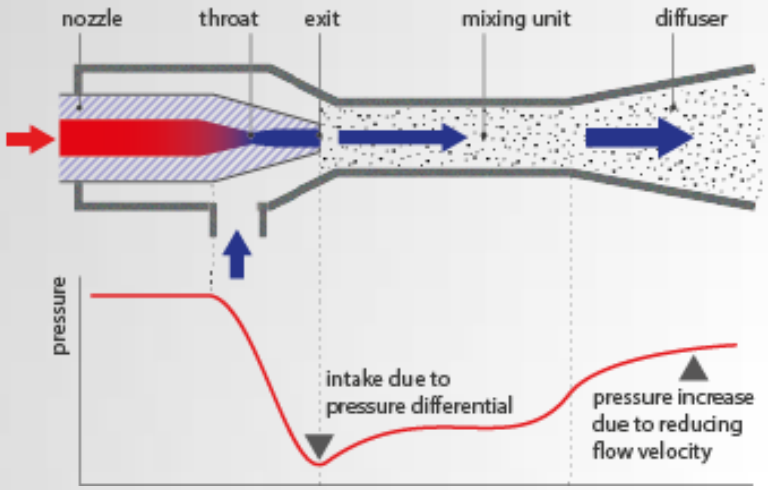
Comparison between technologies





- Conventional booster systems fall short around 27 °C compared to R404A
- Parallel compression can keep up with R404A systems until around 38 °C
- These predictions are confirmed in stores in Spain and Italy

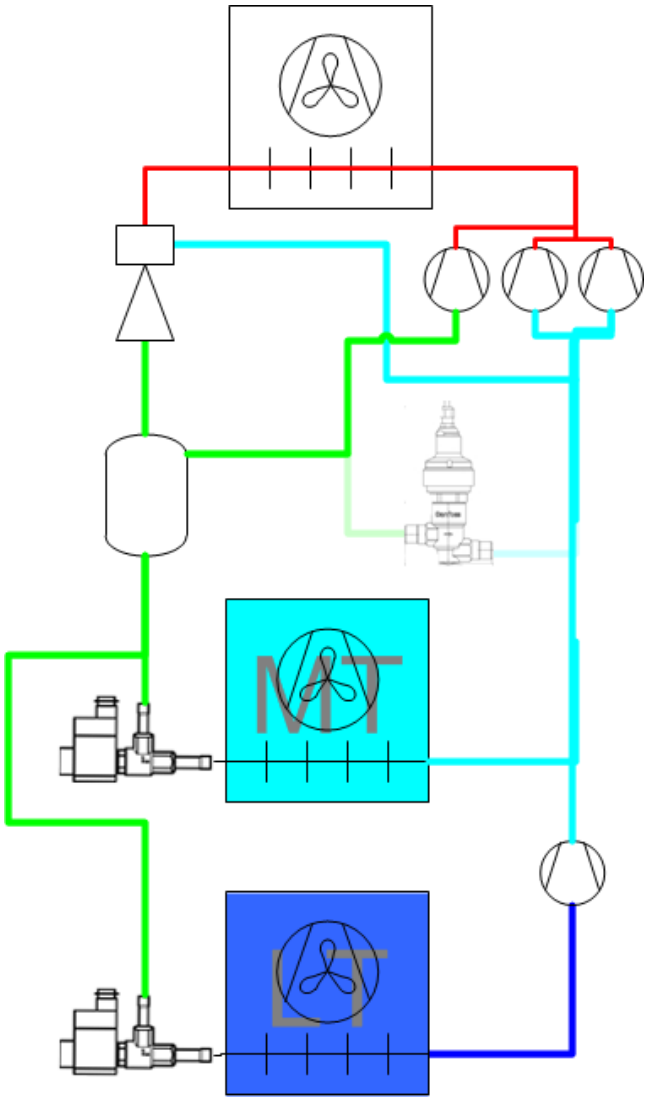
CO_2 with Ejector Technology



- 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

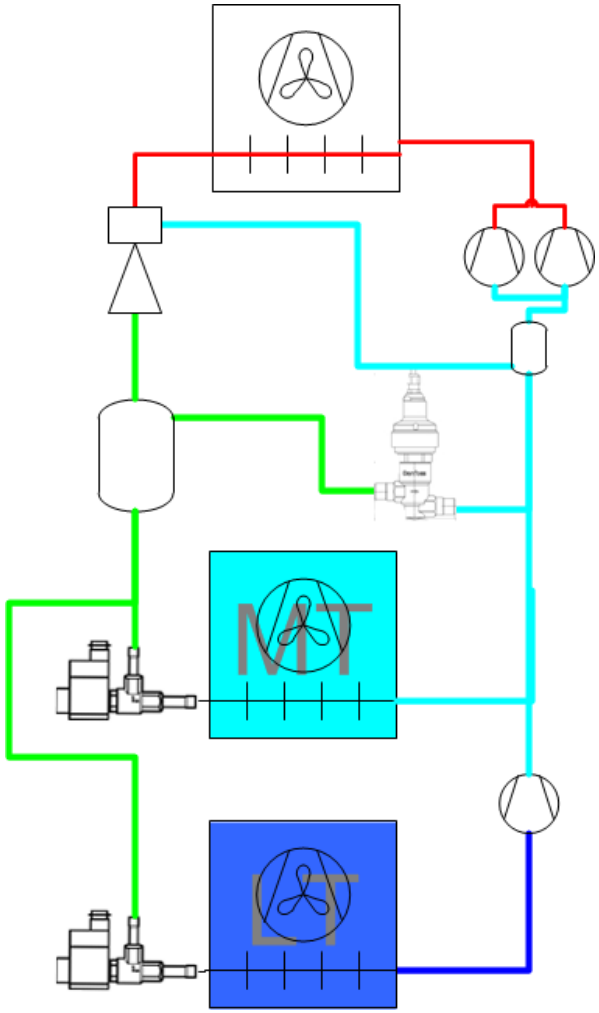
Gas Ejector system

- Systems in operation since 2013 with good results
- First system in operation with Danfoss Multi Ejector since January 2015
- Ejectors are moving gas from MT suction to parallel compressor

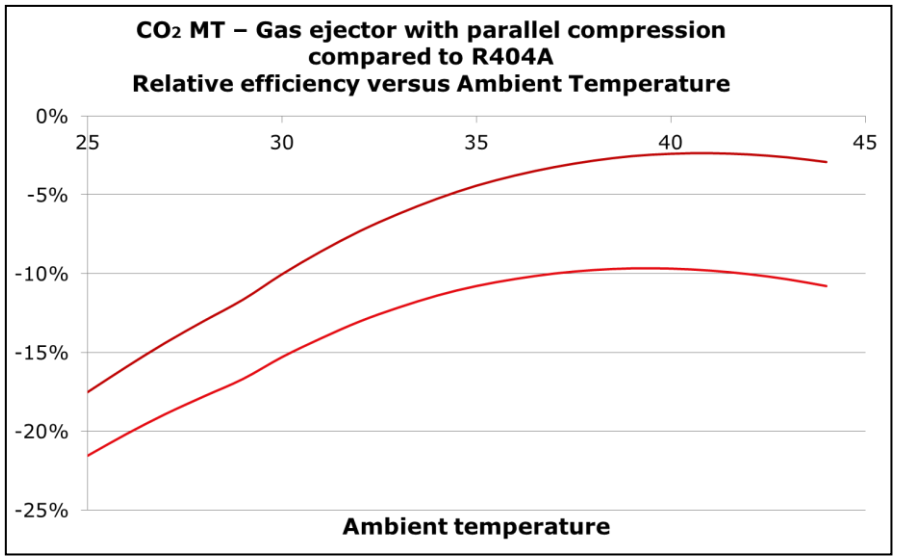


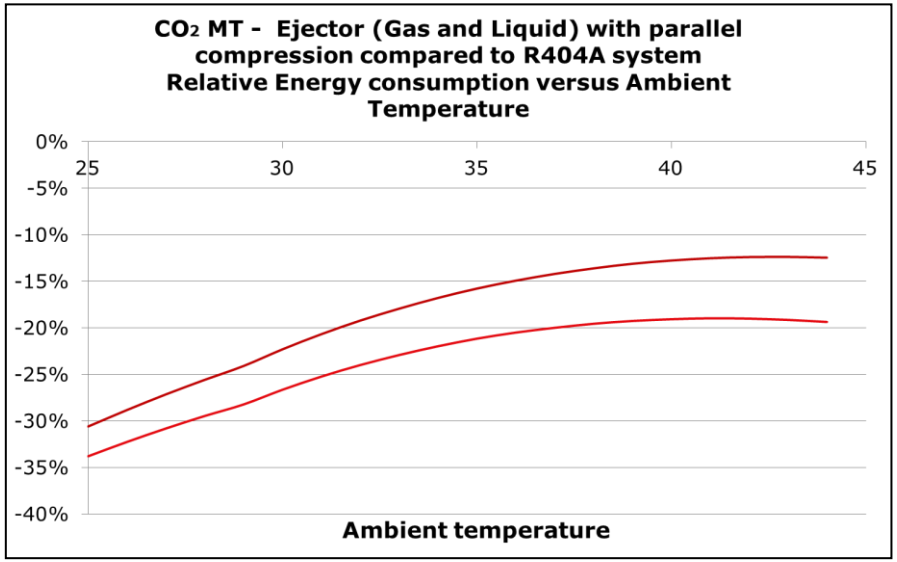
Liquid Ejector System

- Liquid Ejector Systems allow the MT evaporator to be flooded
- The saving is not coming from the parallel compressor or the ejector, but from the higher suction pressure
- The Liquid Ejector is substituting a pump
- Trials have been running since 2013 with good results. Evaporation temperature is in average raised by 5-10 °C.
- The saving of the Liquid Ejector can be added to the saving of the Gas Ejector



Comparison between Technologies

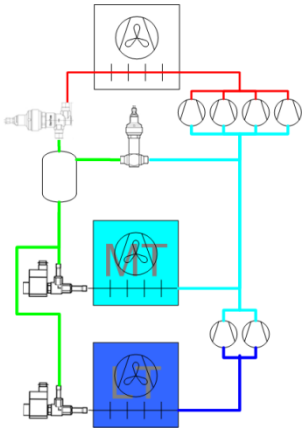




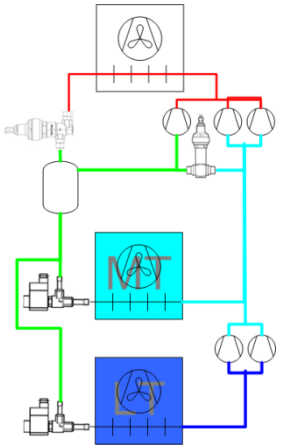
- Ejector technologies show that they are better than R404A systems even at high ambient temperature
- If Gas and Liquid Ejectors are used in parallel, efficiencies can be even more improved
- Predictions are confirmed by test trials and laboratory tests

CO_2 technology summary @ 44 °C

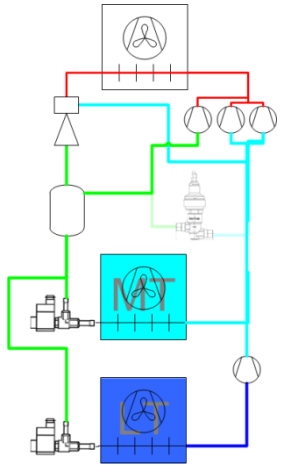
System	Energy saving VS. R404a	Compressor saving VS. Booster
Booster	-25%	0%
Parallel compression	3%	19%
Gas ejector	7%	28%
Liquid & gas ejector	16%	35%



Traditional transcritical booster system

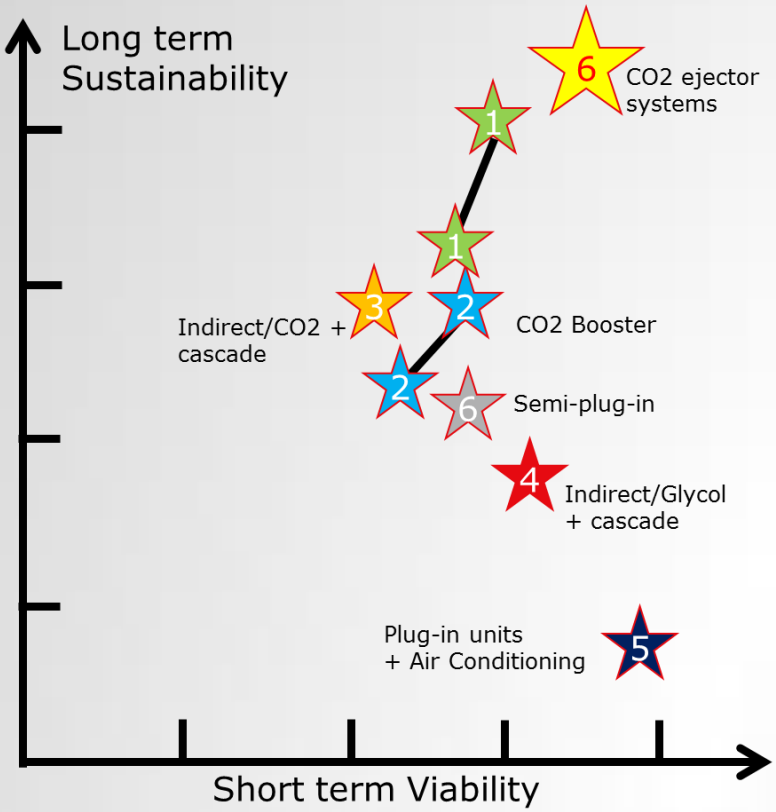


System with parallel compression



System with ejector and parallel compression

Conclusion



- The F-gas regulation will force a technology shift in the commercial refrigeration segment within the EU
- Solutions will eventually evolve as a result of Energy Efficiency improvements 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