MAKING MODERN LIVING POSSIBLE

Trends in CO_2 Refrigeration

ATMOsphere AMERICA the Business Case natural refrigerants

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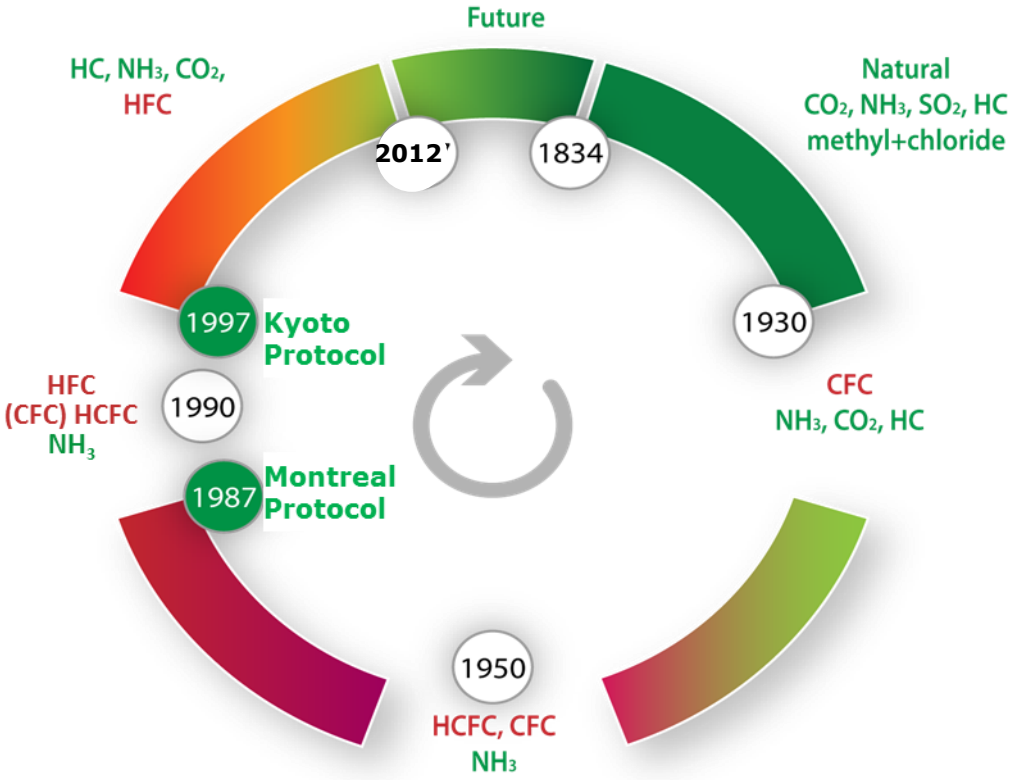
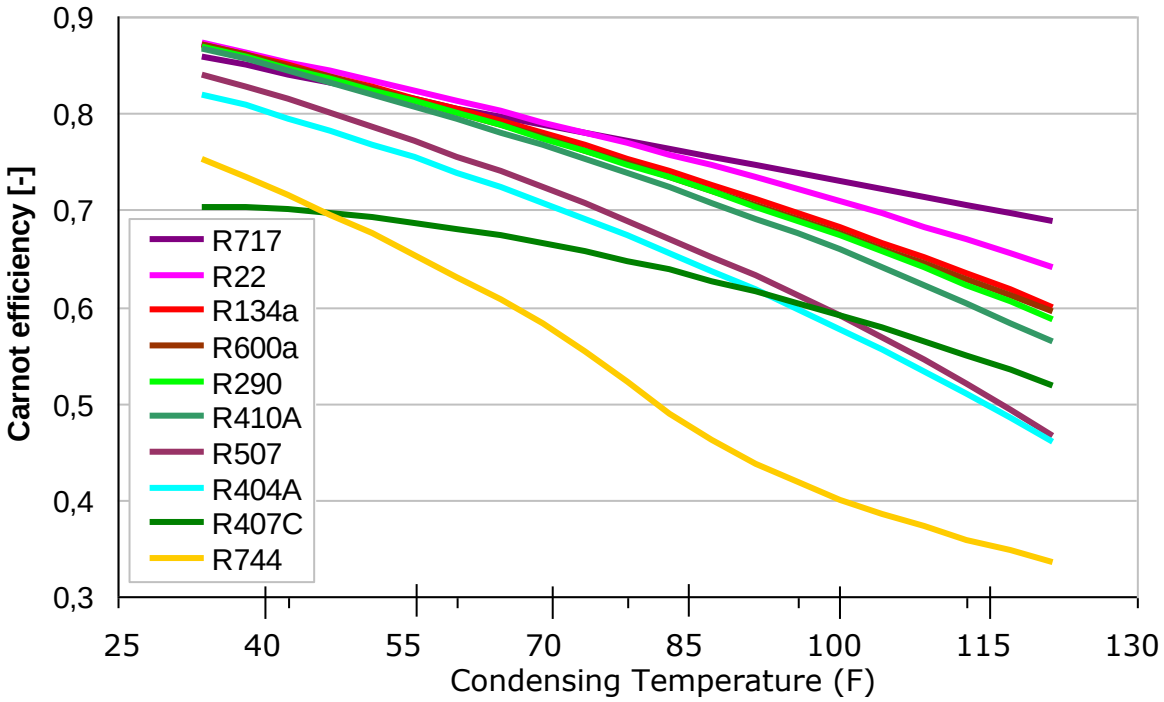
Agenda



- CO2 - history & overview
- Industrial and commercial applications in general
- North America focus
- Barriers for CO_2
- Training and Education
- Conclusion

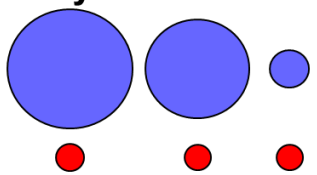
Efficiency of Ideal Reversed Rankine Cycle



Relative sizing of pipes to give the same capacity:

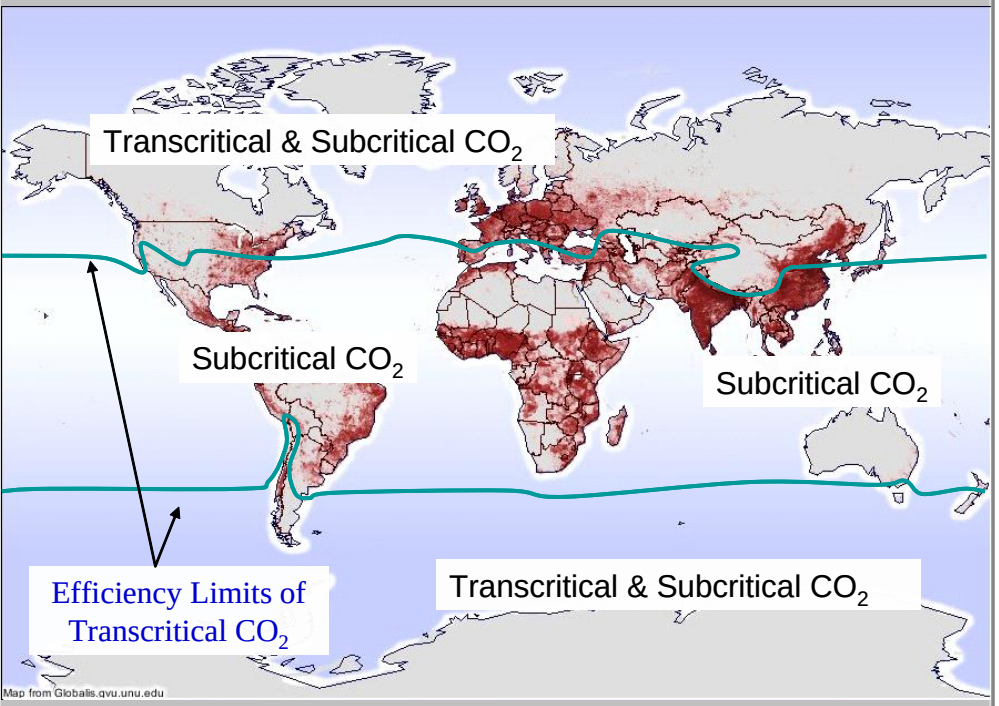
R134a R22 CO_2

Dry suction line



Liquid Line

Poor thermodynamic efficiency can be offset by thermophysical gains. It means component design and system configuration have to be optimised accordingly.

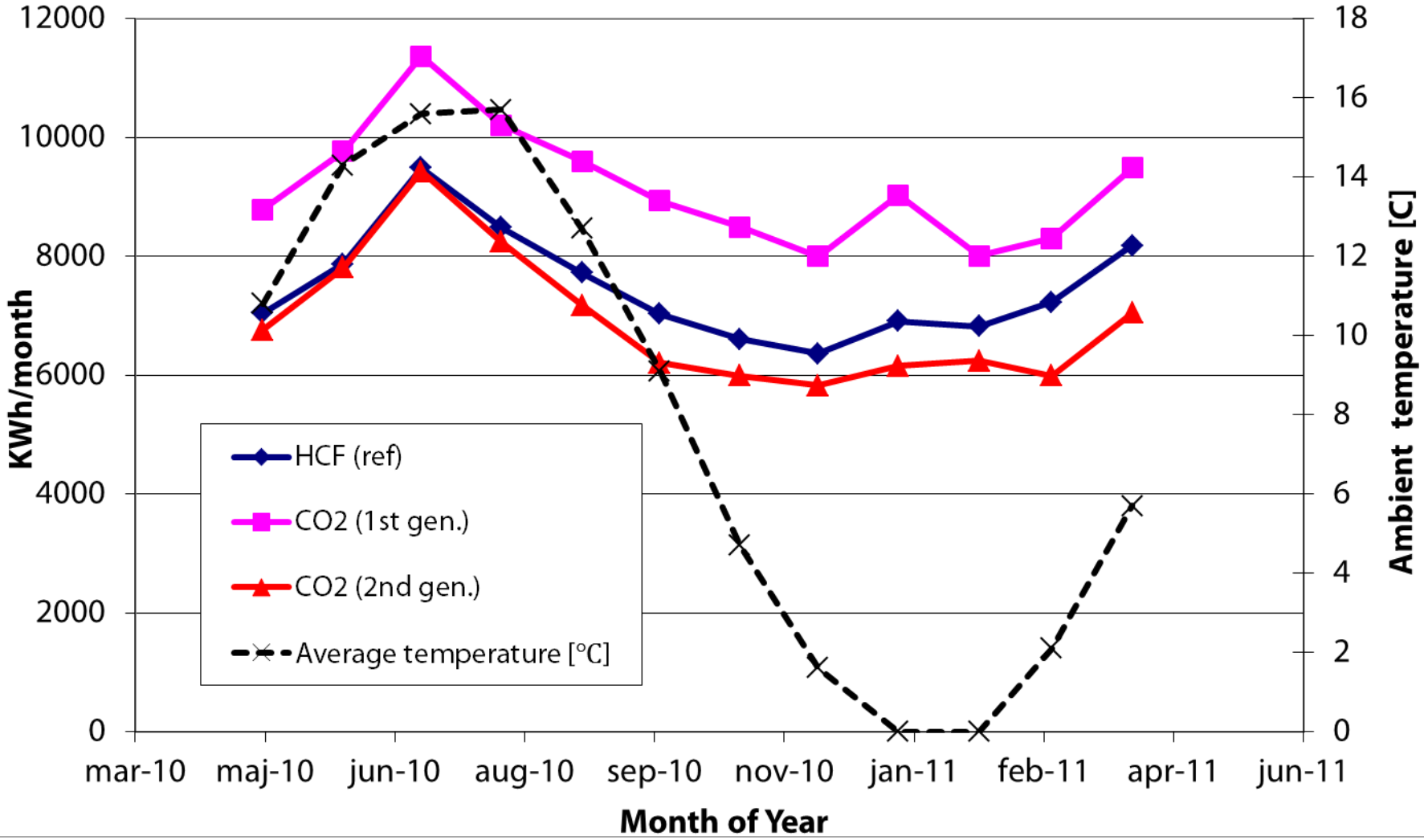


CO_2 Overview

- Non-toxic and Low GWP
- Energy efficient – but observe the limitations for outdoor temp and design the system accordingly
- The state of art performance increases and maturity have not been reached yet
- Systems and components have been under development during the last decade

Fakta Supermarket - case study

Energy Consumption versus technology and month

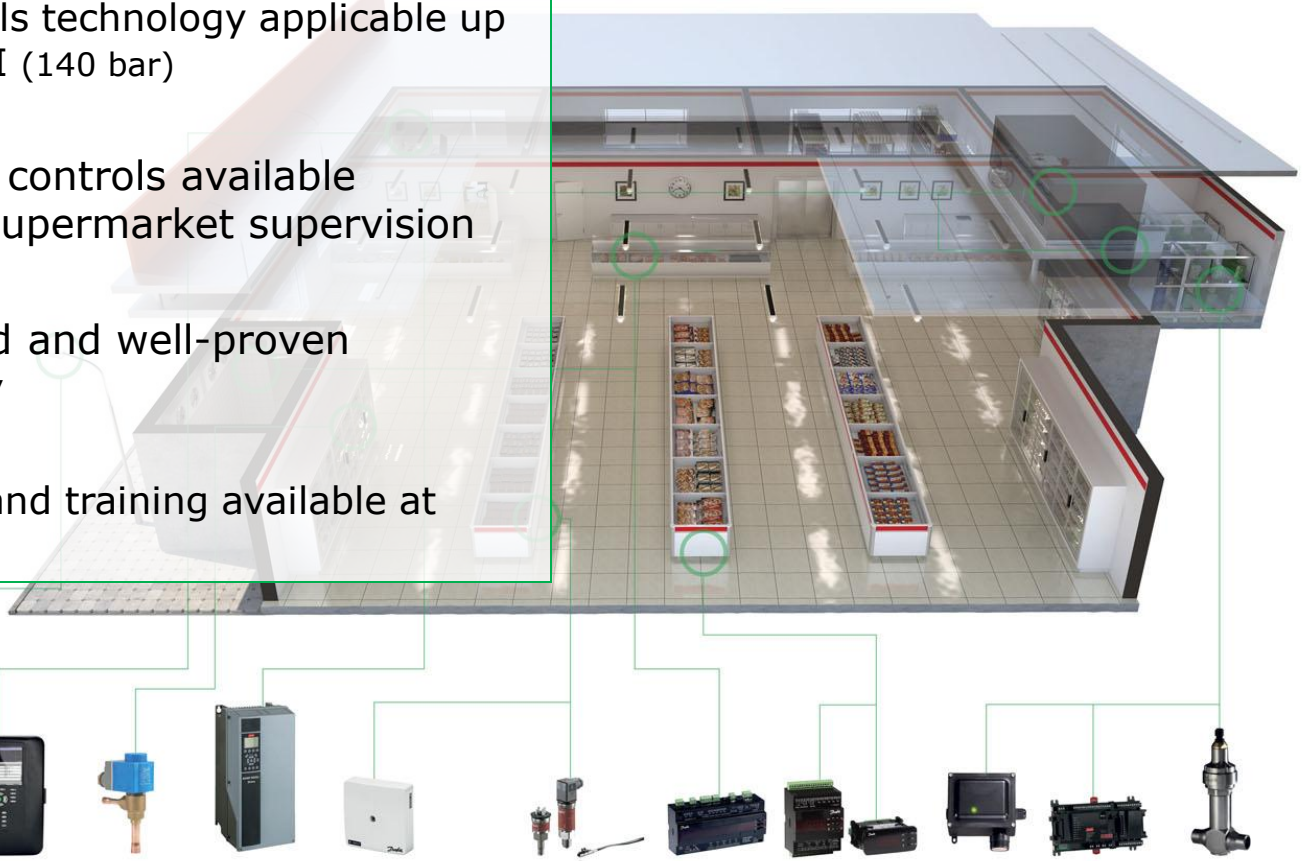


CO_2 in Industrial Refrigeration

- Combination of CO_2/NH_3 have existed in the US for the past 6 years
- The largest system globally installed by US Cold Storage
- Benefits:
  - Reduced installation cost
  - Higher efficiency due to CO_2 viscosity (low cost for circulation pumps) and superior heat transfer property
- New controls technology applicable up to 754 PSI (52 bar)
- CO_2/NH_3 cascade systems have the potential to become the standard for low temperature applications due to lower investment cost – and more important – lower operating cost

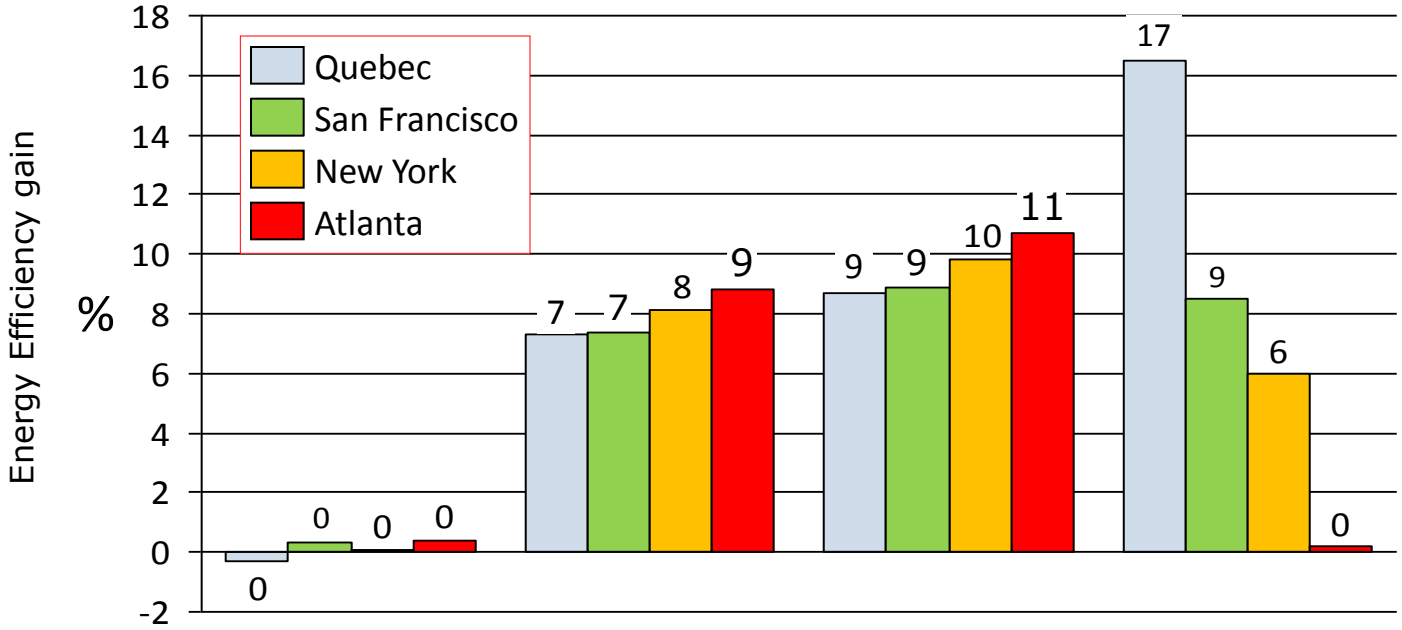
CO_2 in Food Retail

- CO_2 as single refrigerant or in combination with HFC/HFO/HC/NH_3
- New controls technology applicable up to 2030 PSI (140 bar)
- Full line of controls available including supermarket supervision
- Established and well-proven technology
- Education and training available at Danfoss



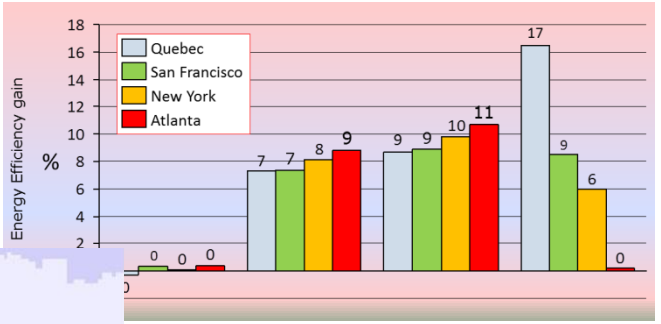
CO_2 configurations compared to traditional system

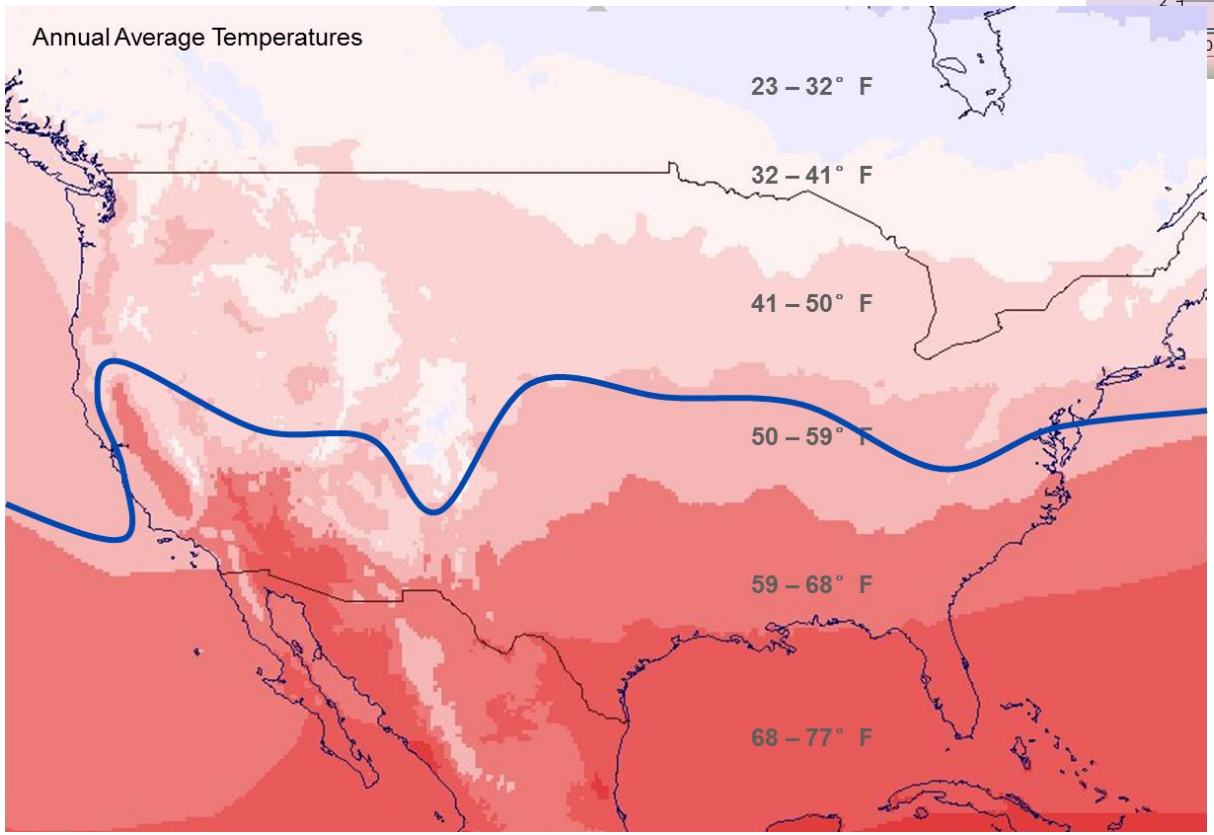
(Traditional = Two parallel single stage R404A system)



Alternative System	R404A/CO_2 Cascade	Propane Chiller	Ammonia Chiller	Transcritical CO2 Booster
MT LT	R404A CO_2	Pumped CO_2 CO_2 DX	Pumped CO_2 CO_2 DX	CO2 DX CO2 DX

Optimal CO_2 Configurations Depend on Climate



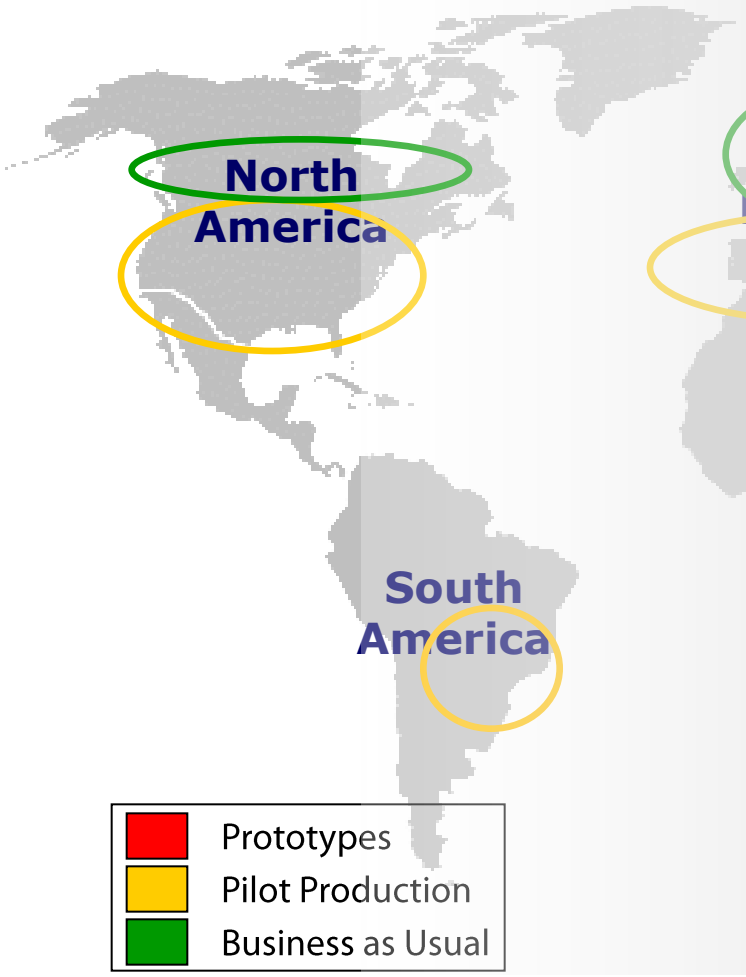


North of the blue line, transcritical CO_2 booster systems will have an efficiency advantage.

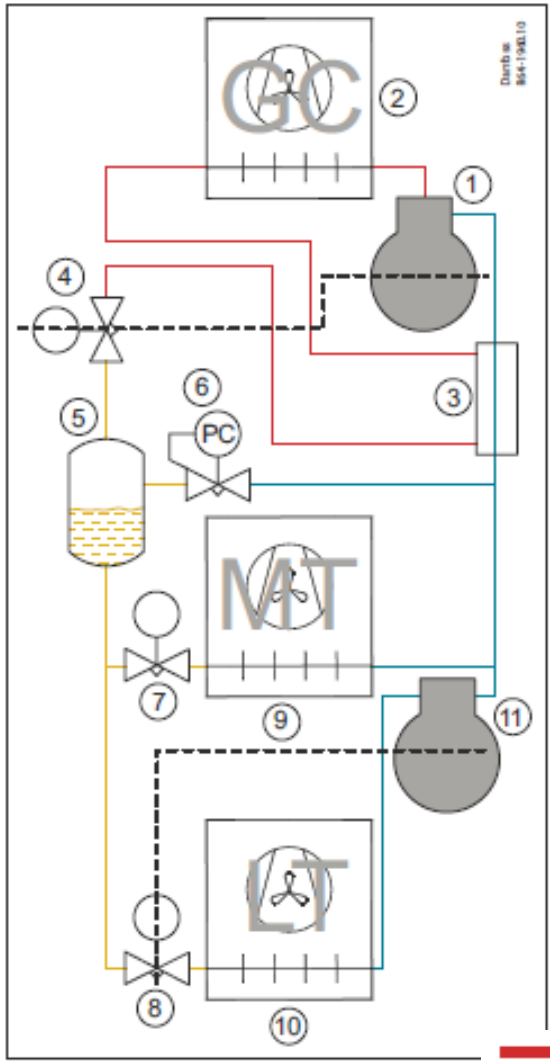
South of the line, a cascade system, for example, Ammonia – CO_2, is more efficient.

The boundary is being pushed south with new innovations made to booster systems.

CO_2 Technology in Supermarkets - North America



- Several cascade systems installed during the last 5 years. Yearly rate in 2012 > 40 systems
- Typically systems with R404A in cascade with CO_2
- Transcritical systems getting increased attention and numerous new installations planned in the US. Expected to see main retail chains with systems in 2013.
- Expect more than 30 transcritical systems in Canada during 2012
- Energy efficiency and environmental branding are the main drivers



Transcritical will come !

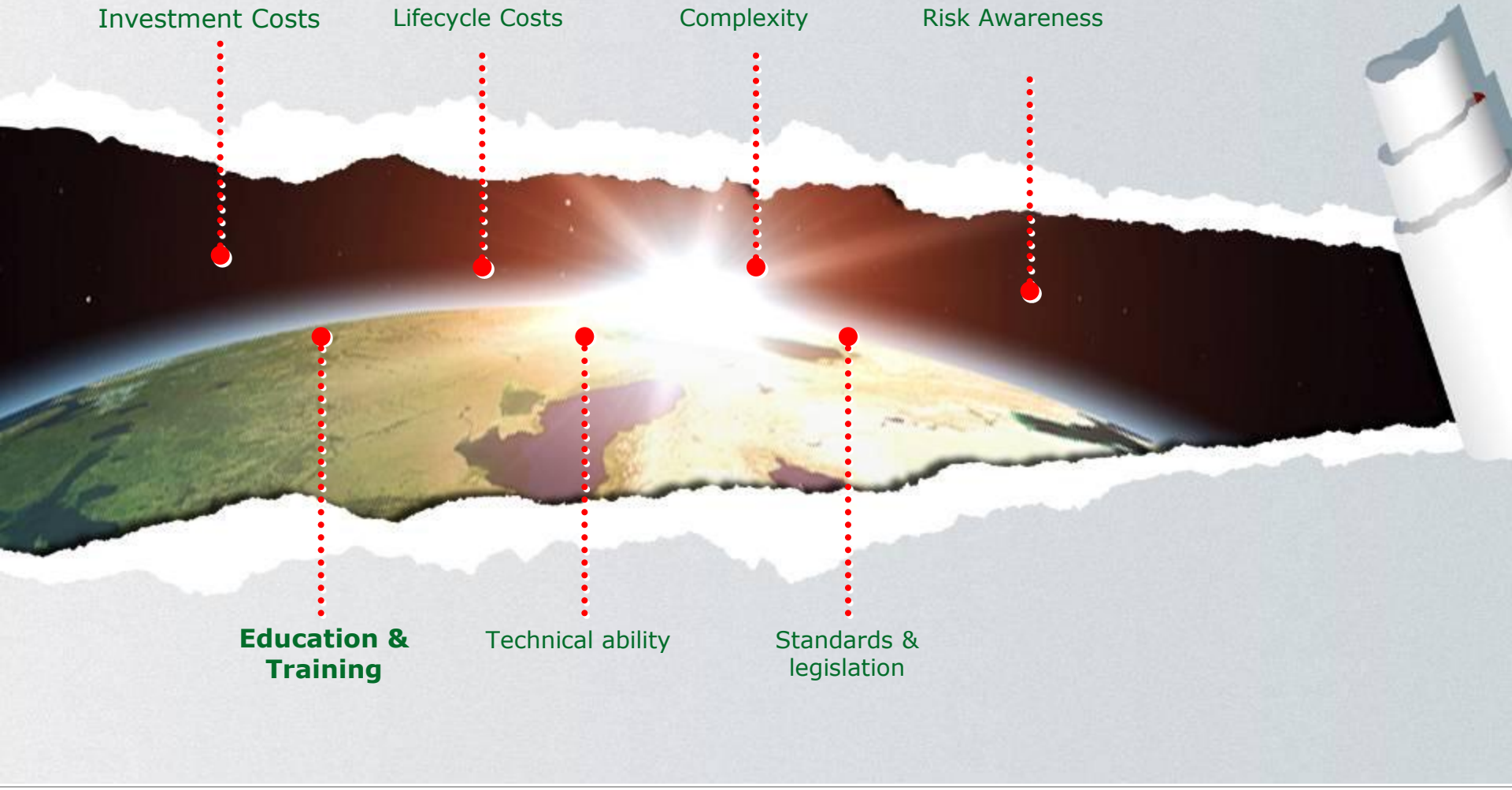
Whole Food in the US has elected to move into the natural refrigeration solution with a Transcritical Booster CO_2 System.

Danfoss has been involved in this project together with Hill Phoenix.

The key drivers are:

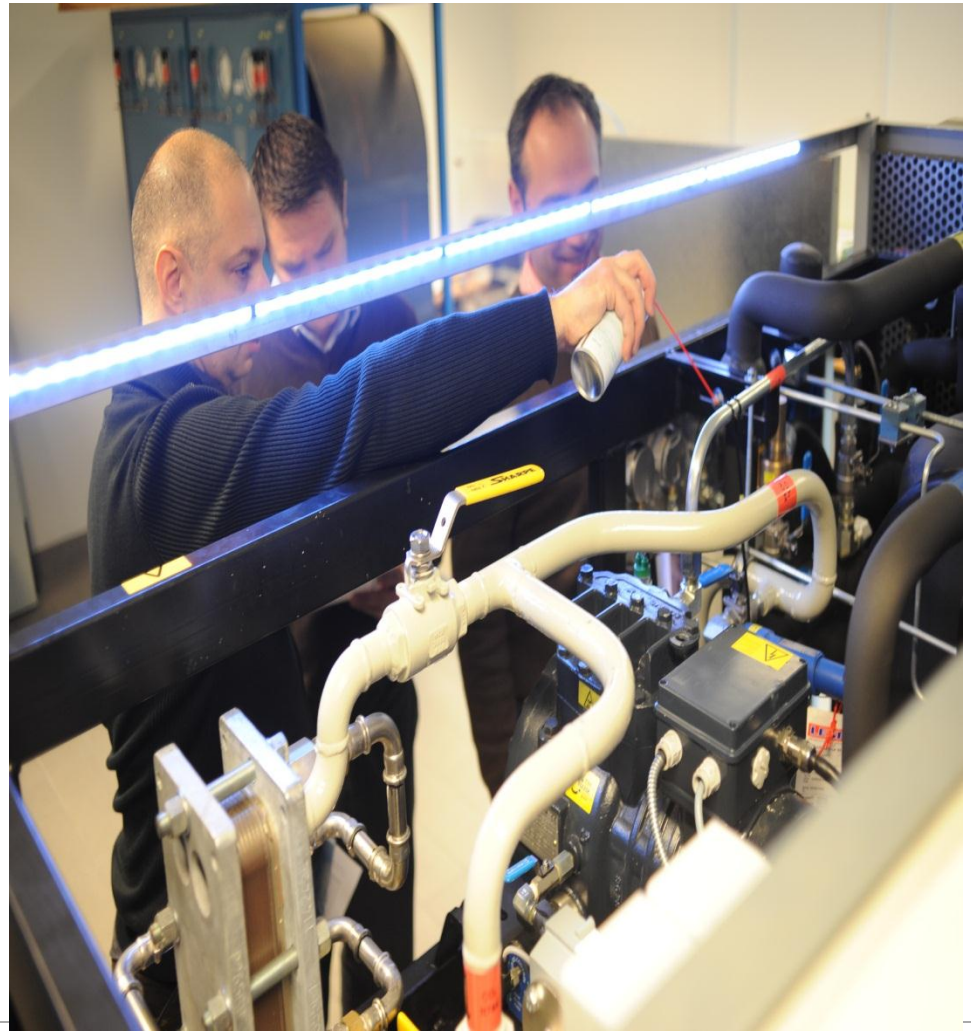
- Corporate environmental responsibility
- Lowering carbon footprint (Free of HFC/HIGH GWP)
- Simple system
- Energy savings

Barriers for new refrigerants



Hands-on Training

- Laboratory to provide real world installation trouble shooting and maintenance skills
- Real-life system dimensioned to fit a small-sized supermarket
- We operate with more than 1460 PSI (100 bar)
- First site opened Feb. 22 2012 (EU)
- Second site planned for Americas



Conclusion

- CO_2 is proven to be a competitive refrigerant and environmentally benign for industrial refrigeration and food retail applications
- Several important barriers still remain, specifically education and training
- During the last 10 years a lot of product development has taken place and system reliability is very high
- North American supermarkets, increasingly utilize CO_2 refrigerant together with HFCs.
- Transcritical systems are planned in many supermarkets chains. More than 30 systems are expected to be installed by end of 2012 in Canada
- Industrial applications with CO_2 and NH_3 are well accepted and will increasingly dominate the market
- The use of CO_2 has shown to trigger innovation. Heat reclaim provides a major opportunity to be exploited in the near future.

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