



## ***Global perspective on CO<sub>2</sub> & Danfoss strategy***

Dr.-Ing. Jürgen Süss

[suess@danfoss.com](mailto:suess@danfoss.com)

VP R&D

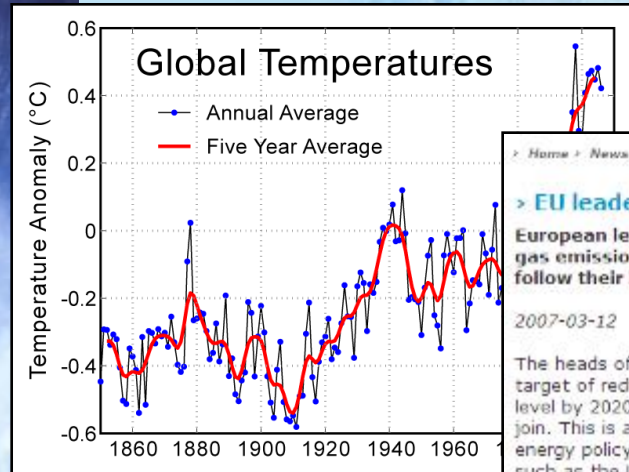
KVCA CO2 strategy seminar

Hedensted

May 14th, 2009



# The Global Warming focus ...



> Home > News > Latest News

### > EU leaders support tough emissions cut

European leaders agreed last week on a mandatory target to cut greenhouse gas emissions by 20% from the 1990 level by 2020, challenging the world to follow their lead in fighting climate change.

2007-03-12

The heads of state and government of the 27 EU Member States have committed to a target of reducing greenhouse gas (GHG) emissions by at least one fifth from the 1990 level by 2020, offering to endorse even a 30% reduction if other developed nations join. This is a key result from the two-day debate on climate change and European energy policy on 8-9 March in Brussels. EU leaders thus challenge other major polluter such as the United States, Russia, China and India to follow the European leadership and commit to deep cuts in GHG emissions.

In addition, it emerged from the meeting a commitment to:

- reduce EU-wide energy consumption by 20% by 2020. However, this target is indicative and non binding.
- implement rapidly the Energy Efficiency Action Plan the European Commission had proposed in October 2006. This will most likely also include minimum efficiency requirements for Mobile Air Conditioning.

### Get the Facts

Global warming is already disrupting people's lives. Get a preview of life on a hotter planet.

- Discover: Real stories
- See: The facts
- Act: And the facts

### Get Involved

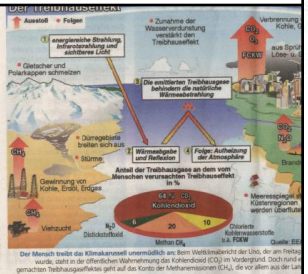
Industry, especially from cars and from making electricity, is a major cause of global warming. Find out how you can make a difference.

### Get Tips to Fight Global Warming

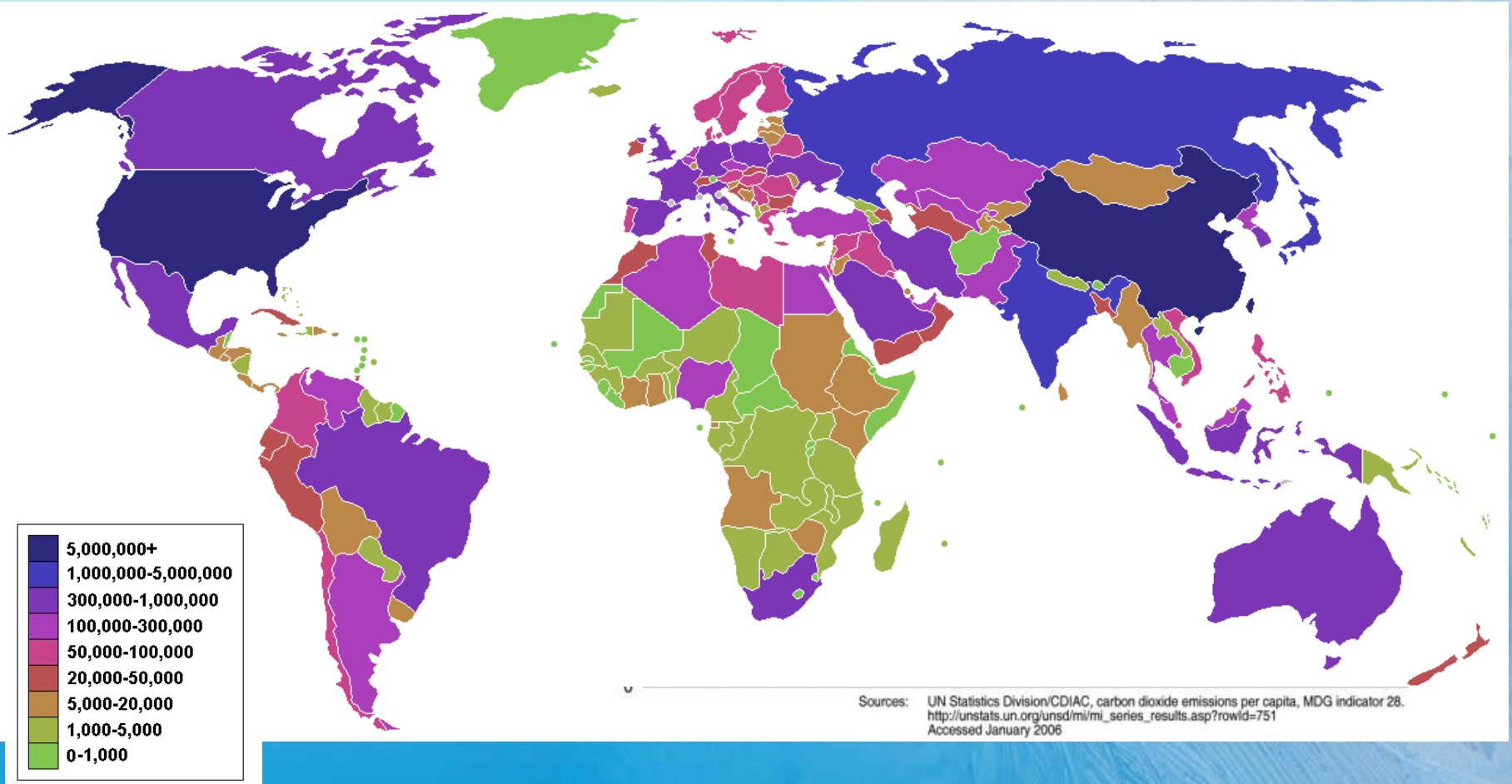
Sign up for updates and see on how you can help. We'll get you started with our low Carbon Diet Guide.

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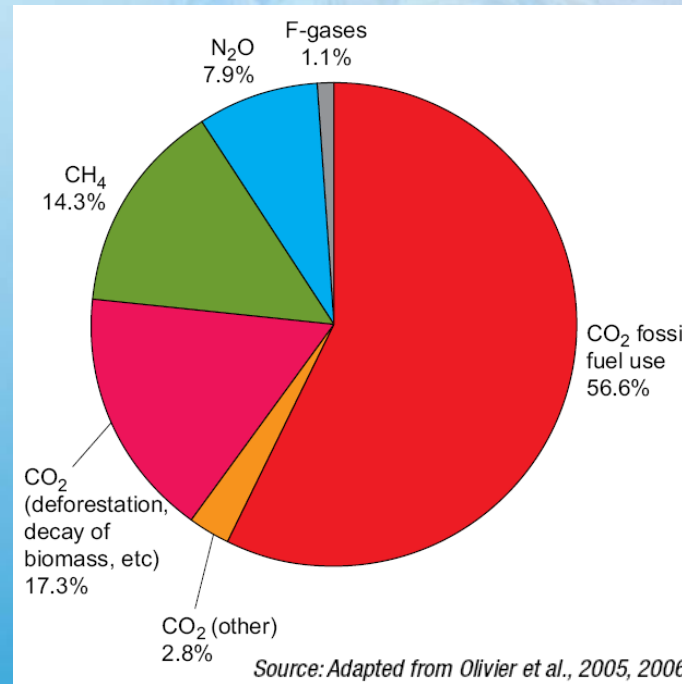


# Total Carbon dioxide emissions by country

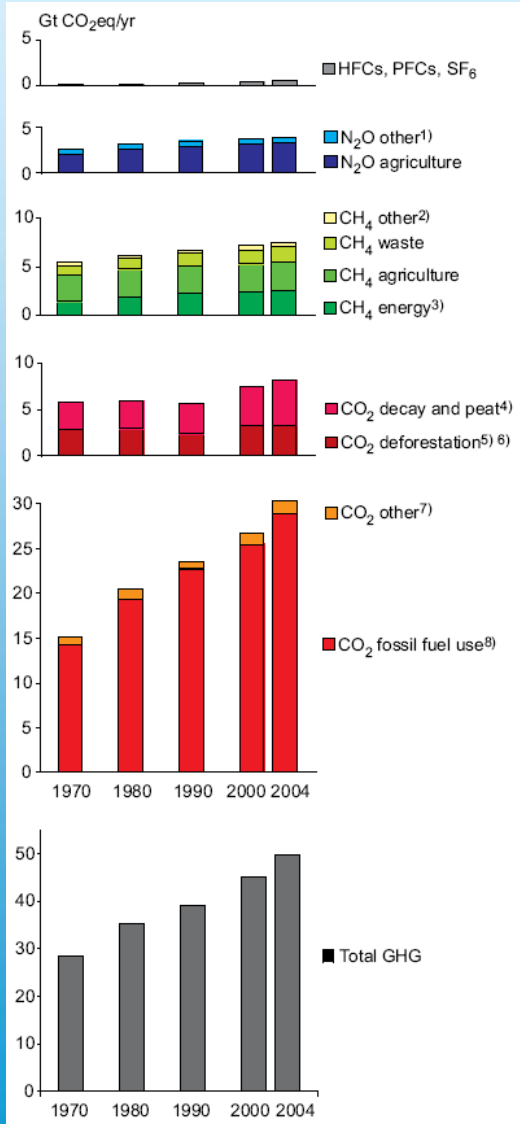




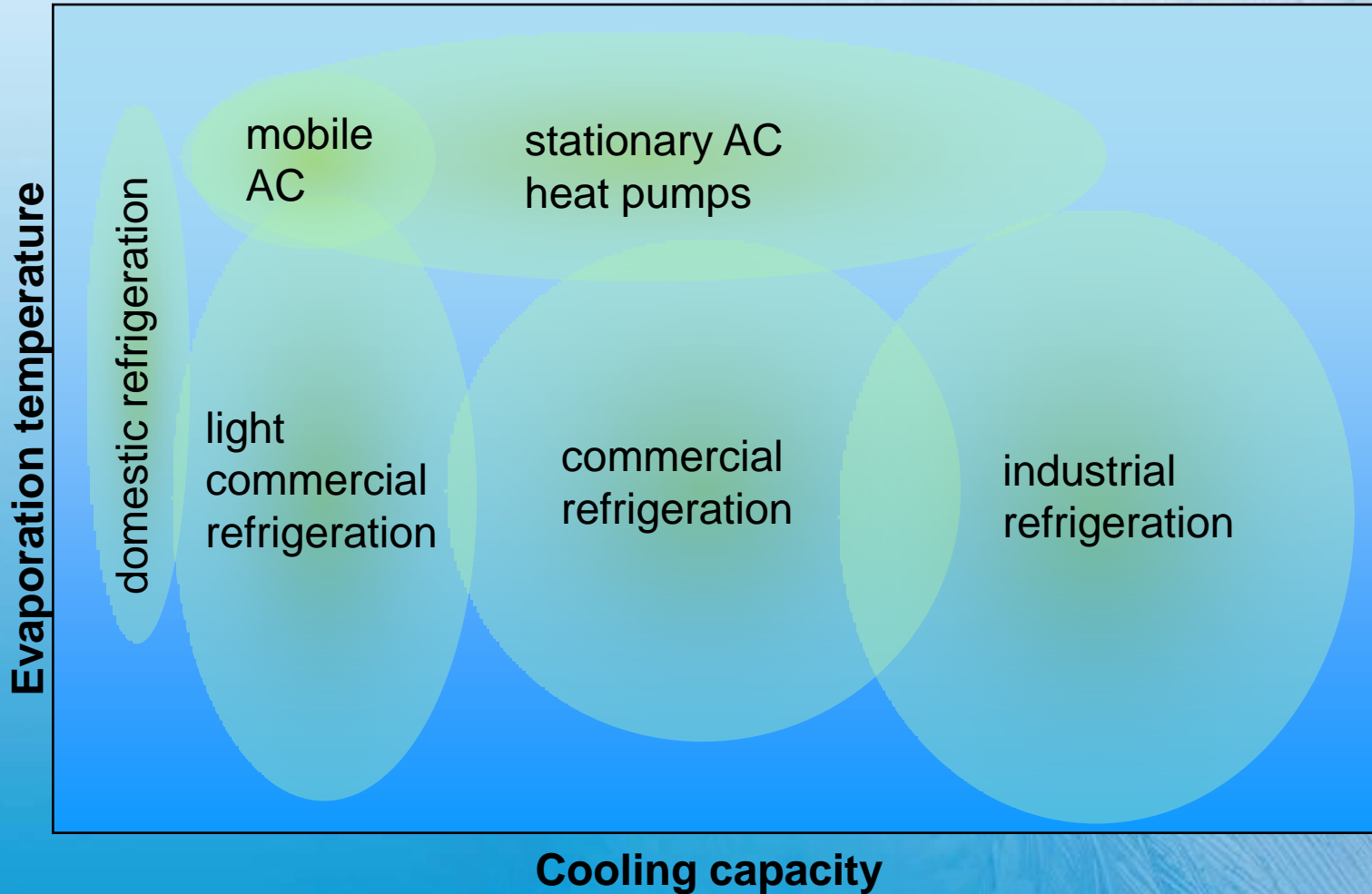
# Global anthropogenic GHG emissions by segment



Refrigeration technologies are very energy-consuming, thus directly contributing to the emission of large amounts of CO<sub>2</sub>. When including air conditioning, they account for about 15% of worldwide electricity use. Energy efficiency, which varies according to units and refrigerants used, is therefore an essential element to take into consideration.



# The refrigeration application map



## Different ways of cooling

The traditional compression process offers the best value proposition for HVAC&R industry

But which refrigerants and technologies should be use for greatest sustainability???

- Reverse Rankine
- Stirling
- Magneto caloric refrigeration
- Vortex tube
- Joule process
- Peltier
- Steam ejector
- Absorption
- Adsorption
- .....



# Refrigerants options

*capacity metal*

**GROUP IA**

**1** 1.00794  
**H**  
Hydrogen

**2** 4.00260  
**He**  
Helium

**3** 6.941  
**Li**  
Lithium

**4** 9.01218  
**Be**  
Beryllium

**11** 22.98976928  
**Na**  
Sodium

**12** 24.304092  
**Mg**  
Magnesium

**19** 39.0983  
**K**  
Potassium

**20** 40.078  
**Ca**  
Calcium

**21** 44.955912  
**Sc**  
Scandium

**22** 47.867  
**Ti**  
Titanium

**23** 50.9415  
**V**  
Vanadium

**24** 51.9961  
**Cr**  
Chromium

**25** 54.938044  
**Mn**  
Manganese

**26** 55.845  
**Fe**  
Iron

**27** 58.9326  
**Co**  
Cobalt

**28** 58.933195  
**Ni**  
Nickel

**29** 63.546  
**Cu**  
Copper

**30** 65.38  
**Zn**  
Zinc

**31** 69.723  
**Ga**  
Gallium

**32** 72.59  
**Ge**  
Germanium

**33** 74.9216  
**As**  
Arsenic

**34** 78.96  
**Se**  
Selenium

**35** 79.904  
**Br**  
Bromine

**36** 83.80  
**Kr**  
Krypton

**39** 88.9059  
**Y**  
Yttrium

**40** 91.224  
**Zr**  
Zirconium

**41** 92.90638  
**Nb**  
Niobium

**42** 95.94  
**Mo**  
Molybdenum

**43** (96)  
**Tc**  
Technetium

**44** 98.90625  
**Ru**  
Ruthenium

**45** 101.07  
**Rh**  
Rhodium

**46** 102.90550  
**Pd**  
Palladium

**47** 106.42  
**Ag**  
Silver

**48** 112.411  
**Cd**  
Cadmium

**49** 114.818  
**In**  
Indium

**50** 118.686  
**Sn**  
Tin

**51** 121.757  
**Sb**  
Antimony

**52** 127.60  
**Te**  
Tellurium

**53** 127.603  
**I**  
Iodine

**54** 131.30  
**Xe**  
Xenon

**55** 132.90545  
**Ba**  
Barium

**56** 137.33  
**La**  
Lanthanum

**57** 138.90547  
**Ce**  
Cerium

**72** 173.49  
**Hf**  
Hafnium

**73** 180.94788  
**Ta**  
Tantalum

**74** 183.84  
**W**  
Tungsten

**75** 186.207  
**Re**  
Rhenium

**76** 186.907  
**Os**  
Osmium

**77** 192.222  
**Ir**  
Iridium

**78** 195.084  
**Pt**  
Platinum

**79** 196.96656  
**Au**  
Gold

**80** 198.90784  
**Hg**  
Mercury

**81** 200.59  
**Tl**  
Thallium

**82** 207.2  
**Pb**  
Lead

**83** 208.9804  
**Bi**  
Bismuth

**84** (209)  
**Po**  
Polonium

**85** (210)  
**At**  
Astatine

**86** (222)  
**Rn**  
Radon

**58** 140.90764  
**Ce**  
Cerium

**59** 140.90764  
**Pr**  
Praseodymium

**60** 140.90764  
**Nd**  
Neodymium

**61** 140.90764  
**Pm**  
Promethium

**62** 140.90764  
**Sm**  
Samarium

**63** 140.90764  
**Eu**  
Europium

**64** 140.90764  
**Gd**  
Gadolinium

**65** 140.90764  
**Tb**  
Terbium

**66** 140.90764  
**Dy**  
Dysprosium

**67** 140.90764  
**Ho**  
Holmium

**68** 140.90764  
**Er**  
Erbium

**69** 140.90764  
**Tm**  
Thulium

**70** 173.045  
**Yb**  
Ytterbium

**71** 174.967  
**Lu**  
Lutetium

**90** 232.0377  
**Th**  
Thorium

**91** 231.03688  
**Pa**  
Protactinium

**92** 238.02891  
**U**  
Uranium

**93** 237.04817  
**Np**  
Neptunium

**94** 237.04817  
**Pu**  
Plutonium

**95** 244.06422  
**Am**  
Americium

**96** 244.06422  
**Cm**  
Curium

**97** 247.07030  
**Bk**  
Berkelium

**98** 247.07030  
**Cf**  
Californium

**99** 251.07642  
**Es**  
Einsteinium

**100** 252.08302  
**Fm**  
Fermium

**101** 257.10375  
**Md**  
Mendelevium

**102** 258.10510  
**No**  
Nobelium

**103** 261.10888  
**Lr**  
Lawrencium

**Table of Selected Radioactive Isotopes**

**more flammable**

**only 8 elements are really suitable for refrigerant molecules**

**Refrigerants**

**Transitional/Service Refrigerants**

**HCFC and HFC partly chlorinated**

**HFC Chlorine free**

**"Low GWP" R134a drop in**

**Natural halogen free**

**Medium and Long Term Refrigerants**

**more toxic**

**Single fluids**

**Blends**

**Single fluids**

**Blends**

**Single fluids**

**Blends**

e.g. R22, R123, R124, R142b

R22-based: R402A, R403A, R408A

e.g. R134a, R125, R32, R143a, R152a

e.g. R404A, R507A, R407-series, R410A

e.g. Blend H, Fluid DP-1, Auto AC-1, R1234yf

e.g. R717, R290, R1270, R600a, R170, R744

e.g. R600a/R290, R290/R170, R723

3000 NORTH LINDER AVENUE, SKOKIE, ILLINOIS 60077

- ~~• Mobile Air Conditioning (HFC)~~

MAC DIRECTIVE  
2006/40/EC

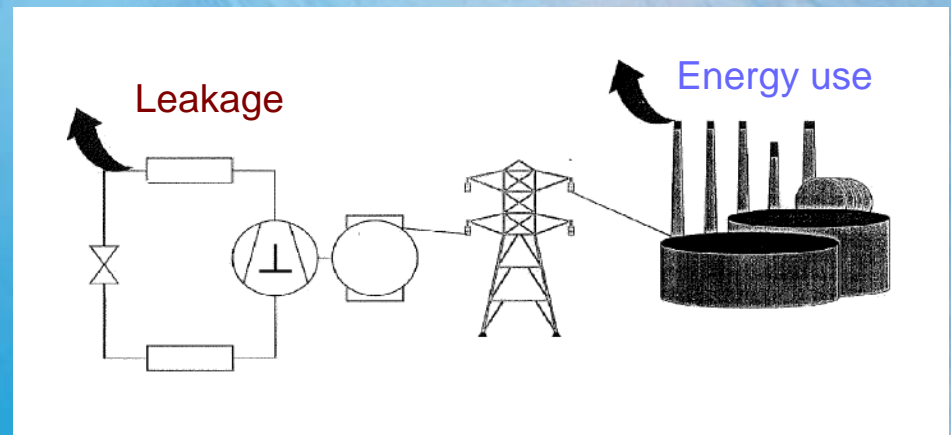
- Commercial Refrigeration  
(Supermarket DX HFC)

- Unitary Air Condition/Heat Pump (HFC)
- Commercial Air Condition (HFC)
- Light Commercial Appliance SME (HFC)
- Water Chiller (HFC)
- Domestic Refrigerator (HFC)
- Domestic Refrigerator (HC)

## GHG emissions of HVAC&R systems

Energy use for system operation  
"Indirect Emissions"

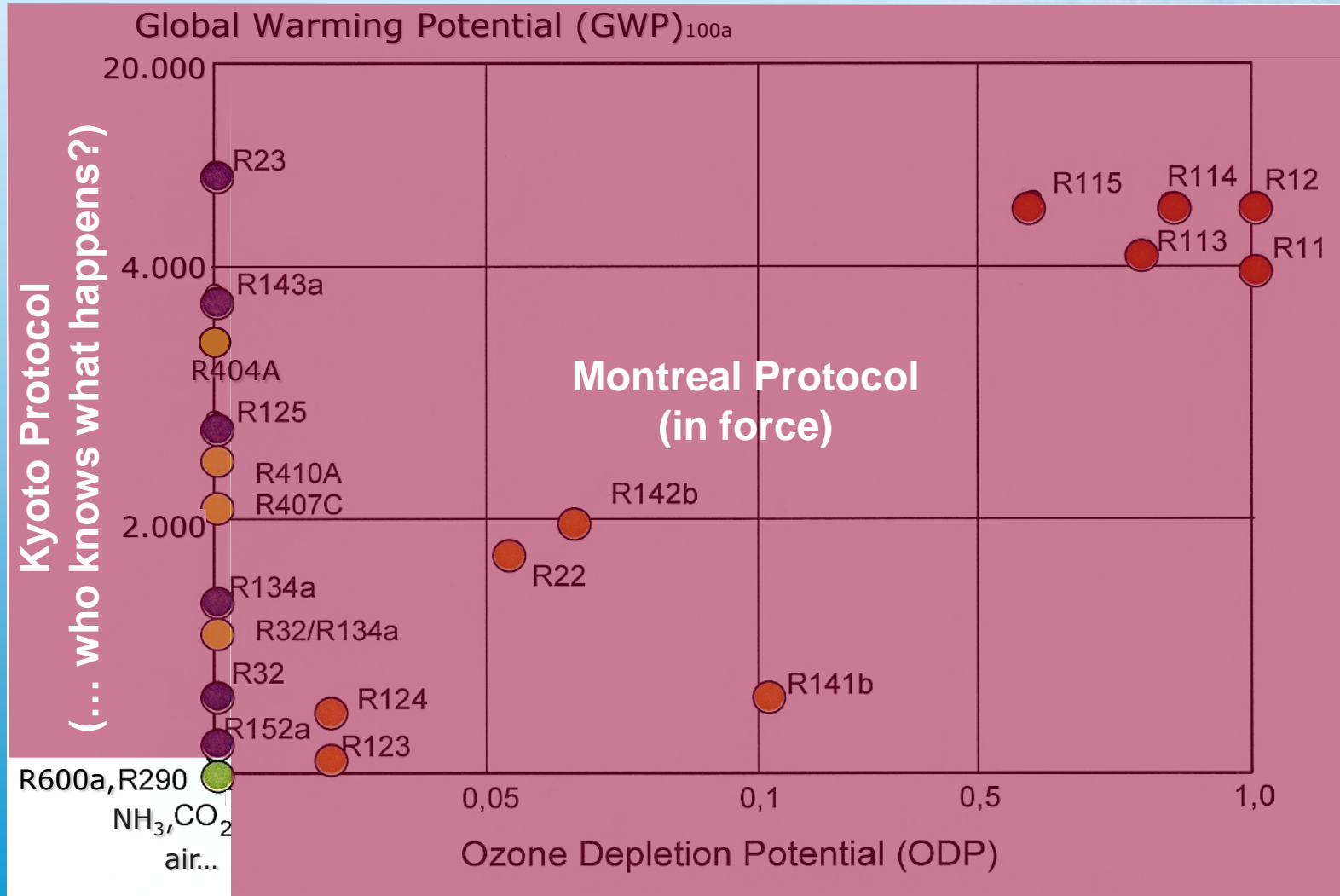
Refrigerant leakage/release  
"Direct Emissions"





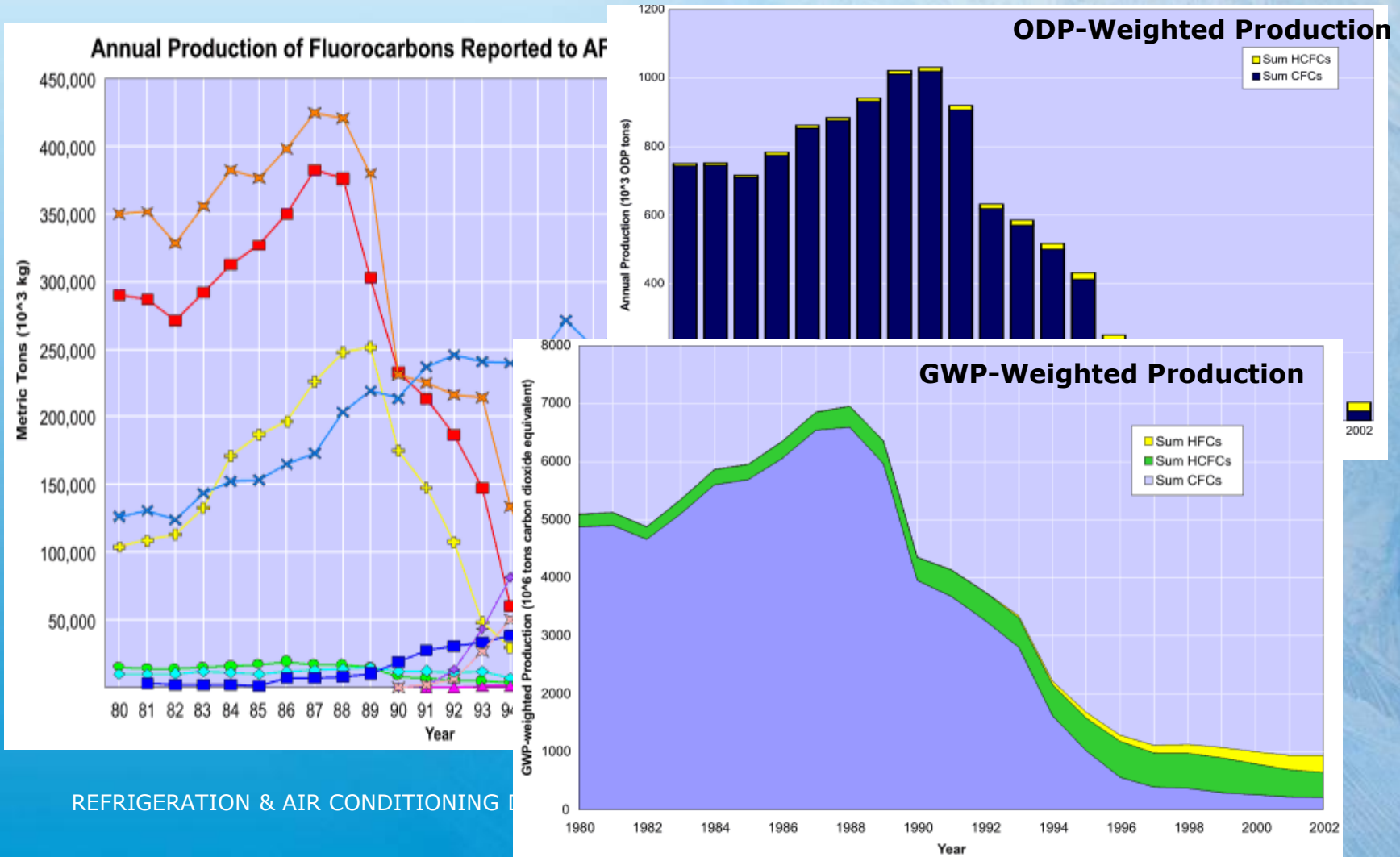


# Ozone Depletion and Global Warming



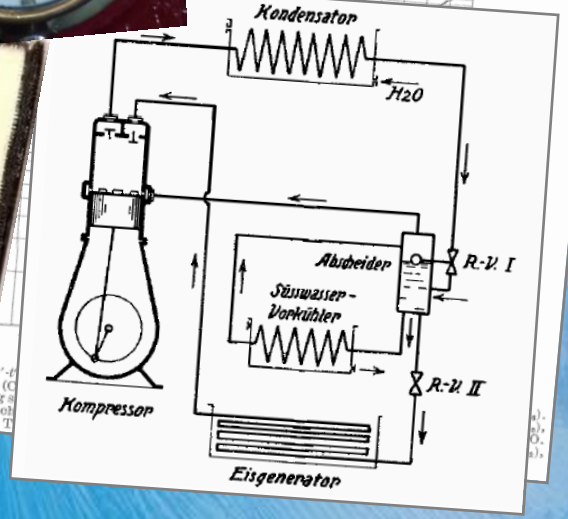
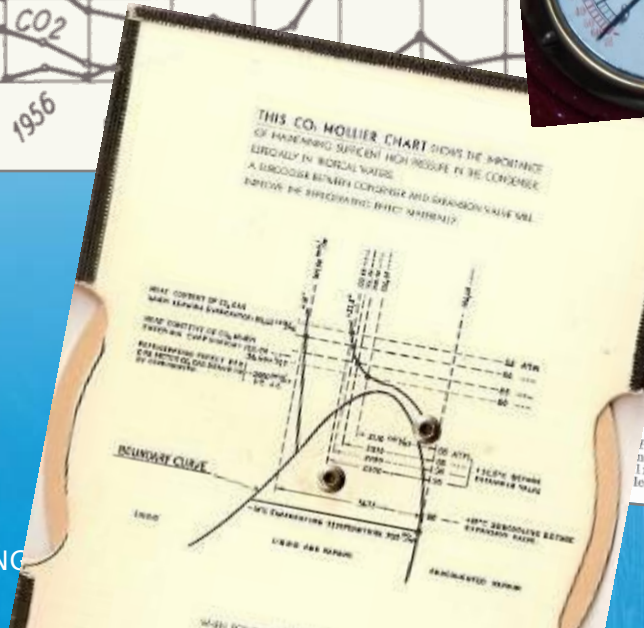
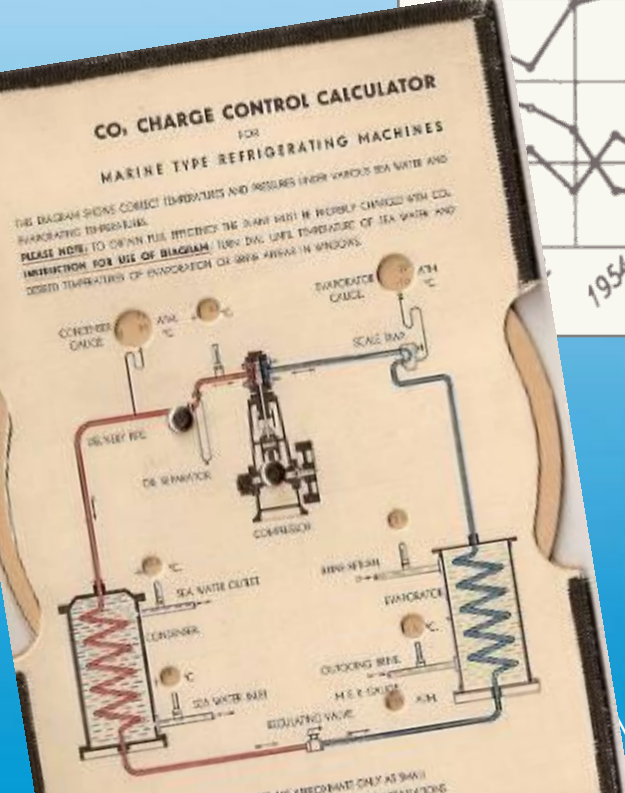
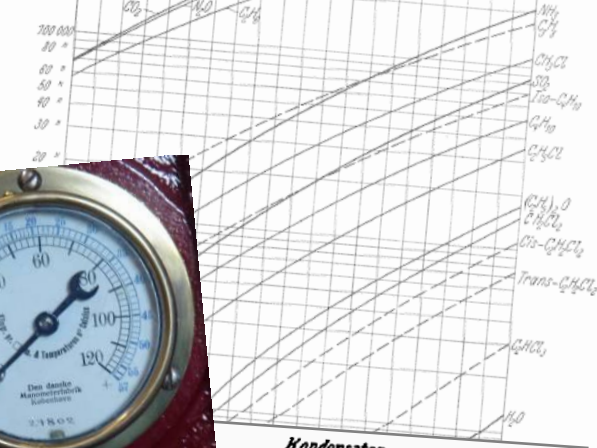
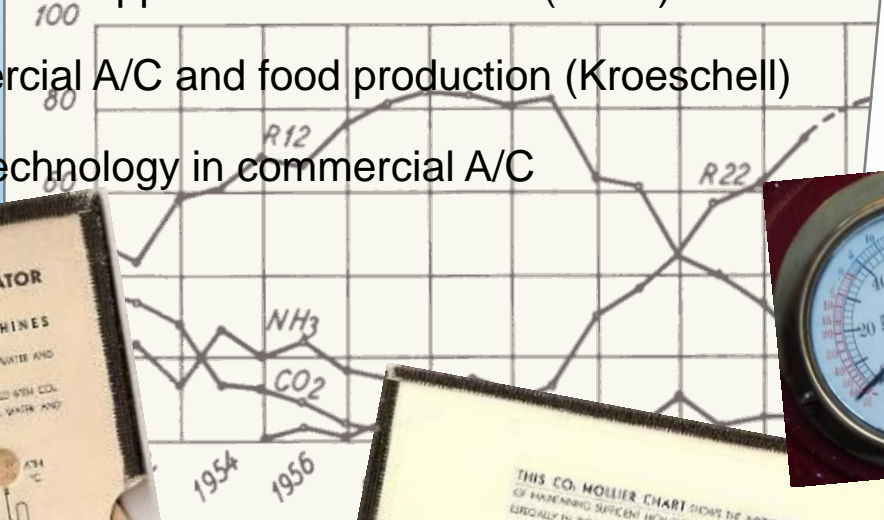


# CFC and HCFC phase-out achievements



# CO<sub>2</sub> as refrigerant in the past

- 1850 Proposal to use CO<sub>2</sub> as a refrigerant (Twinning)
- 1868 First marine applications in the USA (Lowe)
- 1890 Commercial A/C and food production (Kroeschell)
- 1915 Major technology in commercial A/C





# R744 - CO2 revival

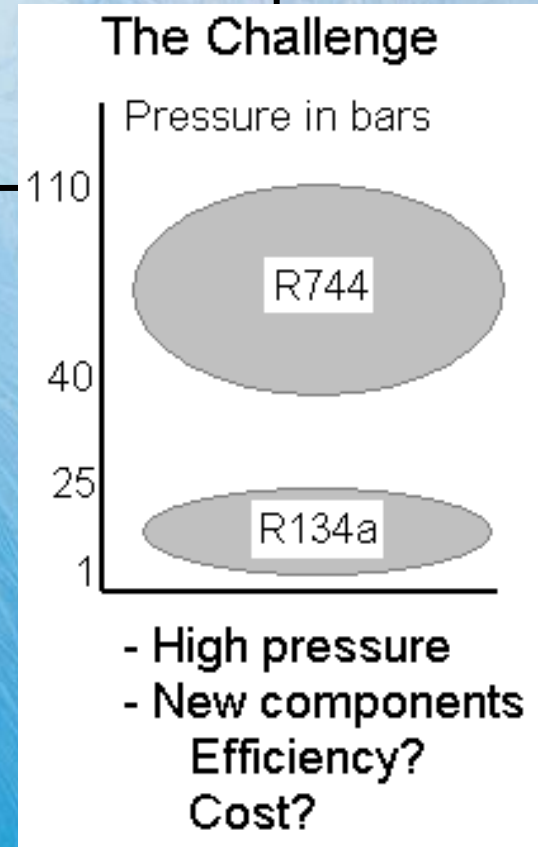
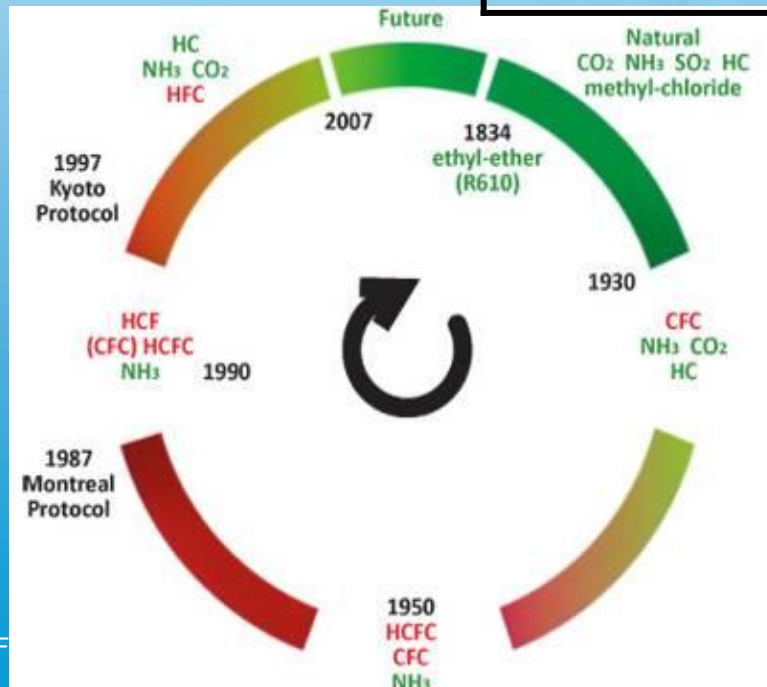
## Environment - OK

- Refrigerant phase outs
- Companies policy
- Natural substance ✓



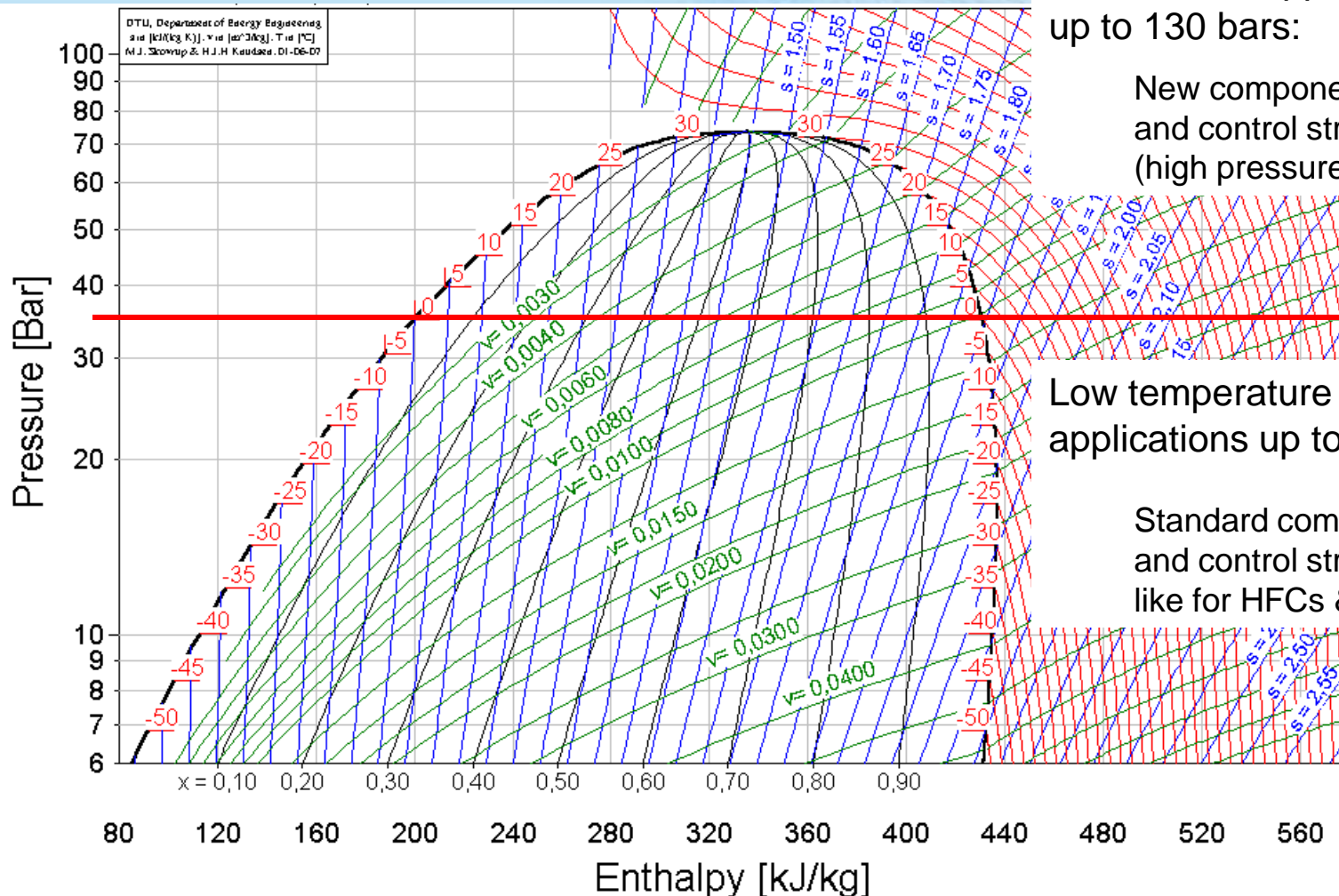
## Safety - (OK)

- High concentrations ?
- High pressure ?
- Non flammable or toxic ✓





# p,h-Diagram of CO<sub>2</sub>



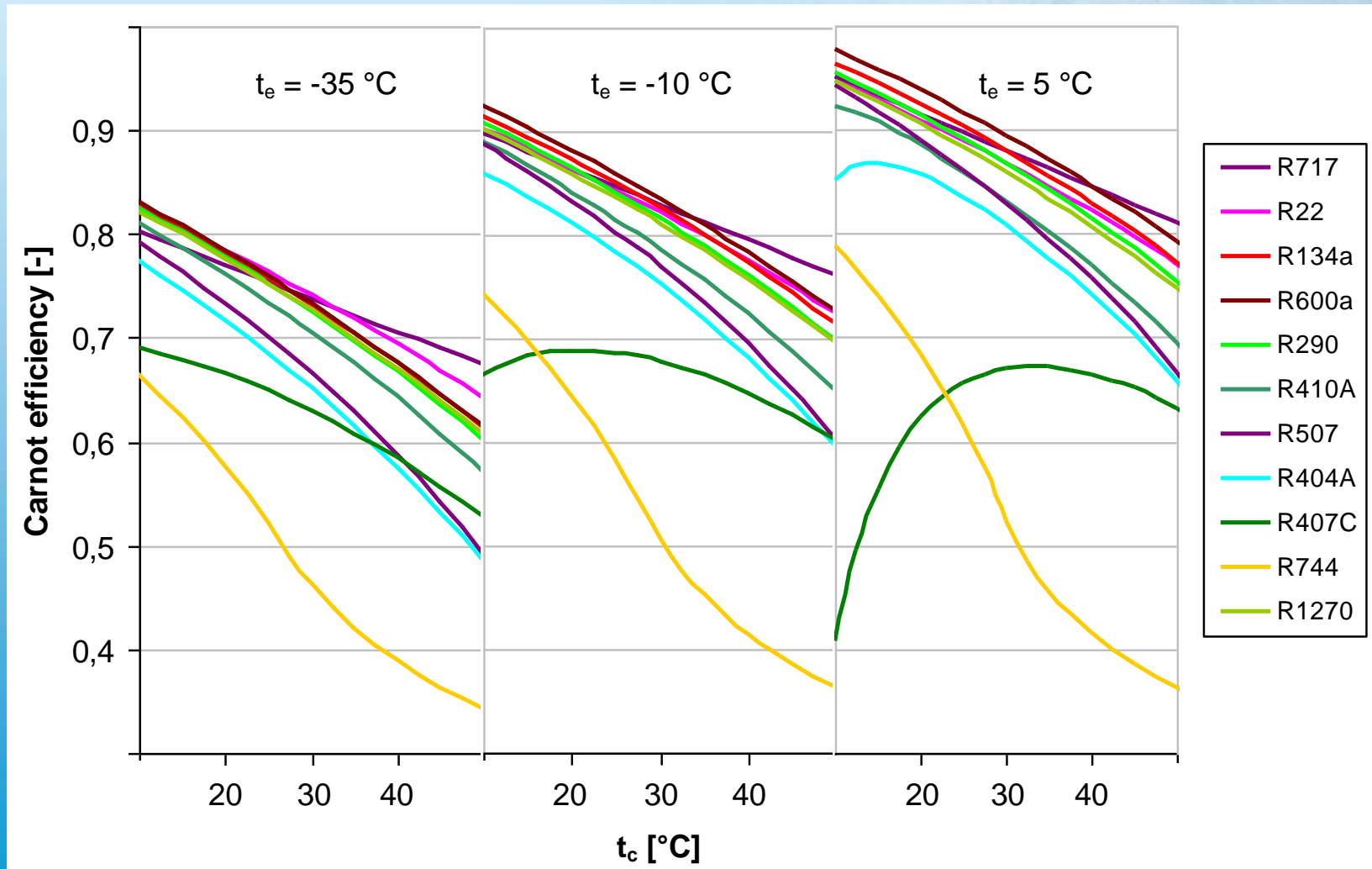
Transcritical applications up to 130 bars:

New components and control strategies (high pressure control)

Low temperature applications up to 35 bars:

Standard components and control strategies like for HFCs & HCs

# Efficiency of ideal reversed Rankine Cycle





# The Automotive case (MAC)

SAE 2009 Alternate Refrigerant Systems Symposium - Windows Internet Explorer

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SAE SAE 2009 Alternate Refrigerant Systems Symposium

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SAE 2009 Alternate Refrigerant Systems Symposium  
July 14-16, 2009  
Kona Resort Suites, Scottsdale, Arizona USA  
www.sae.org/arss

Due to the economic climate and high number of uncertainties in the marketplace, a business decision was made to cancel the 2009 Alternate Refrigerant Systems Symposium planned in Scottsdale, AZ. The next symposium will be scheduled in the June/July timeframe of 2010.

Thank you for your interest in participating in this SAE International event and understanding of our decision. Your participation in future events will be appreciated. Please continue to check the website for future plans and updates.

Emissions from man-made greenhouse gasses (GHG) and their effect on our environment are a continued concern to everyone throughout the world. As a result, the mobile air conditioning (MAC) symposium is an important forum at the tenth SAE International event.

**Status automotive case**

- Ongoing discussion since RACE project (1998)
- Aiming for one global refrigerant
- Technology choice will impact stationary refrigeration applications
- MACs not in Danfoss business scope

\* This is a .pdf file. You'll need t

ARI Automotive Refrigerant Institute PAMA Professional Automotive Manufacturers Association SAE FOUNDATION

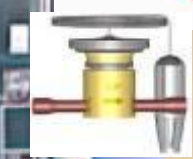
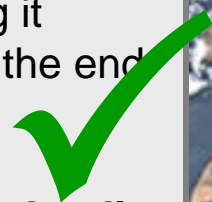
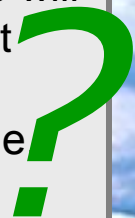
# The Bottle Cooling case (SME)

1) “By the 2004 Olympic Games in Athens, we will **no longer** purchase new cold drink equipment using **hydrofluorocarbons** wherever cost-efficient alternatives are commercially available”

2) “We will require suppliers to significantly improve the energy efficiency of the cold-drink equipment they sell to our system, making it **40-50 percent more energy-efficient** by the end of this decade.”



*Environmental policy  
for cold drink equipment,  
June 27, 2000*



**The way into the future:  
higher efficiency  
at lower cost ...**

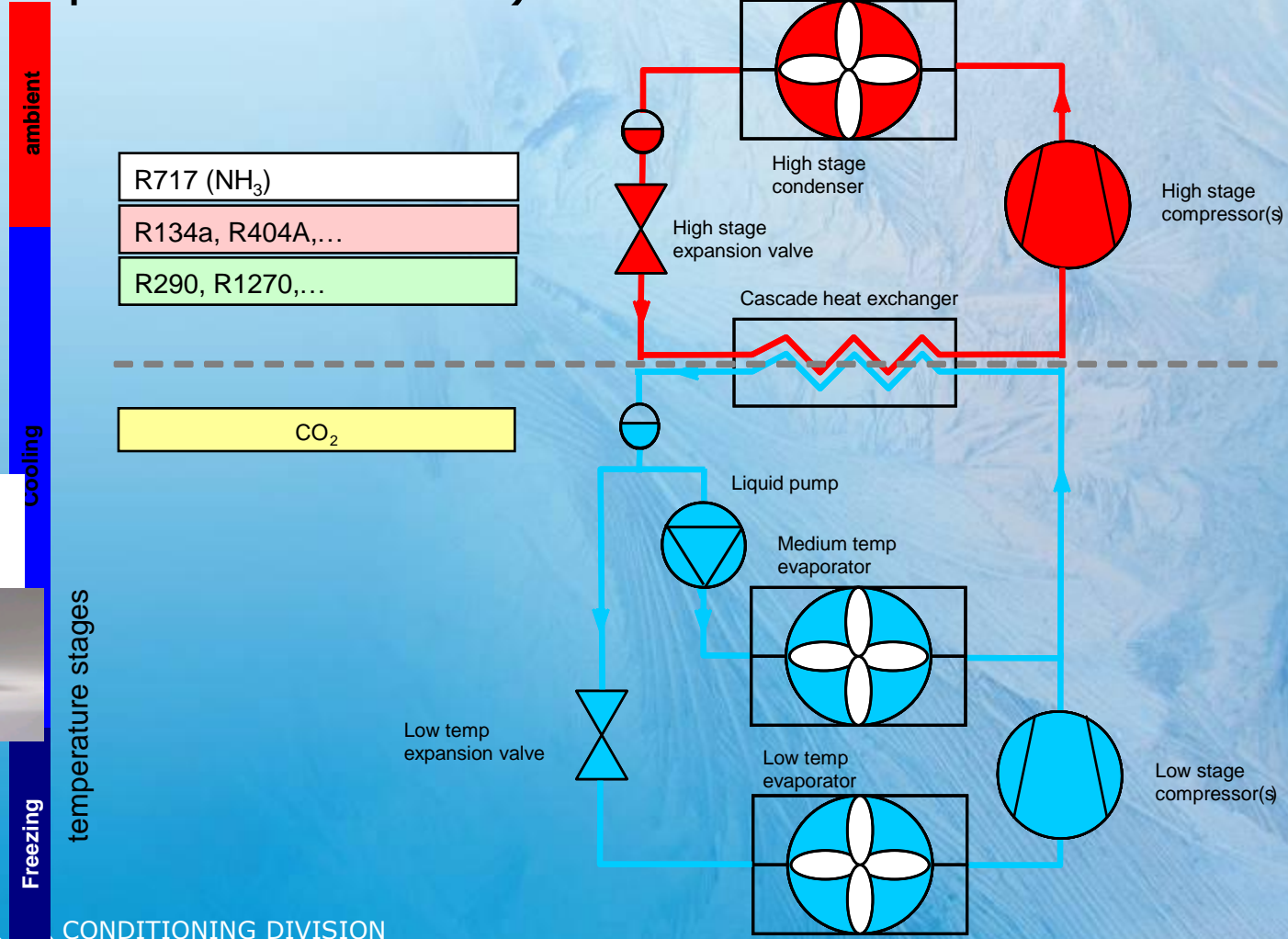




## Status Bottle Cooling (SME)

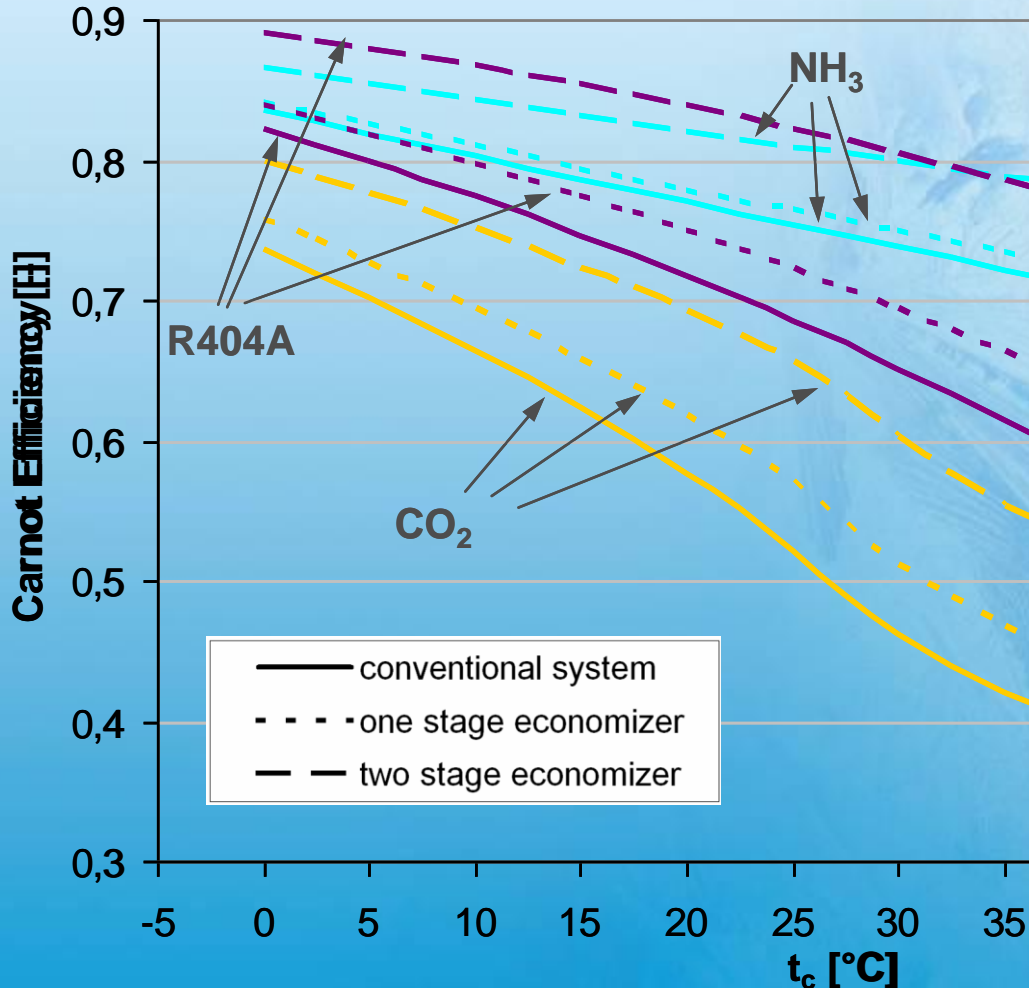
- Depending on the component selection, the system layout and the actual cooling requirement CO2 systems can be better, equal or worse than HFCs ones.
- But with increasing ambient temperature the COP of CO2 systems generally drop faster...

# Cascade system (Two temperature levels)





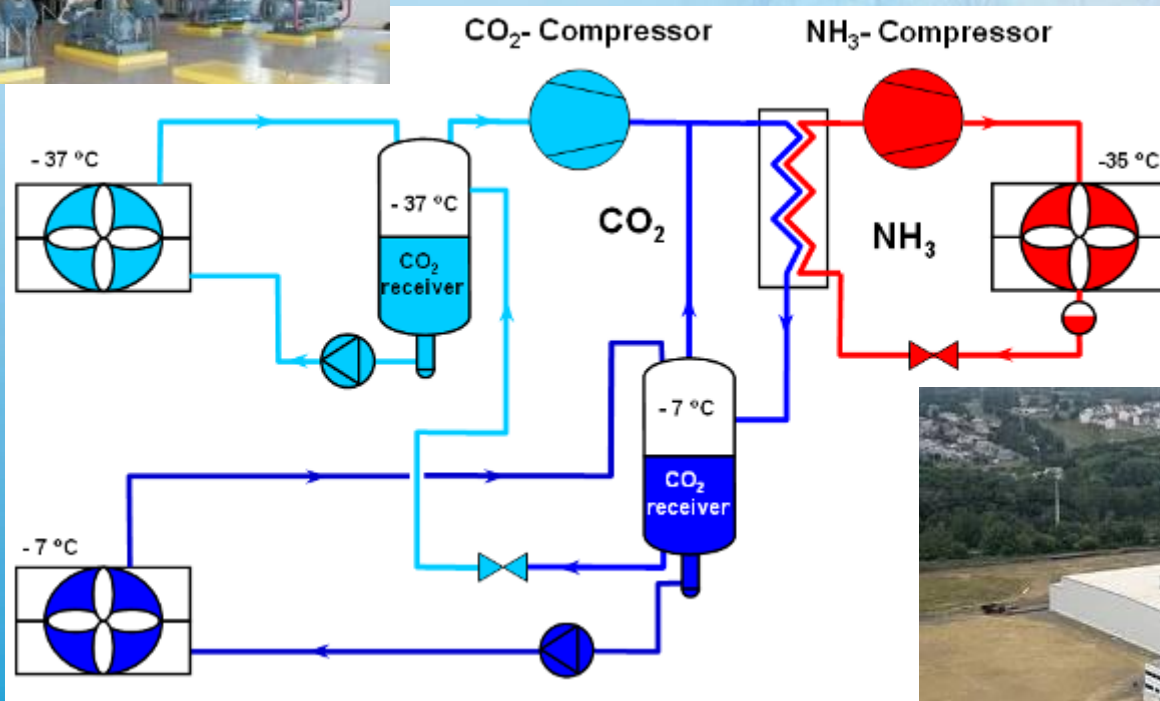
# Status Supermarket Refrigeration (FR)



- Direct GHG emission from the cooling distribution system of FR systems calls for an alternative solution
- Cooling generation with CO<sub>2</sub> has energetic drawbacks in warm climates
- Cascade systems build on state of the art technology and are globally applicable
- CO<sub>2</sub> Booster systems have a low temperature stage close to one of cascade systems
- System technology consolidation is pending



# The Industrial Refrigeration case (IR)



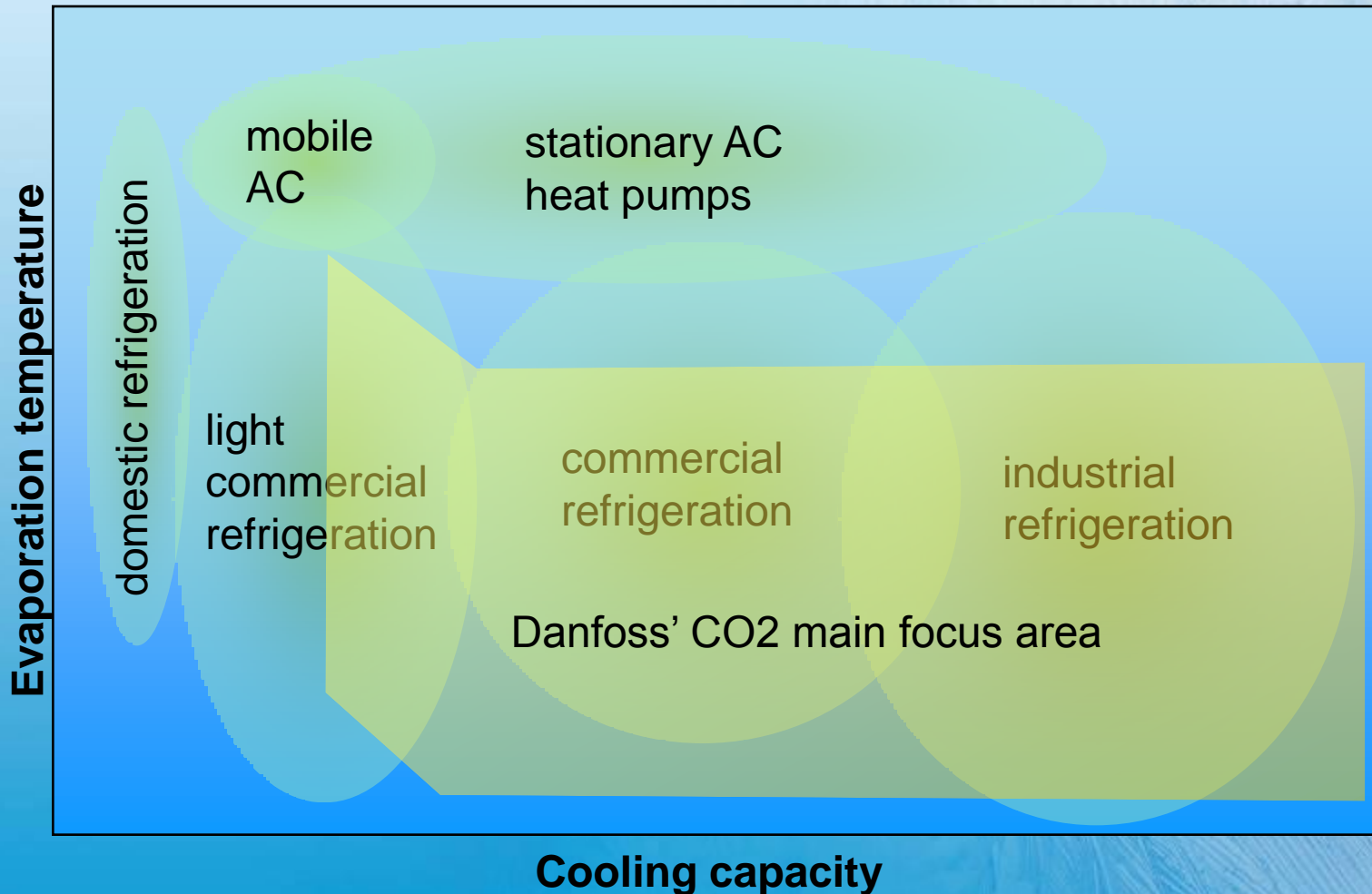
## Status Industrial Refrigeration (IR)



- State of the art technology
- Globally applicable
- Higher efficiency at lower installation cost than ammonia only systems
- Component and system knowhow available
- Ammonia charge reduction



# The refrigeration application map (again)





## Our “hit list” to minimize GHG emissions from the HVAC&R industry

1. Apply latest appropriate technologies and components
2. Service the systems to ensure optimal operation
3. Enhance and ensure energy efficient system operation by adding intelligence/electronics
4. Minimize refrigerant emissions (system layout, tightness & handling practices)
5. Minimize refrigerant charge
6. Enhance system configuration (layout)
7. Enhance component efficiency
8. Apply refrigerants with low GWP

Nobody wants to save energy,  
but everybody wants to save/make money



## The Danfoss' way to reduce GHG emissions

- Develop low charge and low leakage solutions
- Enhance significantly the system's energy efficiency e.g. by applying variable speed and enhancing component intelligence as well as Ease of Use concepts etc.
- Support the application of low GWP (natural) refrigerants where commercially viable and technical feasible



3x25

25% less CO<sub>2</sub> and  
25% more sustainable energy in  
2025

## Danfoss climate strategy - goals and ambitions

In 2025:

- the CO<sub>2</sub> emissions from factories and transport of products must be reduced by 25% compared to the level in 2007
- the share of renewable energy must be increased by 25% compared to the level in 2007