Why Natural Refrigerant Heat Pumps ?

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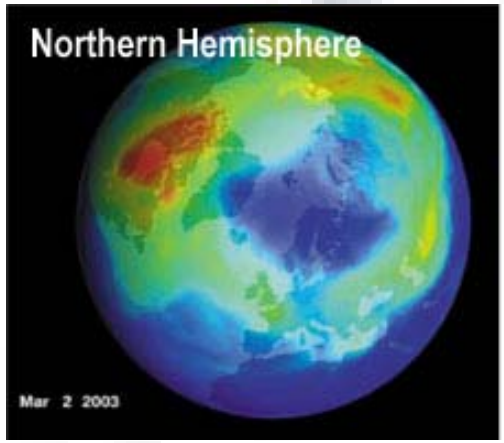
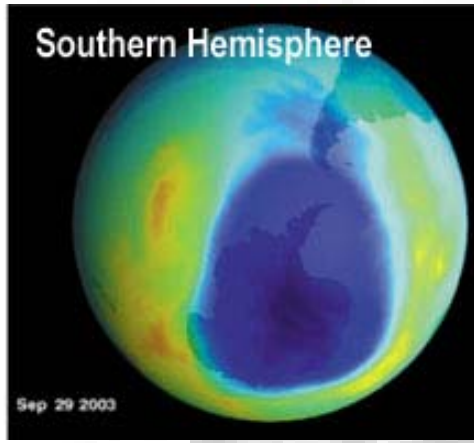
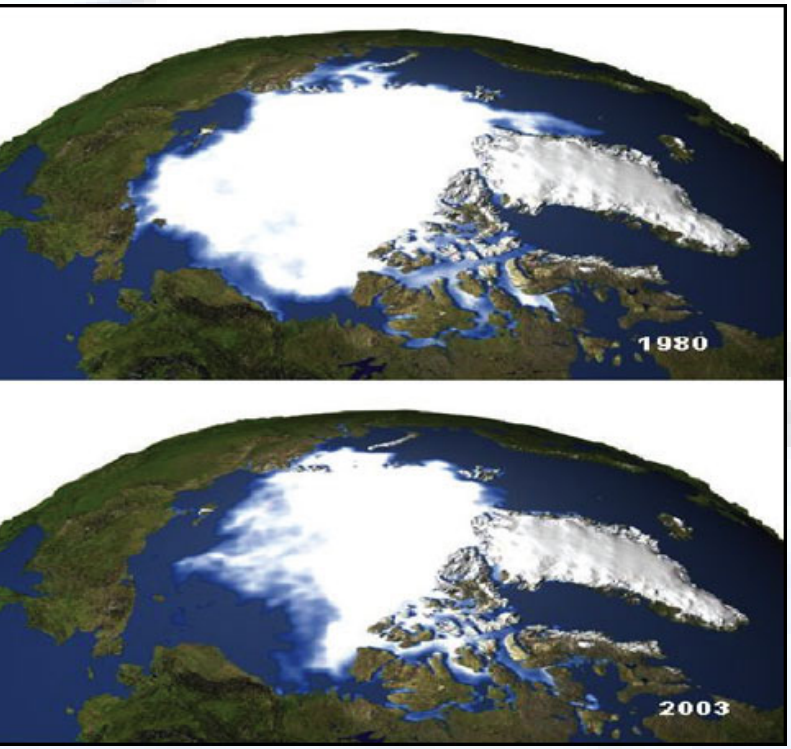
Environmental Context

The ozone hole

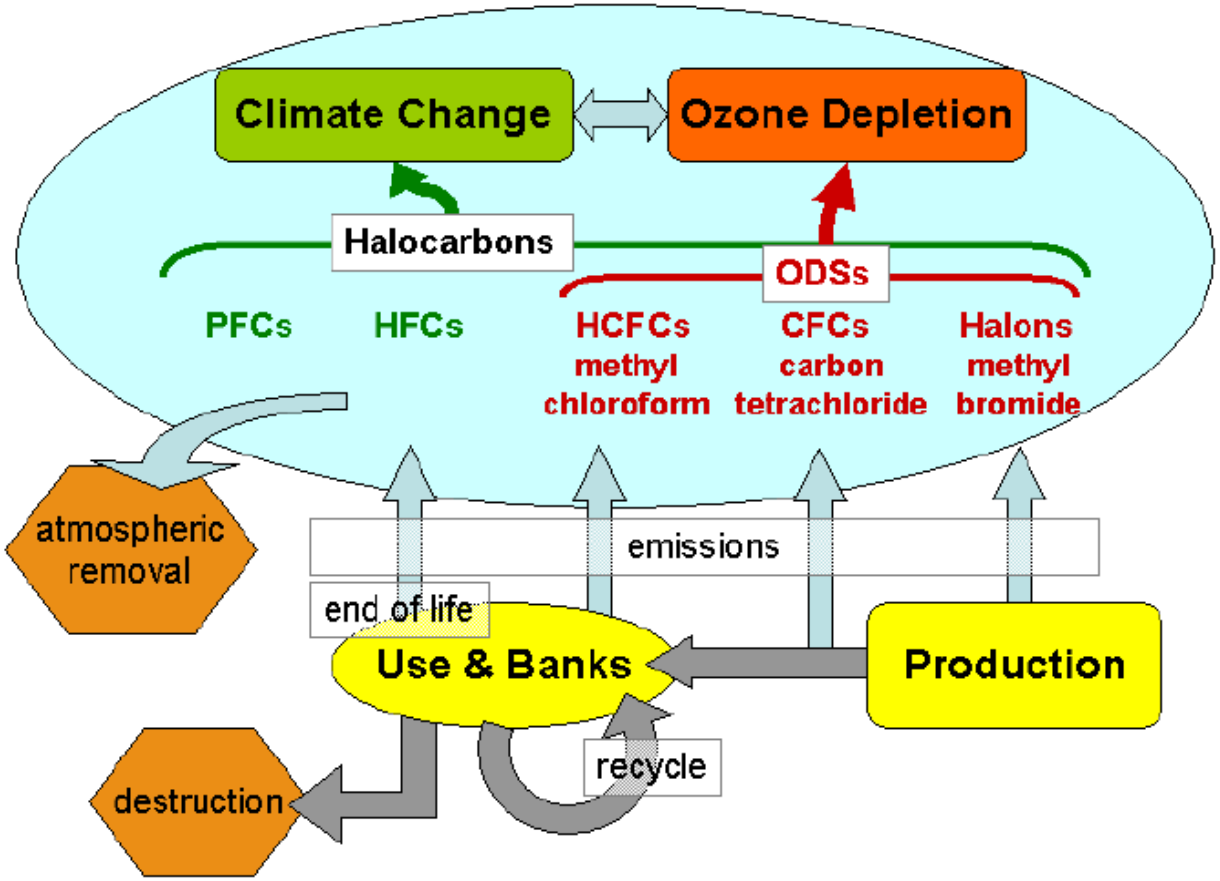






Global warming

Environmental Context



The role of artificial refrigerants

Environmental Context

- The main legislation for Ozone Depletion Substance are:
  - The Montreal protocol in 1987 and his successive amendment
  - The European directive °2037/2000 in date of 29/06/2000
- The main texts on climate change are:
  - The Kyoto protocol, adopted 10/12/1997, which entered into force 16/02/2005.
  - The EC F-gas regulation (01/02/2006)

Ozone Depleting Substances

- **The Montreal protocol:**
  - 1996 : limitation of the consumption at the country level to that of 1989 + 2.8% of the consumption of CFC in 1989.
  - 01/01/2004 : 35% reduction
  - 01/01/2010: 65% reduction
  - 01/01/2015 : 90% reduction
  - 01/01/2020 : 99.5% reduction
  - 01/01/2030 : 100% reduction
- **The European directive**
  - Banning of CFC in date of 01/01/2001
  - Interdiction of the usage of HCFC in date of 01/01/2010 and 01/01/2015 for recycled HCFC.
  - Obligation to recover CFC and HCFC in all refrigeration and air-conditioning equipments
  - Annual control of all installations having more that 3kg of fluids.
  - Minimum qualification requirement the maintenance personnel

Global Warming

- The Kyoto protocol:

  The Kyoto protocol (1997) deals with the climate change and the limitation of the emission of greenhouse gases. The developed countries involved in the protocol engaged themselves to reduce their emission of greenhouse gases by at least 5% compared to their level in 1990 during the period from 2008 to 2012.

  The Kyoto protocol has entered into force in 16/02/2005, as more than 55 countries have signed the text. The six gases concerned by the Kyoto protocol are:

  - CO2 : carbon dioxide
  - CH4 : methane
  - N2O : nitrogen oxide
  - HFC : hydrofluorocarbons
  - PFC : perfluorocarbons
  - SF6 : sulphur hexafluoride

Global Warming

- The F-Gas regulation:

  The fluids concerned by this future legislation are:

  - HFC : hydrofluorocarbons
  - PFC : perfluorocarbons
  - SF6 : sulphur hexafluoride

  For stationary applications, this regulation concerns:

  - Containment
  - Recovery
  - Training and certification
  - Reporting
  - Labelling
  - Control of use
  - Placing on the market

Global Warming

- The F-Gas regulation: Containment

Operators shall ensure that stationary refrigeration, air-conditioning and heat pump equipment containing F-gases are inspected according to following schedule

Quantity of Fluorinated gas	Periodicity
3 kg or more	At least once every 12 months
30 kg or more	At least once every 6 months
300 kg or more	At least once every 3 months

After detection and reparation of a leakage, the equipment shall be inspected for leakage within one month to ensure the effectiveness of the repair.
Operators of installation containing **300 kg or more shall install a leakage detection system**, which shall be inspected at least every 12 months to ensure their proper functioning.
Operators of equipments containing **3 kg or more of F-Gases shall maintain record of the quantity and type of fluid installed, any quantity added and the quantity recovered during servicing or maintenance.** The identification of the company or technician who performed the service or maintenance operations shall also be recorded.

Global Warming

- The F-Gas regulation:

Recovery

Operators of stationary equipment shall be responsible for putting in place arrangements for the proper **recovery by certified personnel** to ensure their recycling, reclamation or destruction.
Residual F-gases contained in refillable and non-refillable containers shall be recovered.

Training and certification

The EC shall establish **minimum requirements** and the conditions of training certification programmes for the relevant personnel.
Each member state shall establish or adapt their training and certification requirements.
The operators shall ensure that their relevant personnel have obtained the **necessary certification**.
Member states shall ensure that the company involves have the required qualification and certified personnel.

Global Warming

- The F-Gas regulation: Labelling

  In regard to the EC directive of dangerous substance and preparation, **equipments containing F-gas shall not be placed onto the market unless the fluorinated greenhouse gas is identified by a label, which clearly indicate that the equipment contains F-gas.**

?

The future for HFC's

- IPCC position
  - Refrigerant bank of 20 Gt CO2 eq. (for a 37 Gt CO2 eq. total annual emission)
  - Emphasize on containment and recycling
- The European position
  - Progressive banning of HFC for automotive applications from January 2009
  - Consensus by the major Industrial Refrigeration companies to promote 'natural refrigerants'
  - Strict legislation in some countries (Austria, Switzerland and Denmark)
  - Revision of the F-gas regulation in 2008

Natural Refrigerants

What is natural refrigerant ?

The name "natural" is used to label a number of solutions in the refrigeration and climate technology.

There are five solutions, all with a different area of application: Water, Air, Carbon Dioxide, Ammonia and Hydrocarbons.

Why natural refrigerants ?

Natural refrigerants have low or zero global warming potential.

Natural refrigerants have good transport properties and allow efficient thermodynamic cycles

Natural Refrigerants

- Hydrocarbons
  - Butane, Propane, Propylene, mixtures
  - Already used in domestic refrigerators and small AC systems
- Ammonia
  - Used in large industrial refrigeration units
- Carbon dioxide
  - Used in industrial refrigeration and as transport media
  - Under development for car AC
- Others fluids
  - Water
  - Air

Natural Refrigerants

Substance name	GWP	Code	Major hazard	Flamability	Toxicity
Carbon Dioxide	1	R744	High pressure	None	5000 ppm
Ammonia	0	R717	Toxic	15-30 vol%	25 ppm
Propane	20	R290	Fire	2.2-9.5 vol%	2500 ppm
Butane	20	R600	Fire	1.5-8.5 vol%	800 ppm
IsoButane	20	R600a	Fire	1.8-8.5 vol%	600-1000 ppm

Major information and risk concerning natural refrigerants

Natural Refrigerants

	T = 0°C				T = 40°C			
Fluid name	P bar	ρ_L kg/m^3	ρ_V kg/m^3	h_{LV} kJ/kg	P bar	ρ_L kg/m^3	ρ_V kg/m^3	h_{LV} kJ/kg
CO2	34.8	927	97.6	231	100*	1102*		1.605*
NH3	4.29	637	3.46	1262	15.5	579	12.0	1099
Propane	4.75	528	10.4	375	13.7	528	10.4	306
Isobutane	1.57	580	4.2	355	5.3	530	13.7	312

CO2 is supercritical at 40°C, properties taken at 100 bars and Cp is given in kJ/kg K

Summary of key transport properties

Natural Refrigerant Heat Pumps

- Hydrocarbons
  - Similar operating conditions
  - Minimise fluid inventory for safety
  - Adapt compressor and lubricant
- Ammonia
  - Low mass flow-rate
  - Minimise fluid inventory for safety
  - Change components (no copper)
- CO2
  - Transcritical cycle
  - High pressure
  - Change components and control

Hydrocarbon heat pumps

air-air reversible heat pump (Delonghi)

ground-water heat pump (Neura)

air-water heat pump (Dimplex)

CO2 heat pumps

air-water heat pump water heater (Sanyo)

air-water heat pump water heater (Carrier)

water-water hea pump (Sintef)

NH3 heat pumps

17 kW water-water heat pump prototype (HSR)

2MW sea water-water heat pump (city of Bodo)

Conclusions

- The use of F-Gas will be more complicated and will induce extra costs
- F-gas might be banned in Europe ?
- Natural refrigerants have large potential for small to large heat pumps
- Developments are required to optimise such heat pumps