Refrigerant Issues
Refrigerant emissions, how important are they?

Petter Nekså
SINTEF Energy Research, Trondheim, Norway
Petter.Neksa@sintef.no

SINTEF location, Trondheim, Norway

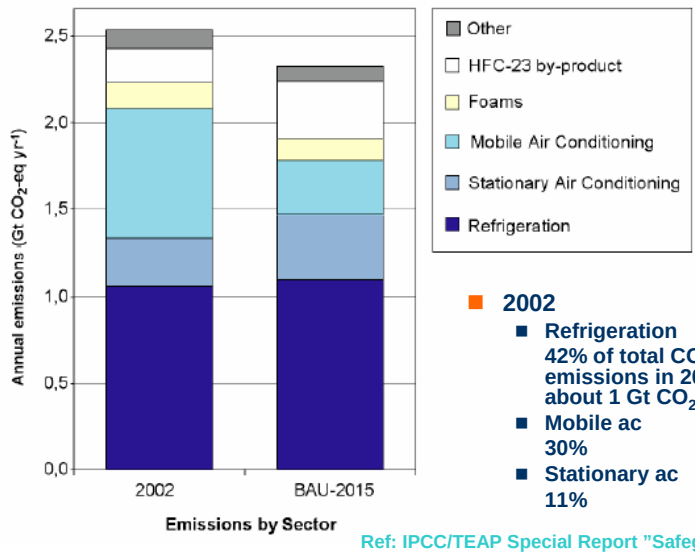
SINTEF does contract research for national and international clients

We work in close collaboration with the Norwegian University of Science and Technology (NTNU)

Outline

- Emission overview
- What options are there for reduction of direct GHG emissions?
- What are the implications of efficiency and cost?
- Example commercial refrigeration
  - German Harnish
  - IPCC
- Example mobile ac
- Example heat pump water heaters
- How will the boundary conditions influence?
- Concluding remarks

Share of Halocarbon Emissions by Sector



- **2002**
  - **Refrigeration 42% of total CO_2-eq emissions in 2002, about 1 Gt CO_2-eq/y**
  - **Mobile ac 30%**
  - **Stationary ac 11%**

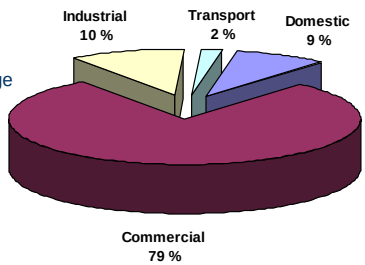
Ref: IPCC/TEAP Special Report "Safeguarding the…, 2005

Options to reduce direct GHG emissions

- **A more wide-spread use of non-HFC refrigerants with reduced or no GWP**
- **Leak-tight systems, improved containment**
- **Reduced refrigerant charge per unit of cooling capacity**
- **Recovery of refrigerant during service and end of life**
- **Reduced refrigeration capacity demand**
- **Not-in-kind technologies**

Different Applications within the Refrigeration Sector
Characteristics and Share of Direct Emissions

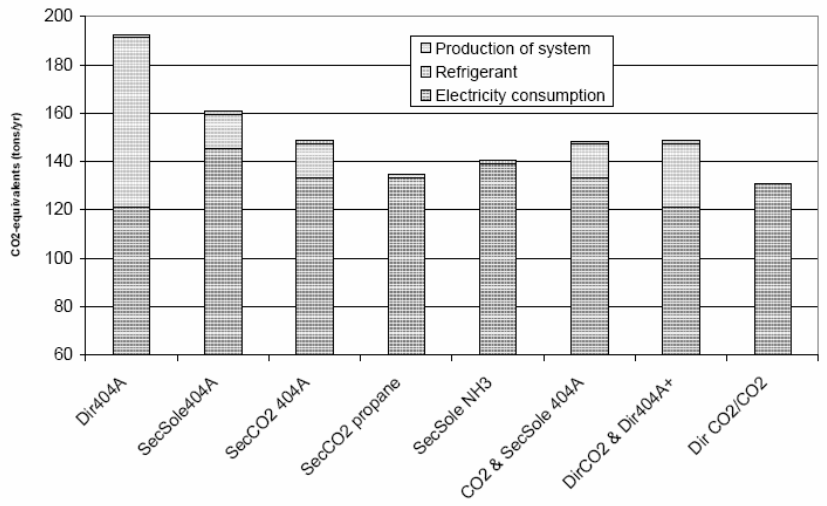
- Industrial
  - Industrial refrigeration, food prosessing and cold storage
  - Annual refrigerant emissions 17% of banked system charge
  - NH_3 and HCFC-22 dominating refrigerants, NH_3 and CO_2 increasingly used
- Transport
  - Transport refrigeration systems on road, rail, sea and air
  - Relatively high emissions, 25-35% of banked system charge annually
  - CFC, HCFC and HFC refrigerants dominate. To a less extent non-HFC refrigerants, NH_3, CO_2 and HCs, are being used
- Domestic
  - Refrigerators and freezers for domestic use
  - Relatively low emissions and long life time (6% of banked system charge annually, lifetime 20 y)
  - HFC-134a and Isobutane (HC-600a)
  - Indirect emissions (energy efficiency) important
- Commercial
  - Stand-alone, condensing units and full supermarket systems
  - High emission rates, 30% of banked system charge annually
  - CFC, HCFC and HFC refrigerants dominate, but non-HFC refrigerants has been introduced (NH_3, CO_2 and HCs)



Refrigeration Sector
Share of Direct Emissions

Ref: IPCC/TEAP Special Report "Safeguarding the…, 2005

Annual GHG emissions for supermarkets in Germany
Case study by Harnish et al., 2003



Ref: Harnish et al, Risks and benefits using fluorinated..., 2003

Emission reduction and mitigation cost for supermarkets in Germany
Case study by Harnish et al., 2003

	Emission reduction in comparison to reference [%]	Specific mitigation cost [€ / t CO_2]
Direct evaporation HFC-404A (reference)	0	reference
Secondary sole system with HFC-404A	16	246
Secondary CO_2 system with HFC-404A	23	130
Secondary CO_2 system with propane	30	113
Secondary sole system with ammonia	27	162
Direct CO_2 evaporation system for freezing and secondary sole loop for HFC-404 a in refrigeration	23	88
Direct CO_2 evaporation system for freezing and direct evaporation HFC-404A for refrigeration	23	19
Supercritical CO_2 direct evaporation for refrigeration and freezing	32	52

Ref: Harnish et al, Risks and benefits using fluorinated..., 2003

Assumptions for case study of for supermarkets in Germany

Case study by Harnish et al., 2003

	Direct evaporation HFC-404A (reference case)	Secondary carrier loop system with sole and HFC-404A in the primary cycle	Secondary carrier loop with CO2 and HFC as the primary refrigerant	Secondary carrier loop system with CO2 and propane as primary refrigerant	Secondary carrier lop system with sole and ammonia as primary refrigerant	Direct evaporation system with CO2 for freezers and a HFC-404A secondary carrier loop system with HFC-404A as primary refrigerant for refrigeration	Direct evaporation of CO2 for freezers and direct evaporation HFC-404A for refrigeration	Direct evaporation of CO2 for both freezers and refrigerators (supercritical)
Electricity consumption	100	120	110	110	115	110	100	108
Incestment cost	100	120	115	120	127,5	110	102	110
Maintenance cost	100	200	200	200	200	150	125	125
Leakage rate of refrigerant	100	100	100	20	20	100	75	100
Refrigerant density	100	20	20	10	10	20	50	50
Material density	100	150	140	150	160	120	100	100

Ref: Harnish et al, Risks and benefits using fluorinated…, 2003

LCCP- Annual GHG emissions for supermarkets with world average as baseline

Case study by IPCC/TEAP Special Report, 2005

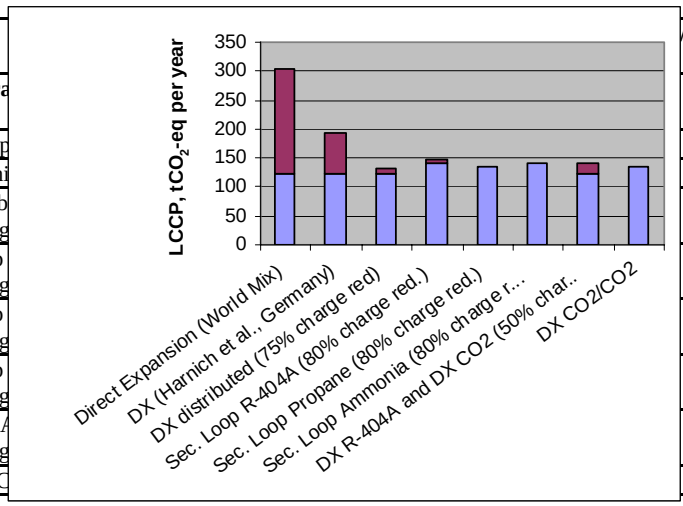
	Refrigerant Emissions	Energy	LCCP, in tCO_2-eq./yr		
Configuration	**% of charge/yr**	**Consumption**	**Indirect**	**Direct**	**Total**
Direct Expansion (DX)	30%	baseline	122	183	305
DX (Harnisch et al. data)	11.5%	baseline	122	70	192
DX distributed 75% charge reduction	6.5%	baseline	122	10	132
Sec. Loop R404A 80% charge reduction	6.5%	baseline + 15%	140	8	148
Sec. Loop propane 80% charge reduction	6.5%	baseline + 10%	134	0	134
Sec. Loop ammonia 80% charge reduction	6.5%	baseline + 15%	140	0	140
DX R404A and DX CO_2 50% charge reduction	6.5%	baseline	122	20	142
DX CO_2/CO_2	11.5%	baseline + 10%	134	0	134

Ref: IPCC/TEAP Special Report "Safeguarding the…, 2005

LCCP- Annual GHG emissions for supermarkets with world average as baseline

Case study by IPCC/TEAP Special Report, 2005

Configura	/yr Total
Direct Exp	305
DX (Harni	192
DX distrib 75% charg	132
Sec. Loop 80% charg	148
Sec. Loop 80% charg	134
Sec. Loop 80% charg	140
DX R404A 50% charg	142
DX CO_2/C	134



Ref: IPCC/TEAP Special Report "Safeguarding the..., 2005

LCCP- Annual GHG emissions for supermarkets with world average as baseline

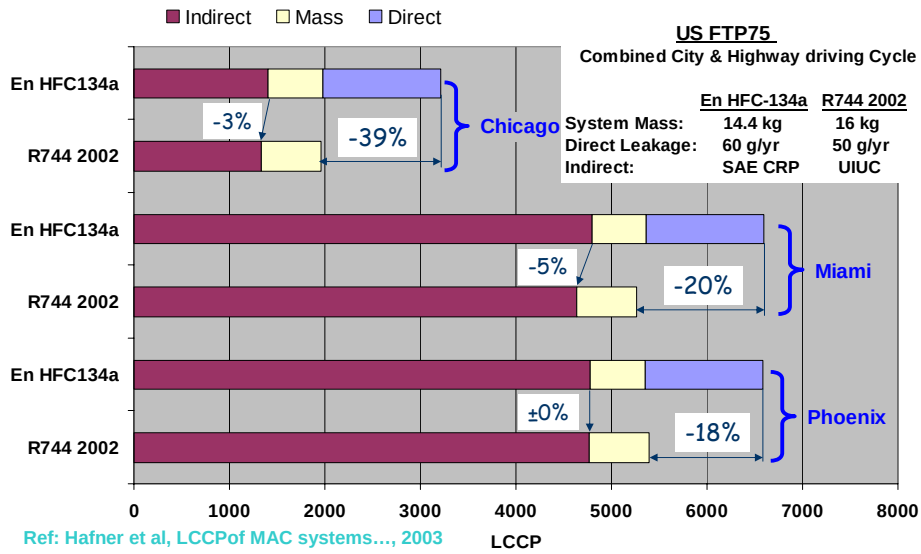
Case study by IPCC/TEAP Special Report, 2005

Configura	/yr Total

- In full supermarket systems, up to 60% lower LCCP values can be obtained by applying direct expansion systems using alternative refrigerants, improved containment, distributed systems, indirect systems or cascade systems.
- Mitigation cost was found to be in the range of 20 to 280 US$/t$CO_2$-eq
- Improved energy efficiency may also lead to negative mitigation costs

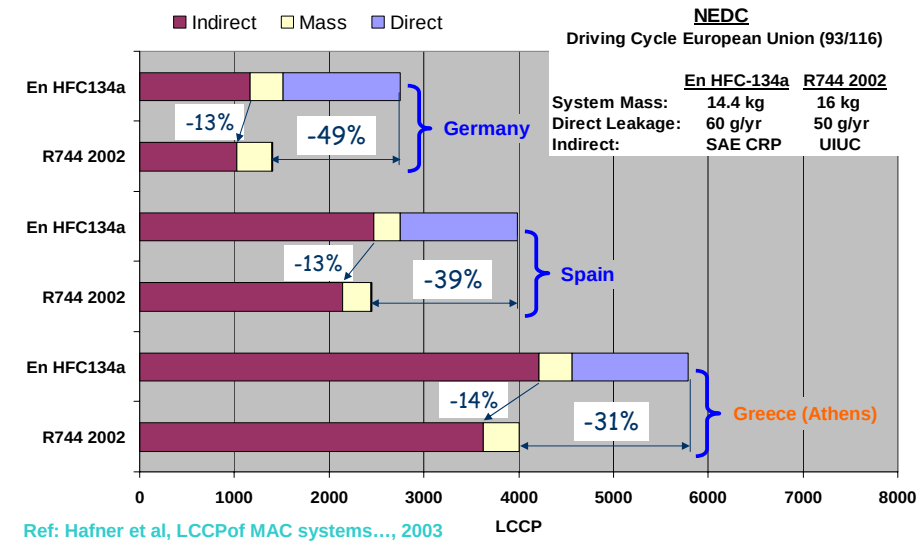
Ref: IPCC/TEAP Special Report "Safeguarding the..., 2005

LCCP comparison Mobile Air Conditioning
En HFC-134a versus *2002* R-744
US locations & US FTP75



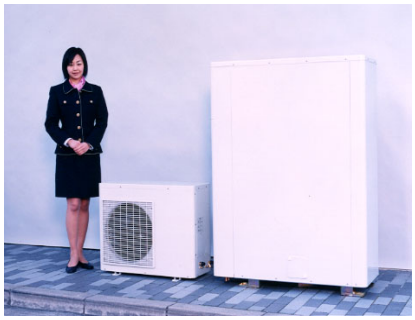
Ref: Hafner et al, LCCPof MAC systems..., 2003

LCCP comparison Mobile Air Conditioning
En HFC-134a versus *2002* R-744
European locations & NE-Driving Cycle



Ref: Hafner et al, LCCPof MAC systems..., 2003

Possibilities to reduce GHG emissions by use of heat pumps
Example- CO_2 Heat Pump Water Heaters



- **Ambient air as heat source**
- **4.5 kW heating capacity**
- **85°C DHW temperature**
- **The first commercialized CO_2 heat pump – the model has been replaced by the so called "EcoCute"**
- About 120.000 sold in the Japanese market in 2004
- Several manufacturers

LCCP figures, the influence of boundary conditions

- Power production GHG emissions (CO_2)
  - Vary from country to country, may be almost zero
  - Trend towards more efficient power production and CO_2-free solutions
- Cost of emission mitigation
  - What are the cost of containment?
  - How will cost of new technology develop?
- Energy efficiency
  - Improved energy efficiency
- Developing countries
  - Direct conversion from CFC to non-HFC refrigerants possible

Concluding remarks

- There is a large potential for reducing GHG emissions from direct emissions, especially from some applications
- Several alternatives exists, also long term solutions
- With more efficient power production, the relative importance of direct emissions will increase
- With increasing focus on greenhouse gas emission reductions, regulations on the use of HFC chemicals may be expected, possibly followed by phase-out targets and dates as announced by some European countries.