Swedish contribution to Annex 54

Björn Palm
Royal Institute of Technology,
Stockholm, Sweden

Introduction

- Several research projects have been running in parallel related to low-GWP refrigerants during Annex 54
- This presentation will also include market development and outlook for the future

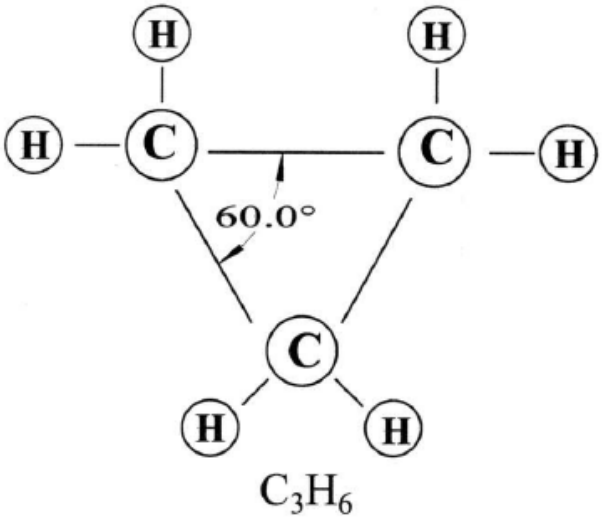
Research highlights

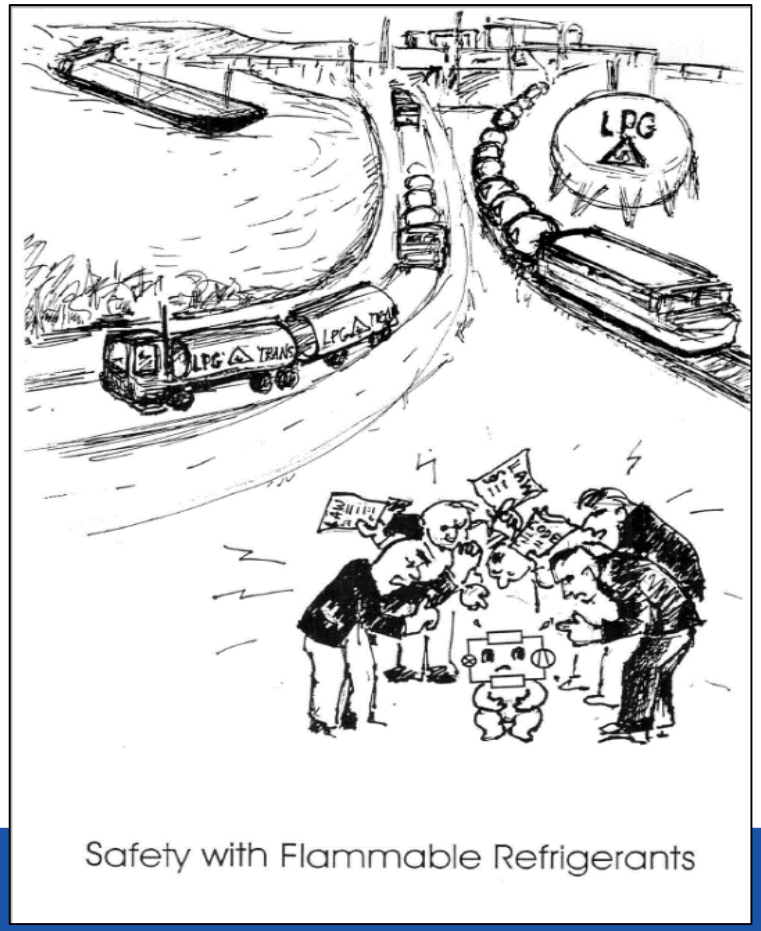
Research on hydrocarbons started 1995

Some old topics 1995 - 2018:

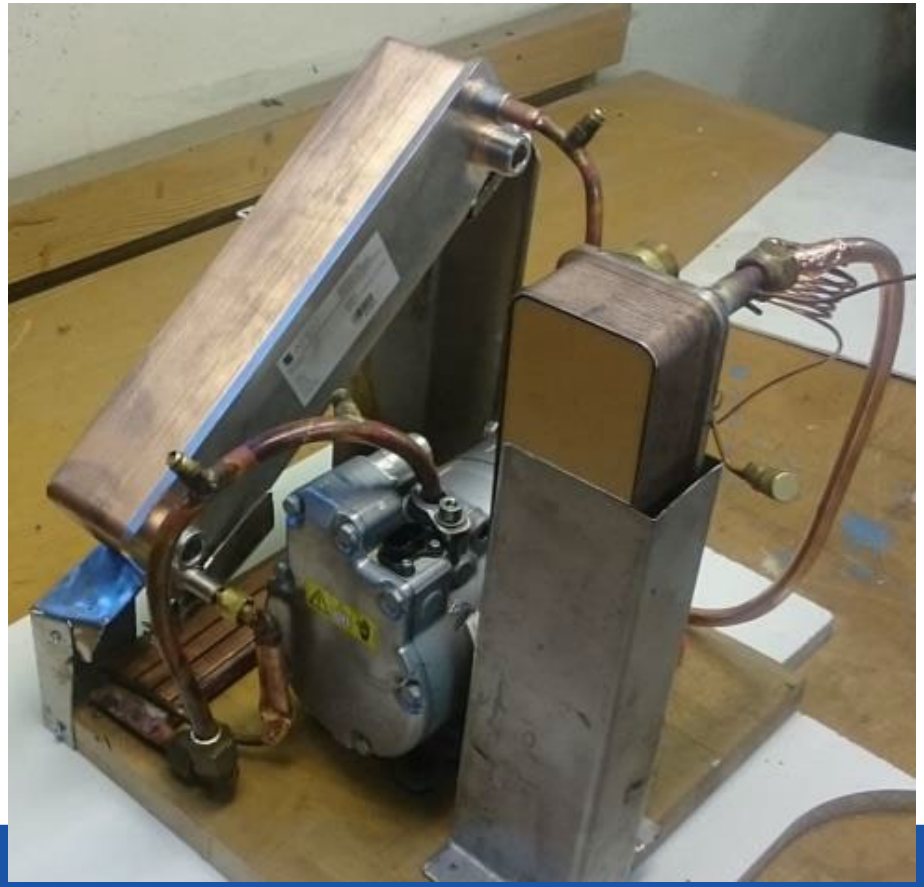
- Propane vs R22 in heat pumps
- Propane heat transfer in plate heat exchangers
- Cyclopropane as refrigerant in refrigerators
- Safety with flammable refrigerants in domestic hp
- Low GWP blends to replace R22
- High temp heat pumps with low GWP refrigerants
- Domestic CO2 heat pumps
- Performance of low GWP heat pumps vs R22 and R134a
- Domestic ammonia heat pump

Cyclopropane





Low-charge propane heat pump



EU-projects with Swedish participation

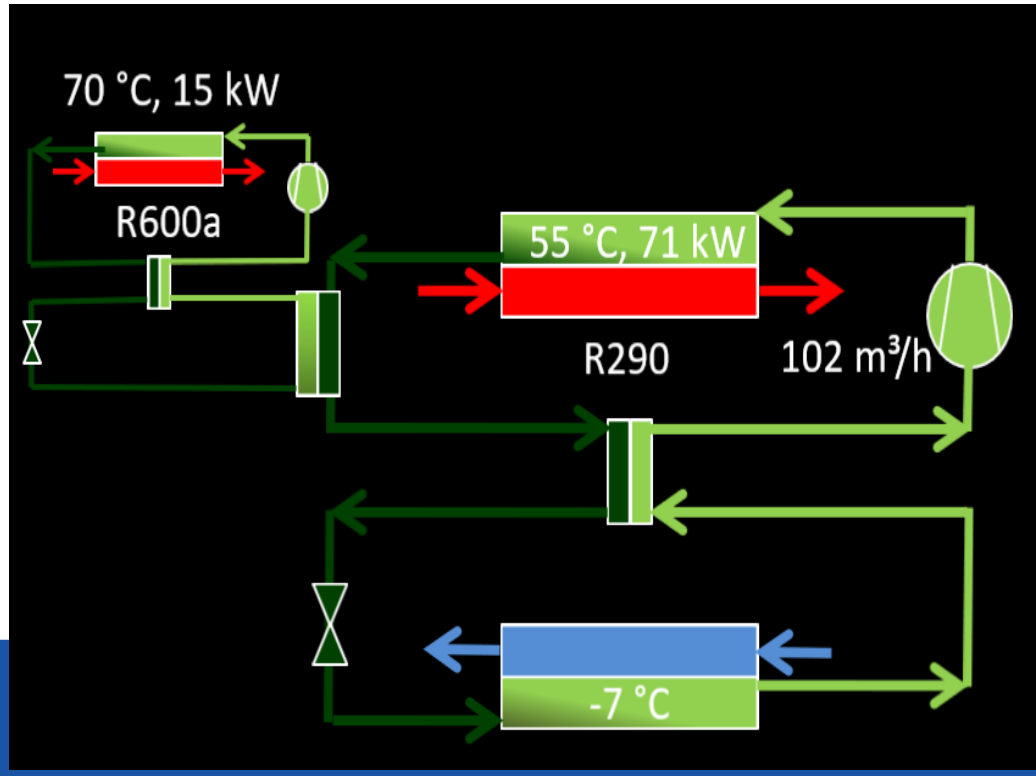
- SHERHPA 2004 – 2007: Domestic ammonia heat pump
- NARECO2 2007 – 2009: Educational material for CO2 refrigeration
- GreenHP 2012 – 2016: Propane hp for multi-family houses
- NXTHPG 2012 – 2016: Low charge propane hp for multi-family houses

Research on charge reduction

ECO-Pack, economizer hp with isobutane

- Small hp using subcooling of larger hp as heat source
- Could provide domestic hot water at high temp
- Built for small charge
- 12 kW with 150g

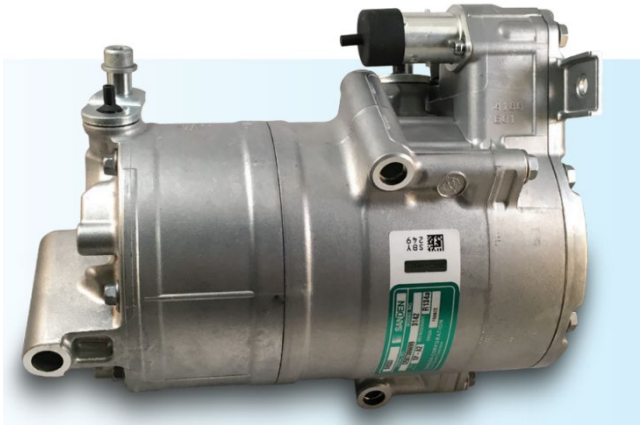
- Presented at GL conf

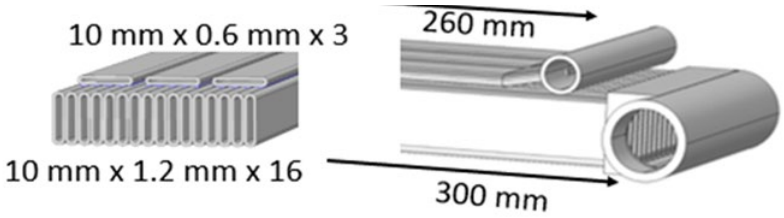


ECO-Pack, economizer hp with isobutane

- Small hp using subcooling of larger hp as heat source
- Could provide domestic hot water at high temp
- Built for small charge
- 12 kW with 150g

- Presented at GL conf





PROPACK – Air to air split AC system

- 3.5 kW cooling
- Goal of 150 g propane, not quite reached
- Interesting component development (hx, compressor)

900 g R32

607 kg CO_2

Target

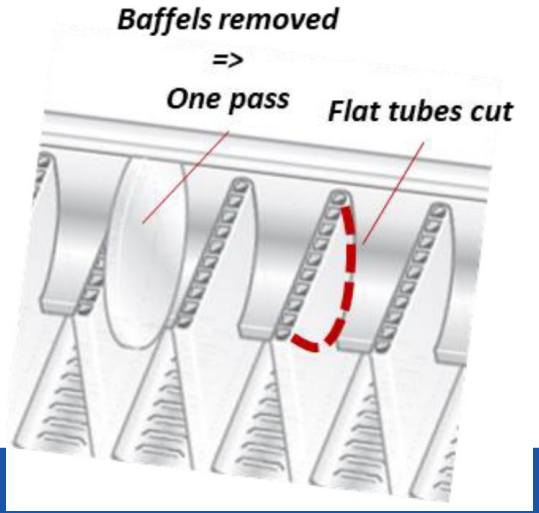
12 kBTU/h ~ 1 ton ~ 3.5 kW

150 g R290

0,45 kg CO_2

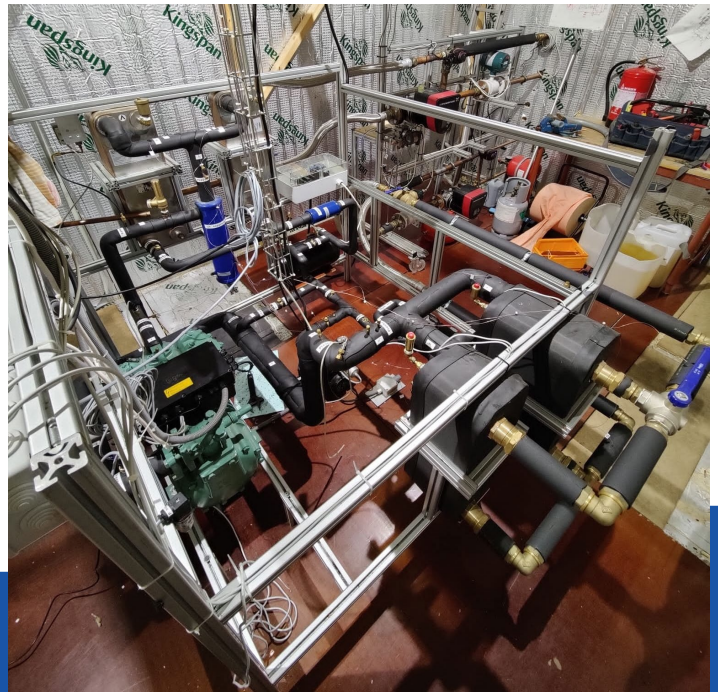
PROPACK – Air to air split AC system

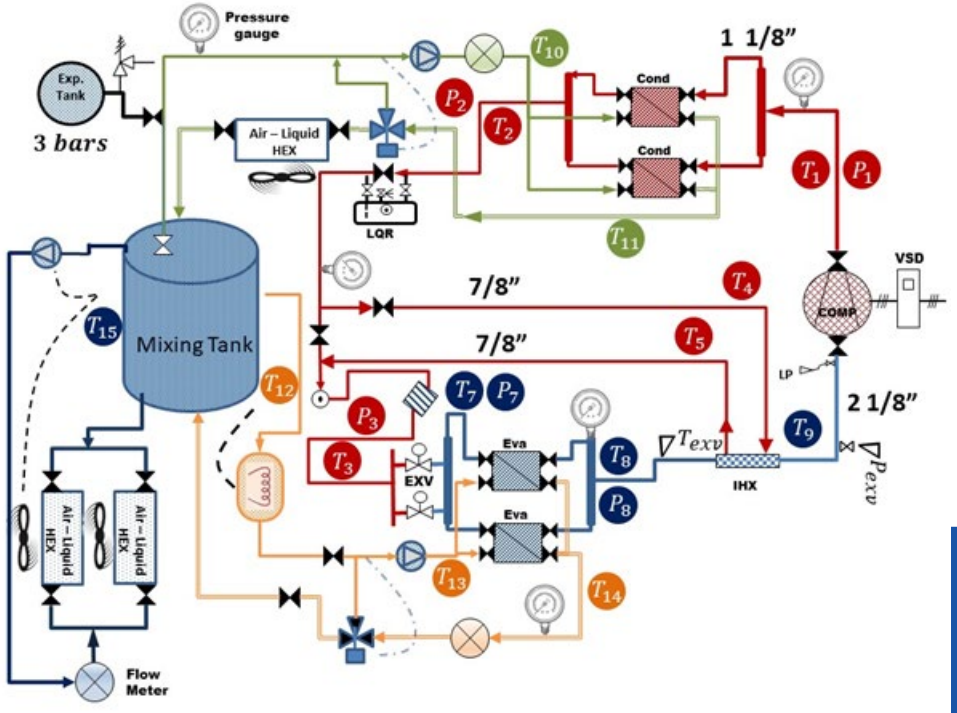
- 3.5 kW cooling
- Goal of 150 g propane, not quite reached
- Interesting component development (hx, compressor)



Low GWP refrigerants for high temp hp

- Focus on oils with different refrigerants
- Temps up to 120C
- Hydrocarbons and synthetic refrigerants considered
- Project still running…



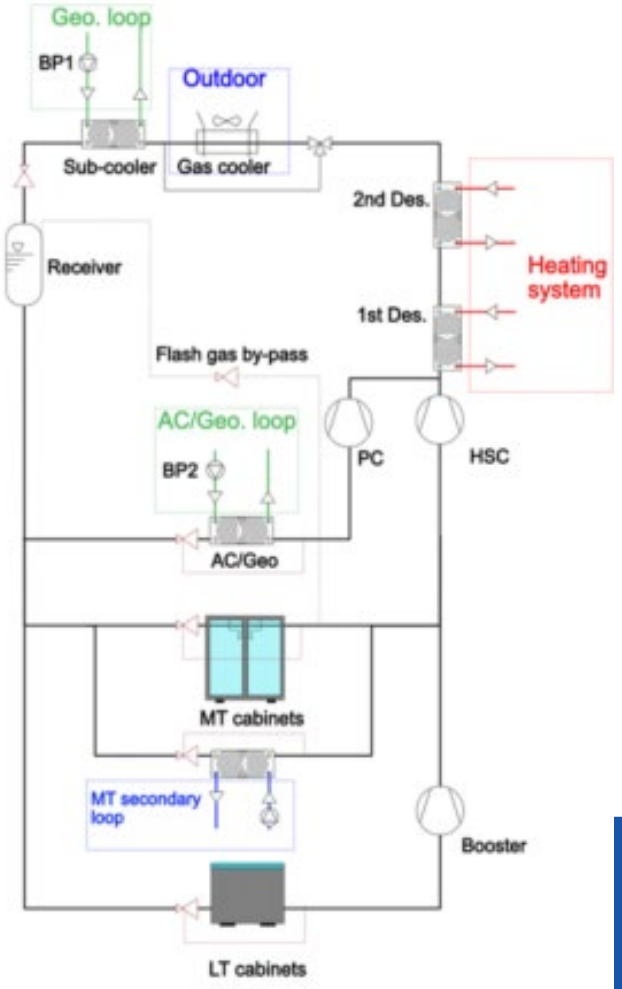


Fundamental studies of boiling in flat channels

- Using IR camera to determine surface temperatures inside heated channels
- Important for future low-charge heat exchangers
- Still ongoing

Trans-critical CO2 systems for supermarket refrigeration systems

- CO2 very common in supermarket refrigeration in Scandinavia
- Often combined with heating using gas cooler / condenser / desuperheater



Refrigerants for low GWP heat pumps on the Swedish market

Refrigerants for low GWP heat pumps on the Swedish market

Air-to-air hp (split type):

- No production in Sweden
- Imported splits mostly use R32 (or high GWP like R410A)

Air-to-water hp, split type:

- Many producers in Europe, one in Sweden
- Typically use R32

- Air-to-water hp, monobloc
- Many producers in Europe and one in Sweden using propane

Refrigerants for low GWP heat pumps on the Swedish market

Brine/water-to-water hp:

- Common type in Sweden
- Offered by two manufacturers with low GWP synthetic refrigerants R452B and R454B
- Hp with low charge of propane under development

- Exhaust air hp
- At least three manufacturers in Sweden
- Propane has been used since 1990s
- R32 is also used, as well as the high GWP R407C

Refrigerants for low GWP heat pumps on the Swedish market

Larger residential and commercial units

Site built (50 – 1000 kW):

- CO2 and ammonia preferred

Pre-manufactured (20 – 160 kW or higher):

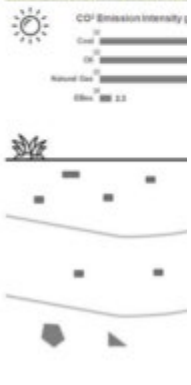
- Propane hp offered by at least two manufacturers
- R513A used by one manufacturer
- R32 used by one manufacturer

Case studies

Case studies

Case 1: Ebox, a propane heat pump for multifamily buildings

- Factory built systems allows:
  - standardized designs which decrease cost
  - high quality as systems can be tested before delivery
  - high safety levels of the systems even with flammable refrigerants
- Flexible capacity of the systems
- Simple installation
- Short installation time

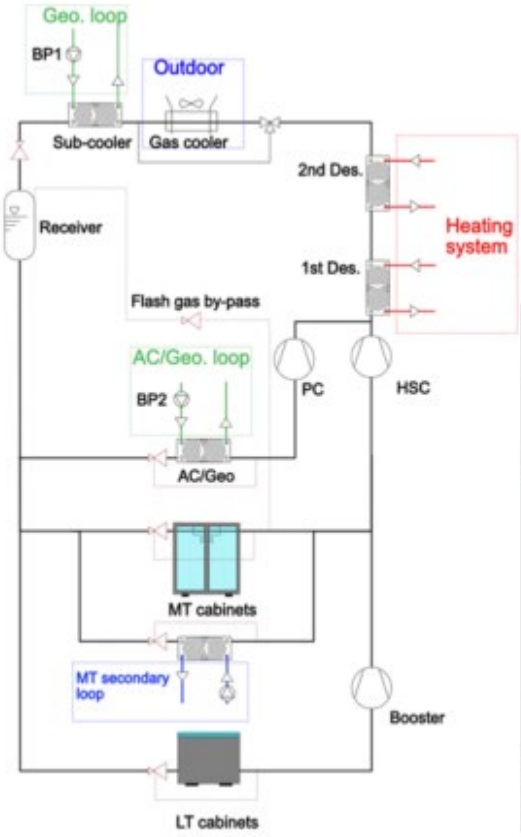


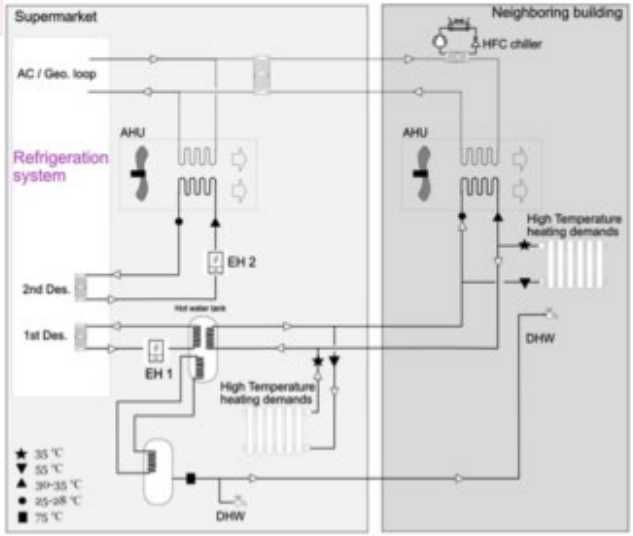
Case studies

Case 2: CO_2-system for heating and cooling

- Combining refrigeration in supermarket with heating of neighboring buildings

- Geothermal wells as extra heat source
- Heating 11000 + 5000 m^2
- 20 boreholes, 225 m
- AC (passive) via borehole field or active



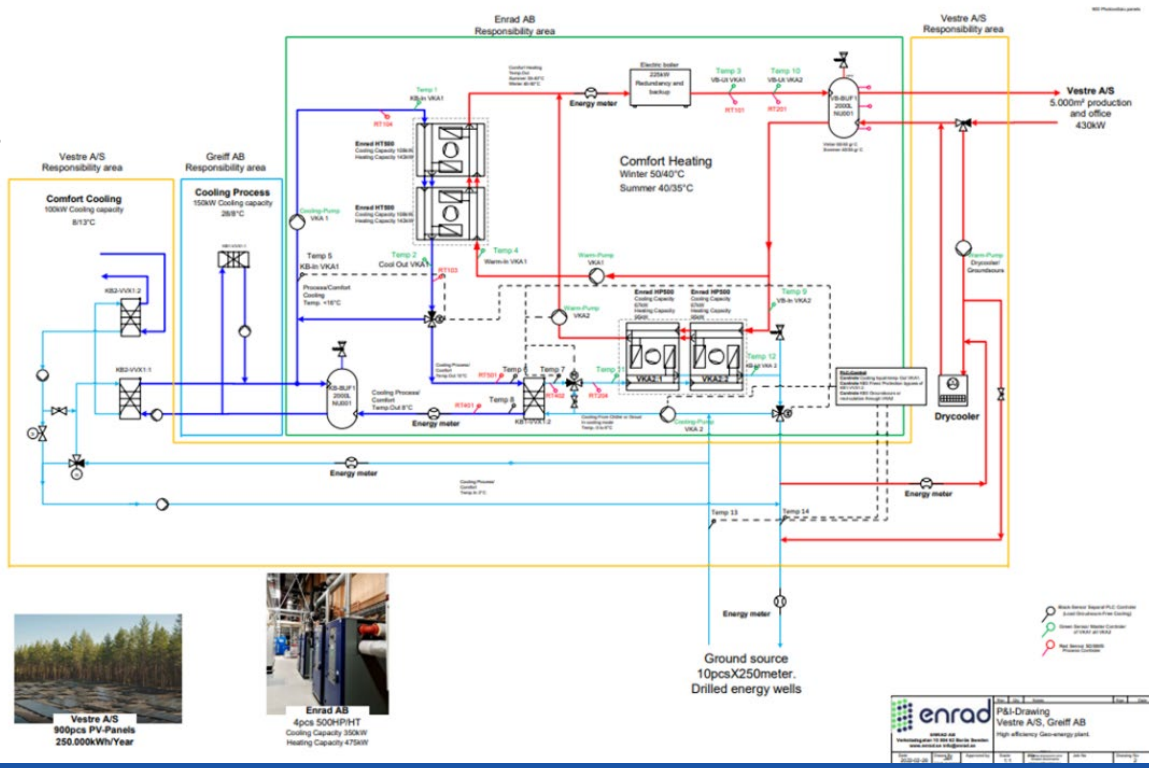


Case studies

Case 3: R290 Heat pumps/chillers

Installed in furniture factory by Enrad

- Waste heat recovery
- 17 geothermal wells
- 900 rooftop solar panels



Design recommendations for low charge

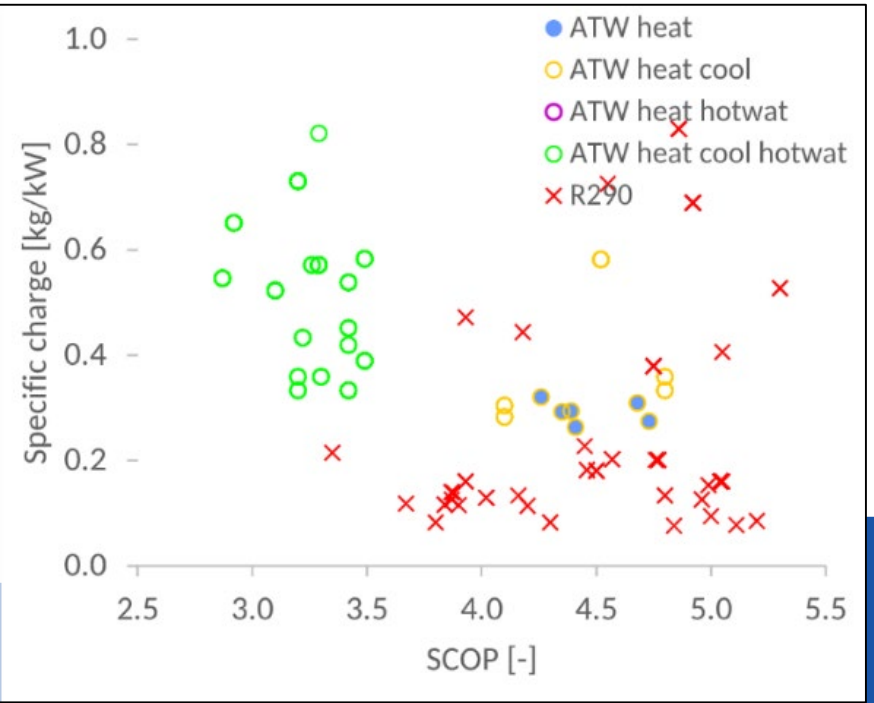
Design recommendations for low charge

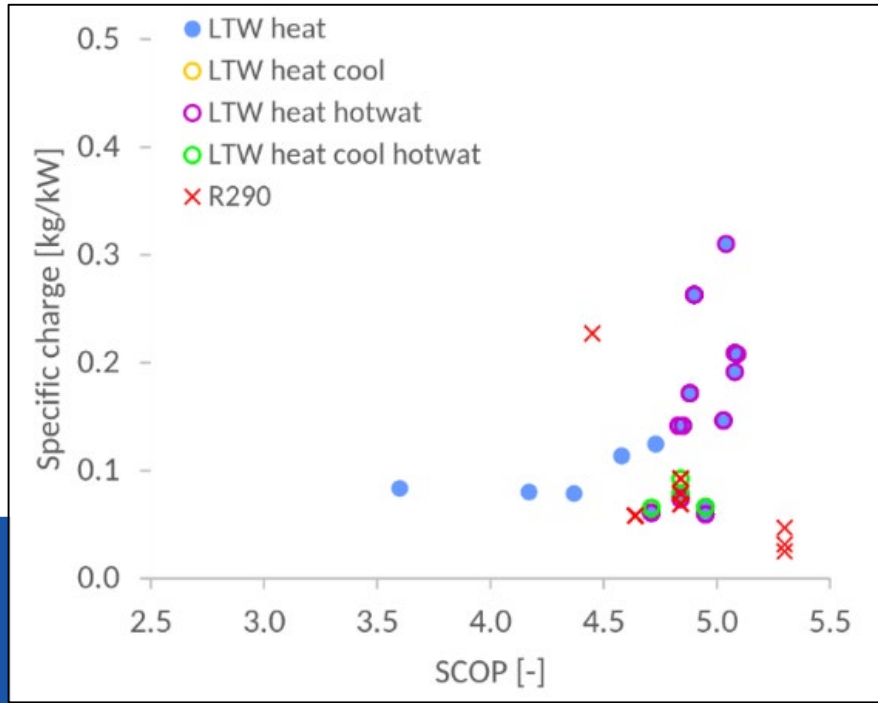
- Charge reduction should not be achieved by decreasing the heat transfer areas
- All lines should be as short as possible, in particular, it is important to have a short liquid line
- Flat channel hx should be used, e.g., extruded aluminum multichannel tubes or plate heat exchangers with small pressing depth
- Special care should be taken when designing the headers
- The charge of oil in the compressor should be selected based on the volume of the system

Design recommendations for low charge

- No clear connection between charge and efficiency

Below: Specific charge vs SCOP for small to medium size heat pumps. Left: Air to Water, <20 kW. Right: Liquid to Water <30 kW

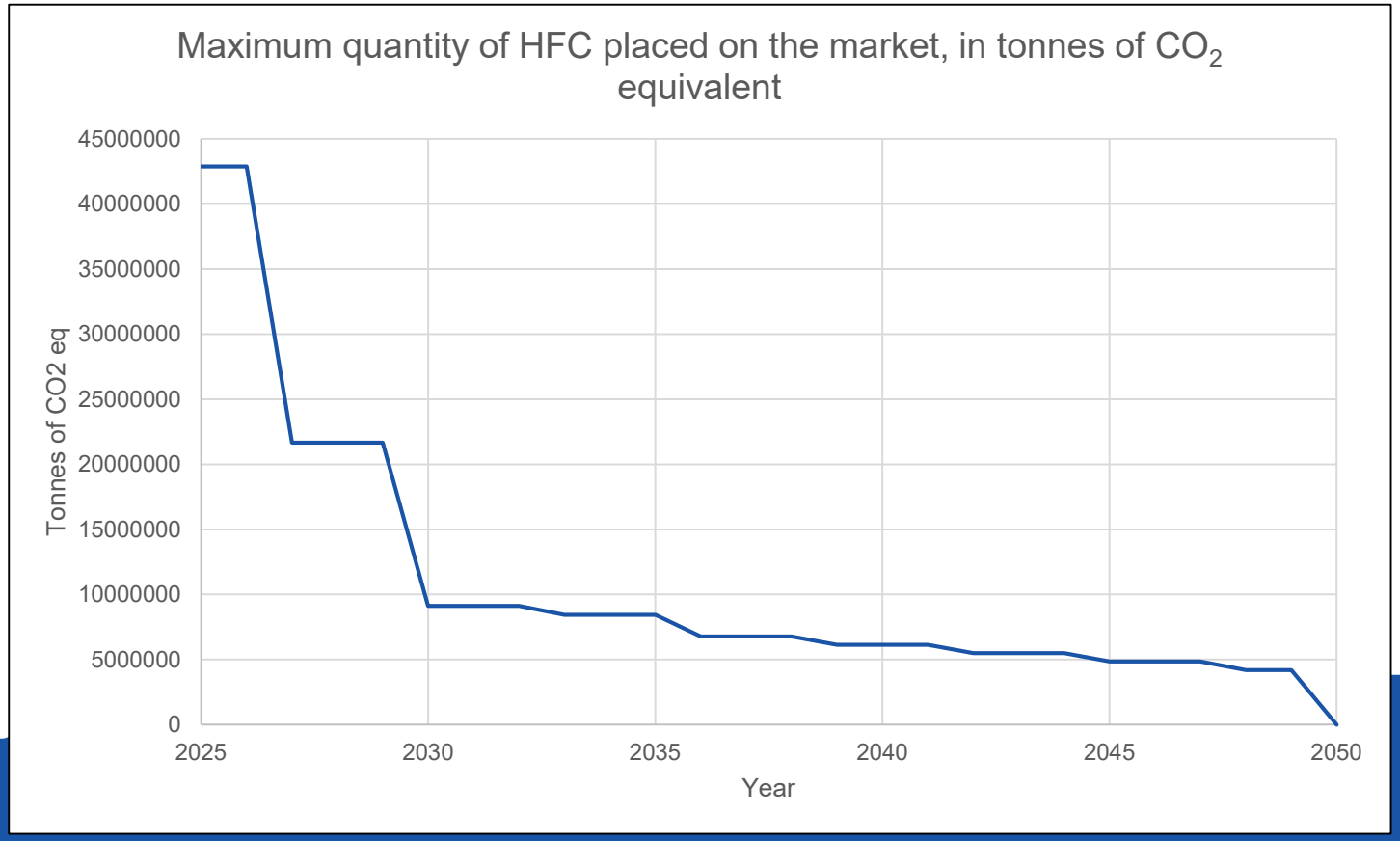




Changing legislation and outlook for the future

New F-gas directive in EU

- Requires a phase out of HFC refrigerants to 2050
- Does not involve HFOs



New F-gas directive in EU

- Also includes a product ban, prohibiting sales of systems below 12 kW using any type of F-gas (including HFO) from 2027 - 2035 depending on type.
- (Some possible exceptions when safety requires non-flammable refrigerants)

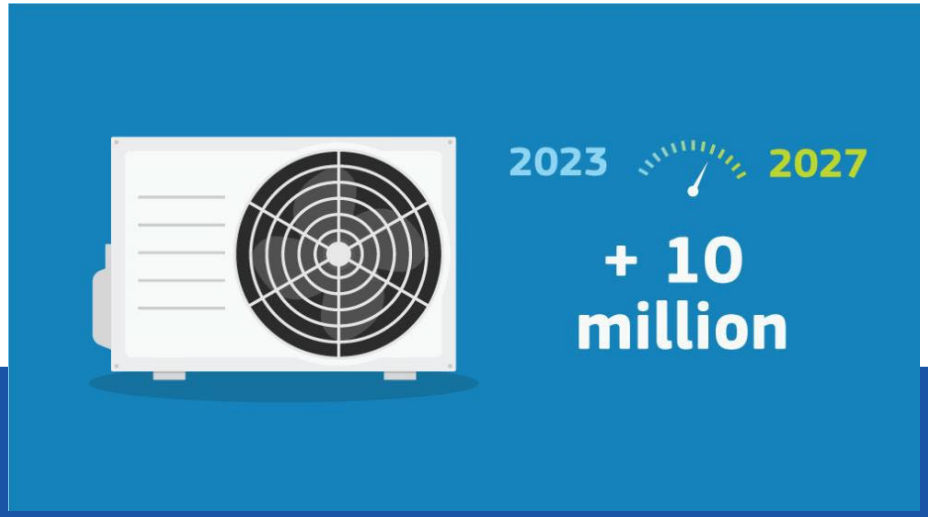
Regulations against PFAS?

Proposal for a ban on all PFAS in EU

All common low-GWP synthetic refrigerants are PFAS

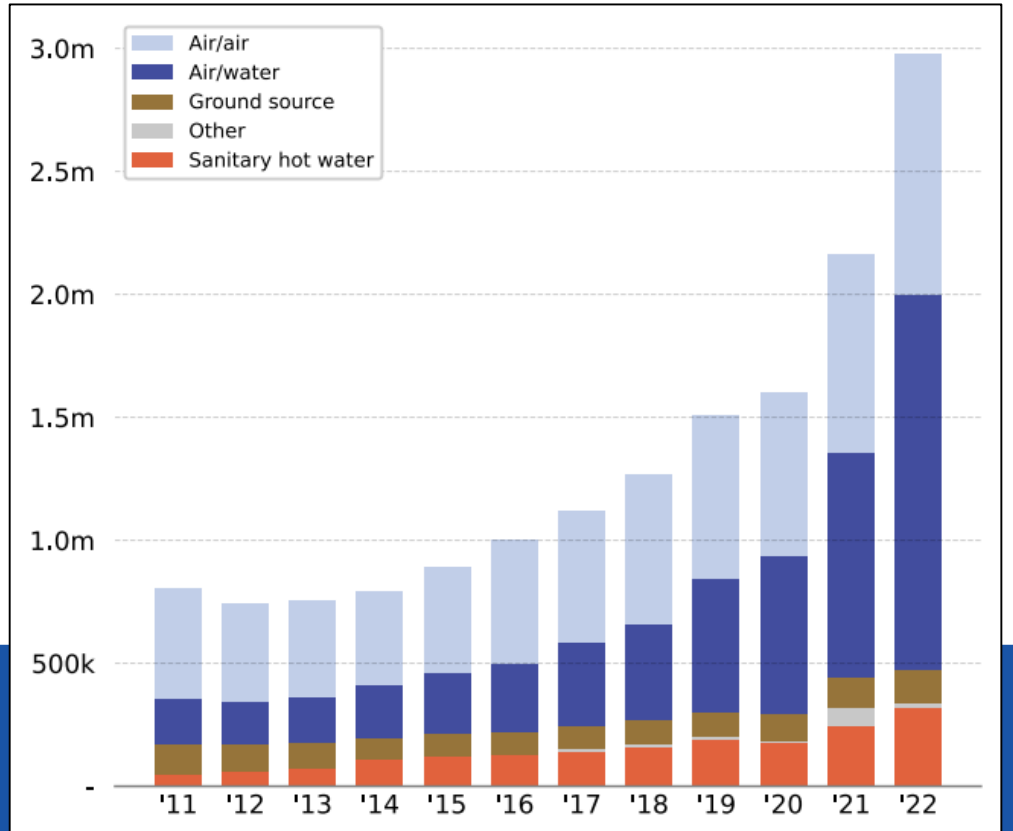
Market development

- EU decisions to phase out fossil fuels requires electrification of the heating sector
- Over 60 Million gas heaters need to be replaced!
- EU is soon presenting a Heat Pump Action Plan
- A *Net Zero Industry Act* was taken in 2023, including hp



Market development

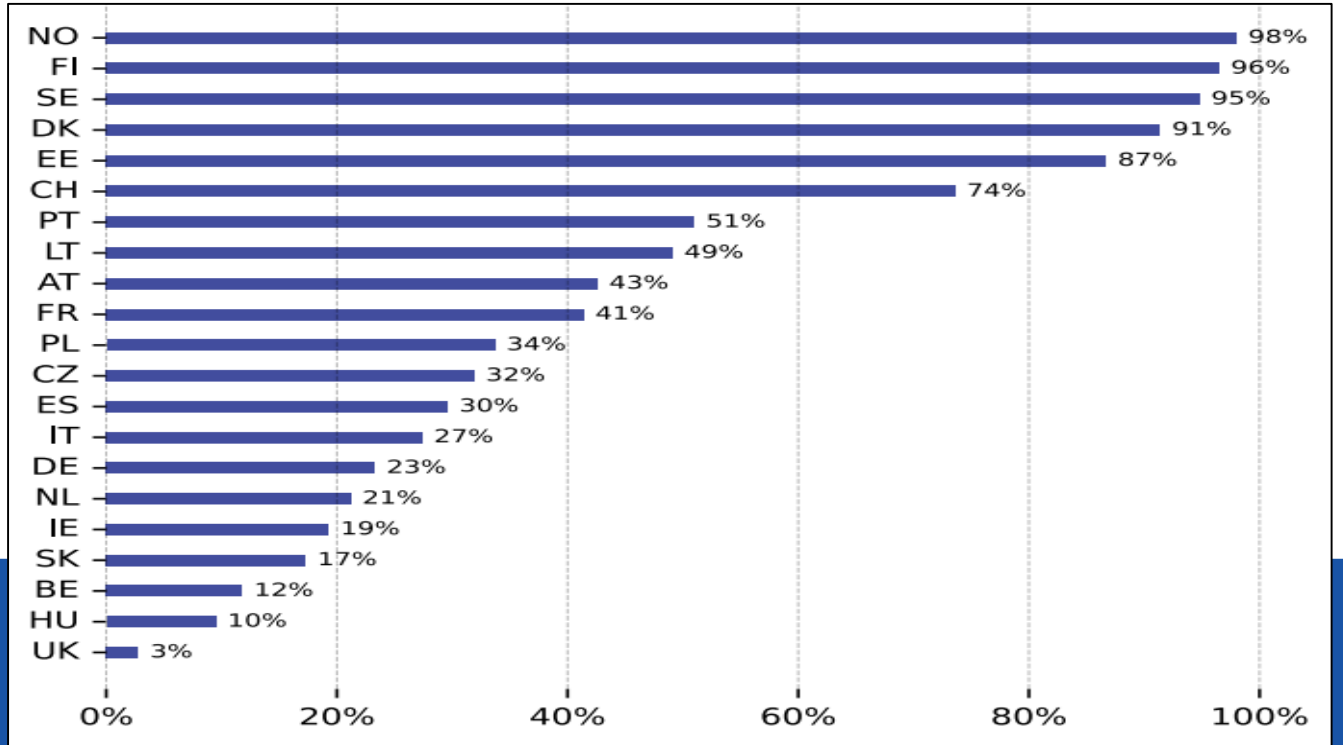
- EU market has been growing exponentially since 2013
- Dip in EU market for 2023, expected to be temporary



Market development

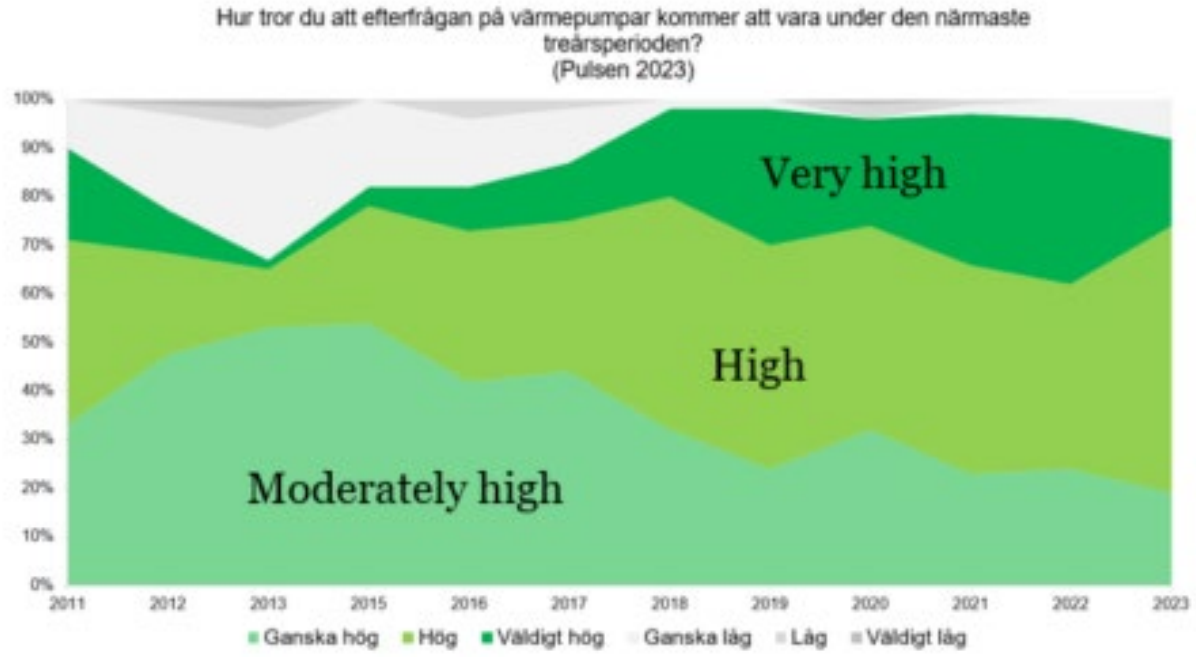
- Market matureness in the European countries

- Below: Heat pump market shares in % of combined sales of boilers and heat pumps

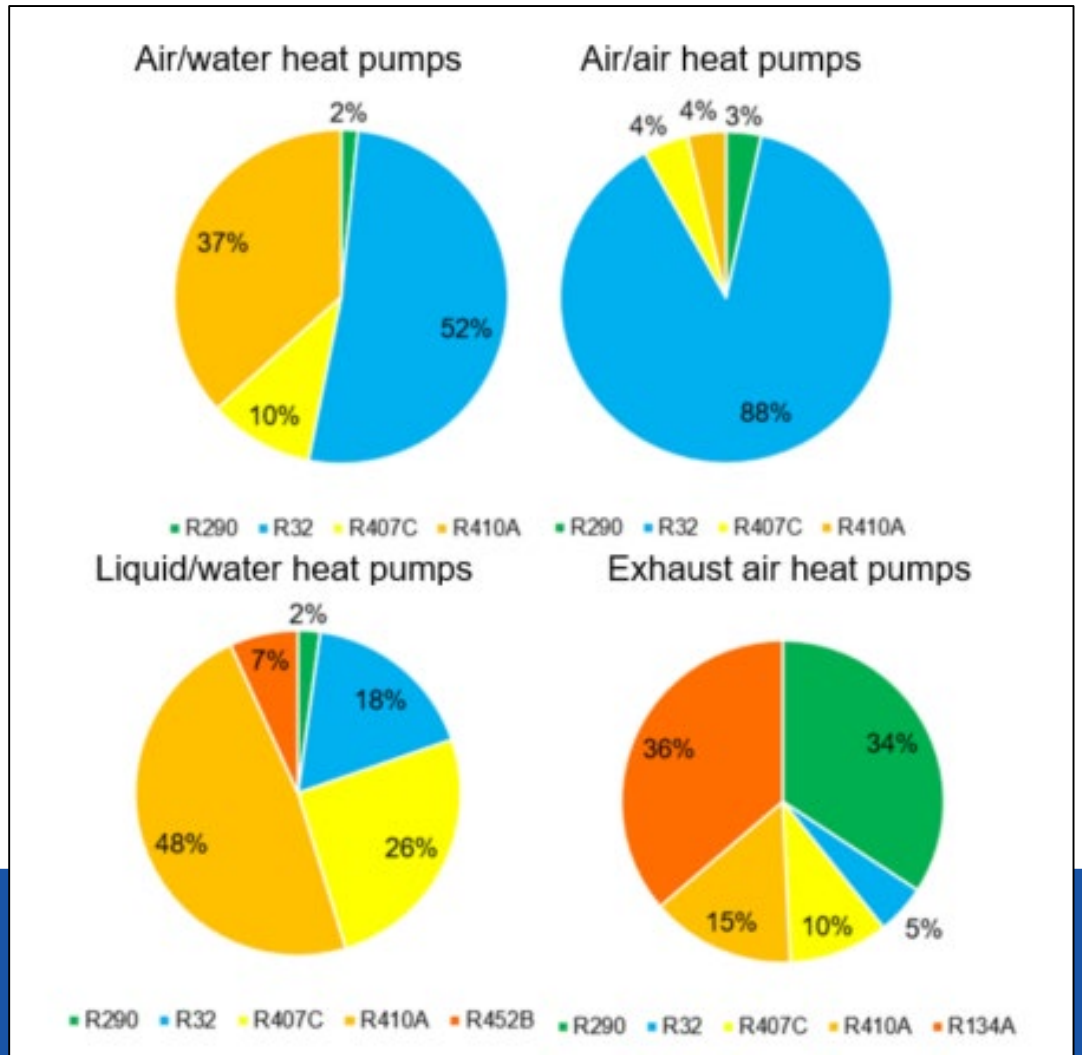


Expectations of hp producers and importers

Expectations about heat pump market next three years



Installers´ estimate of distribution of type of refrigerant in systems installed 2023



A Study of Market Opportunities of Low-GWP Refrigerants in Sweden: Analysis of Collected Data from Six Heat Pump Manufacturers

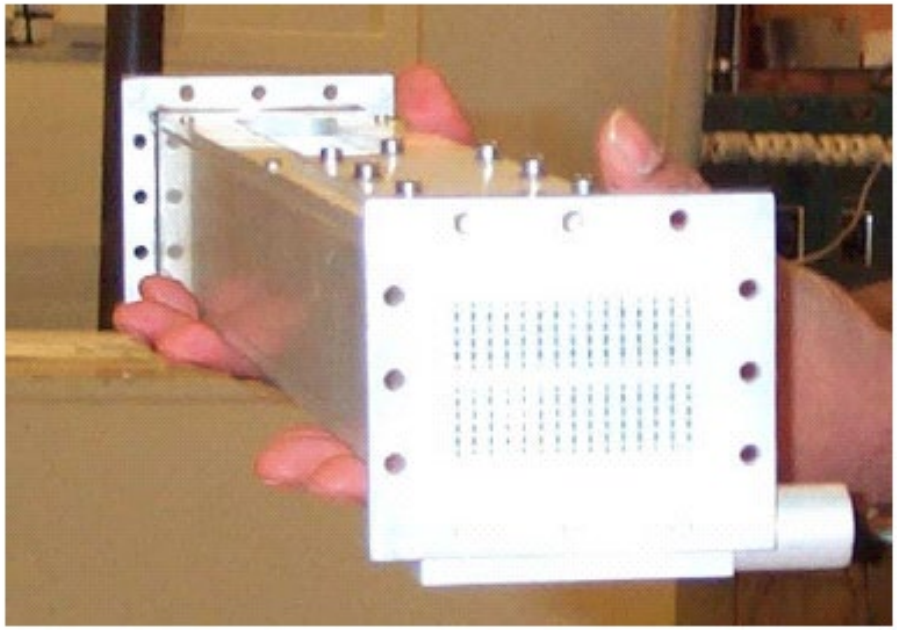
Five manufacturers/sales companies were asked about current and future refrigerants in their products.

Some conclusions:

- All expect a growing market demand for low GWP products
- Medium-term barriers of low GWP refrigerants
  - Differences in regulations between countries
  - Safety issues related to flammability
  - Availability of trained installers and technicians
  - Major growth opportunities: Only HC, CO2 and NH3

Thank you for your attention!

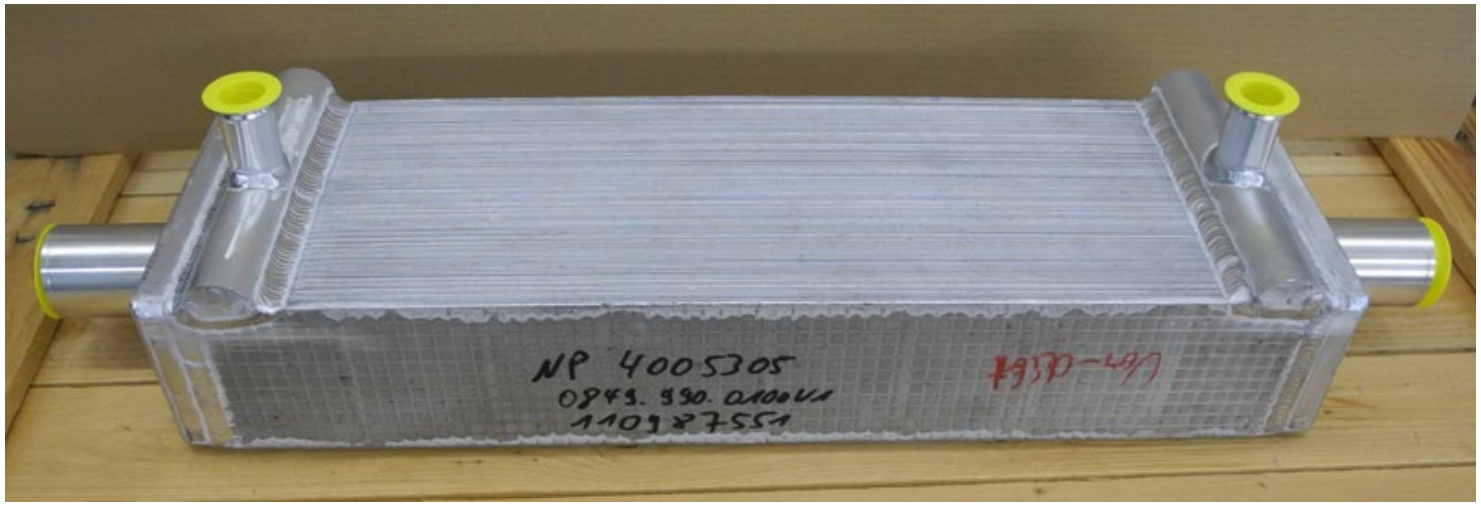
Björn Palm
bpalm@energy.kth.se



Extra slides for discussion

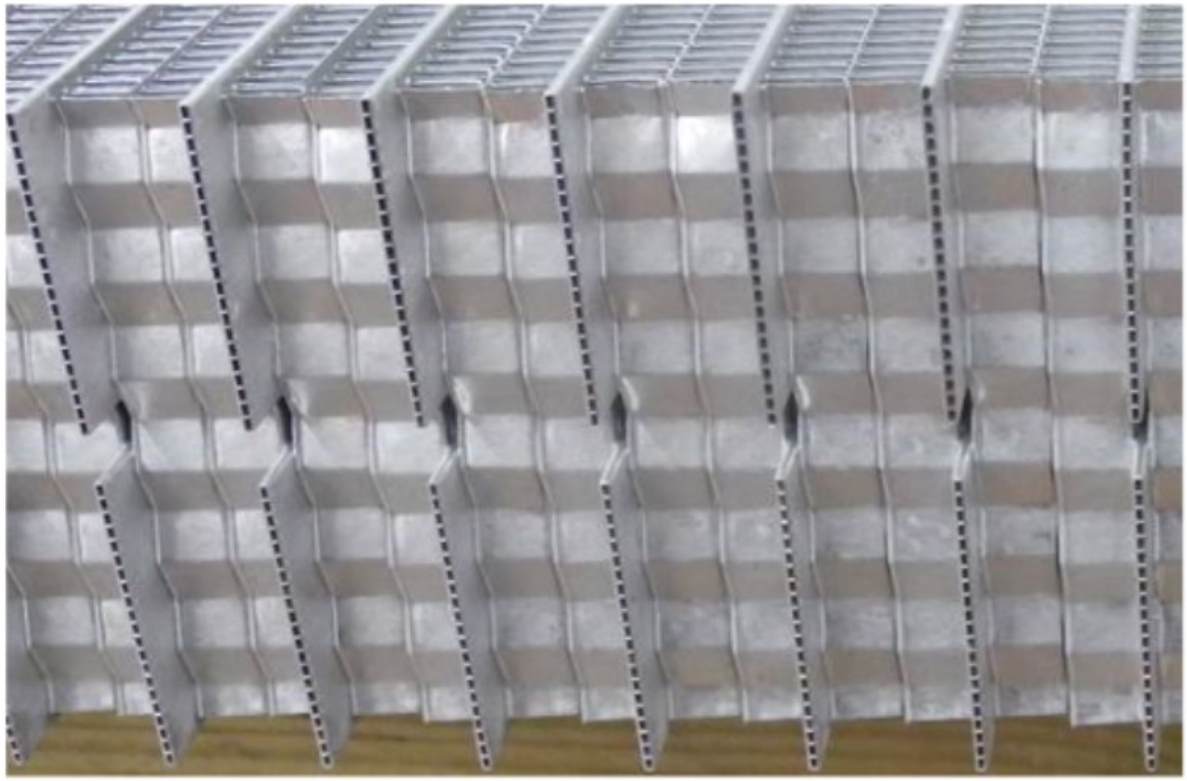
Condenser

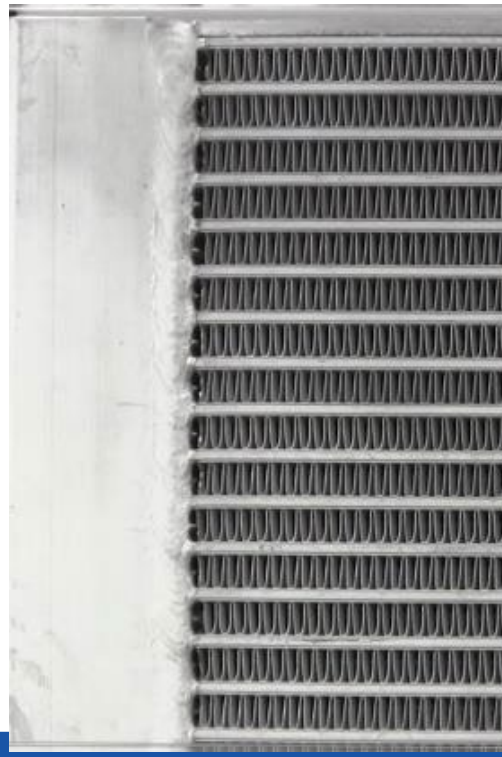
Photo by AKG

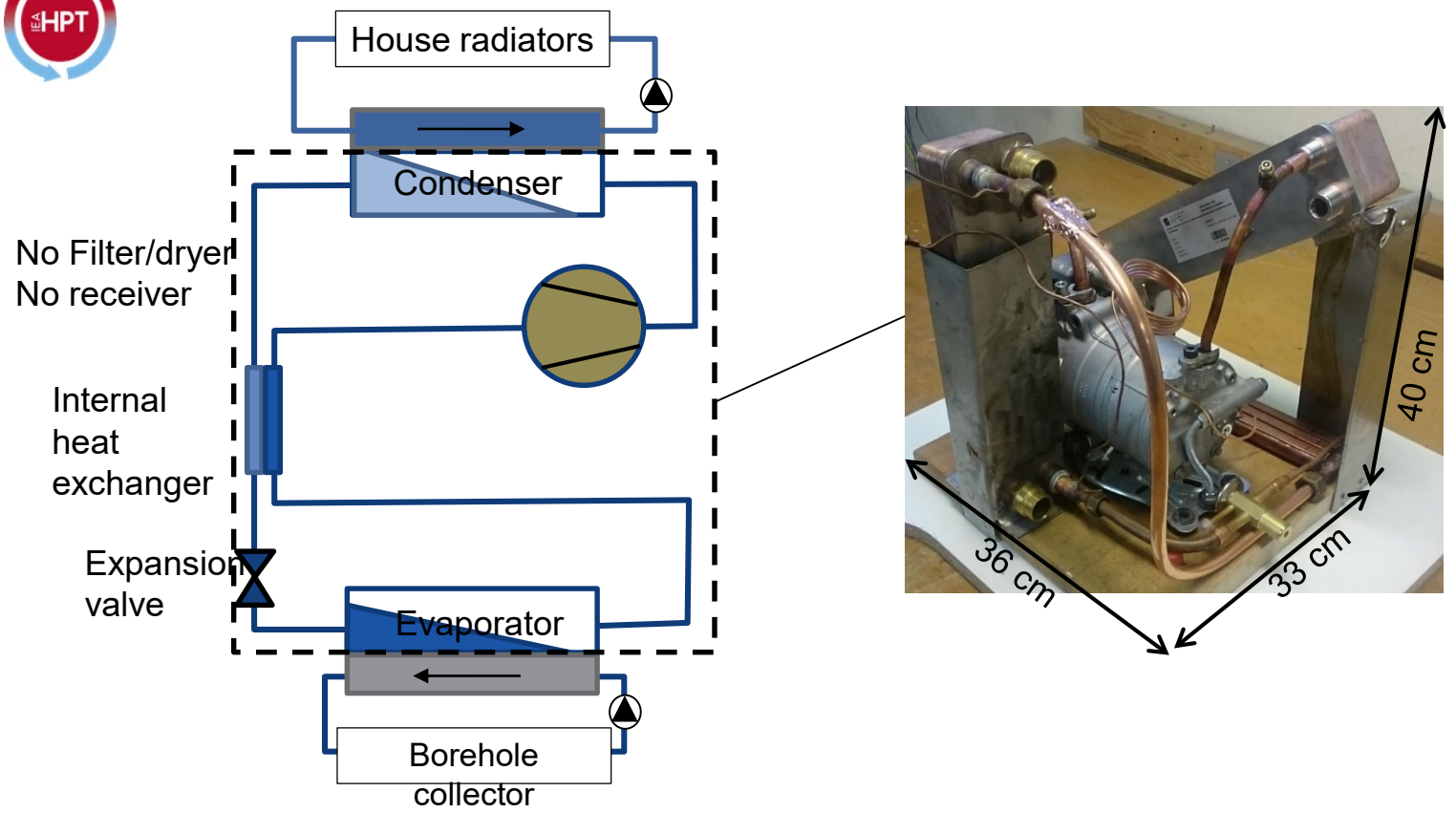


Evaporator design

Flat multichannel tubes, 18 channels, 1mm x 2mm






House radiators
Condenser
No Filter/dryer
No receiver
Internal
heat
exchanger
Expansion
valve
Evaporator
Borehole
collector
40 cm
36 cm
33 cm

Compressor: Sanden SHS33

Electric vehicle climatization

Scroll

Wide operational range

800-8500 rpm

Made for 1234yf and R134a

R290 OK

Inverter Control

Suction side

Discharge side

< 1 dl oil

3

210 mm

6,8 kg

< 15 g

R290

Standard compressor

> 1 liter oil

364 mm

>20 kg

~ 70 g

R290

Heat transfer ⇔ Charge & Pressure drop

Plate distance δ=2 mm

~ 0,9 liter/m²

Evaporator ~ 70g R290 Condenser ~ 125g R290

2004

~ 0,44 liter/m²

2013

δ=1 mm

~ 0,5 liter/m²

2017

Pentaprop 2017

δ< 1 mm

< 0,4 liter/m²

Evaporator < 25g R290 Condenser < 55g R290

Evaporator and Condenser

Airec - PentaProp

Asymmetric brazed plate heat exchanger



Q_2= 4.8 kW
T_1=40°C T_2=2.5°C
T_{sup}=T_{sub}=4 K