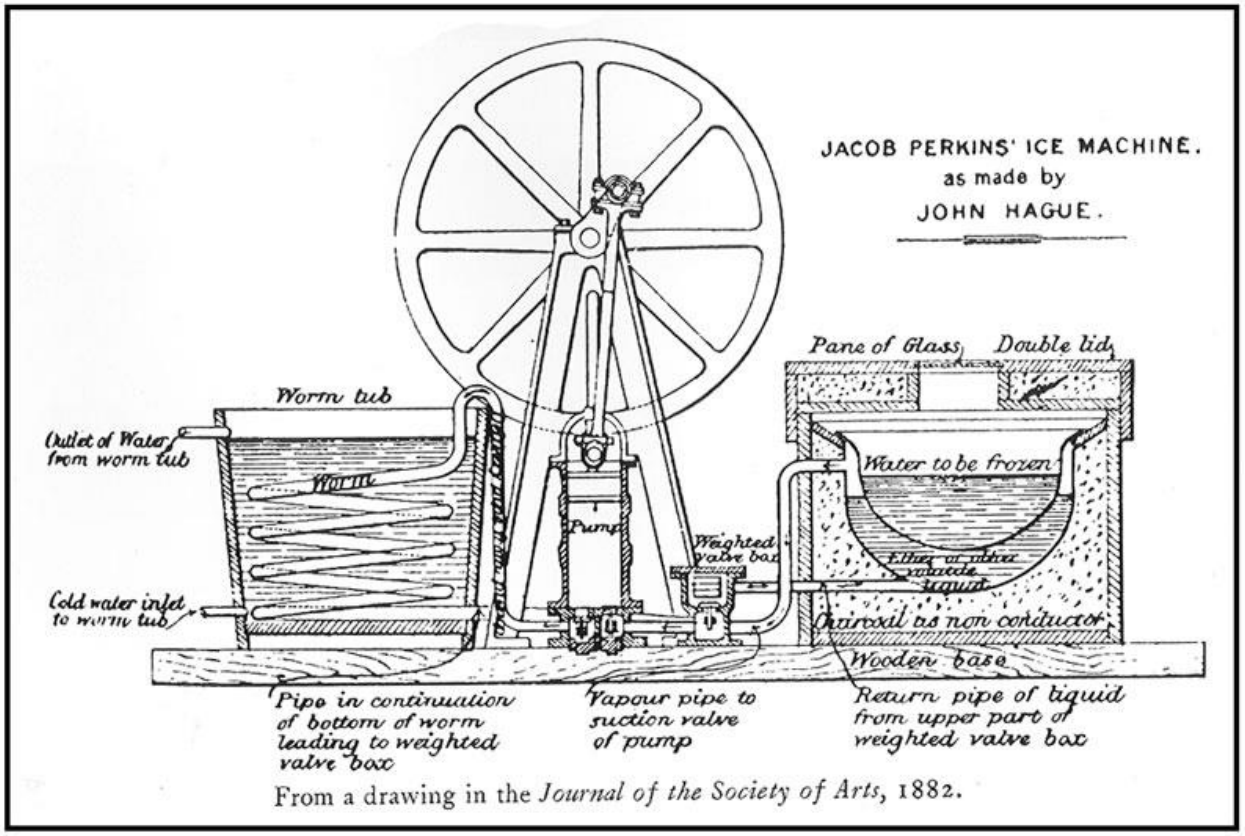
Technology Status and The Importance of Research,

Björn Palm, Dept Energy technology,
KTH Royal Institute of Technology

The original heat pump

Patent from 1834



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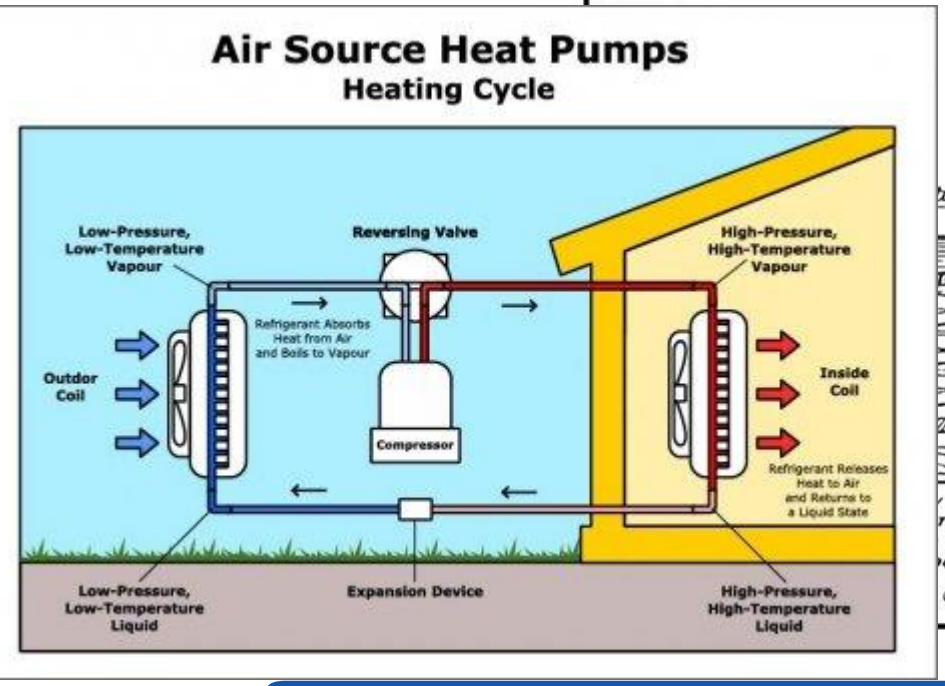
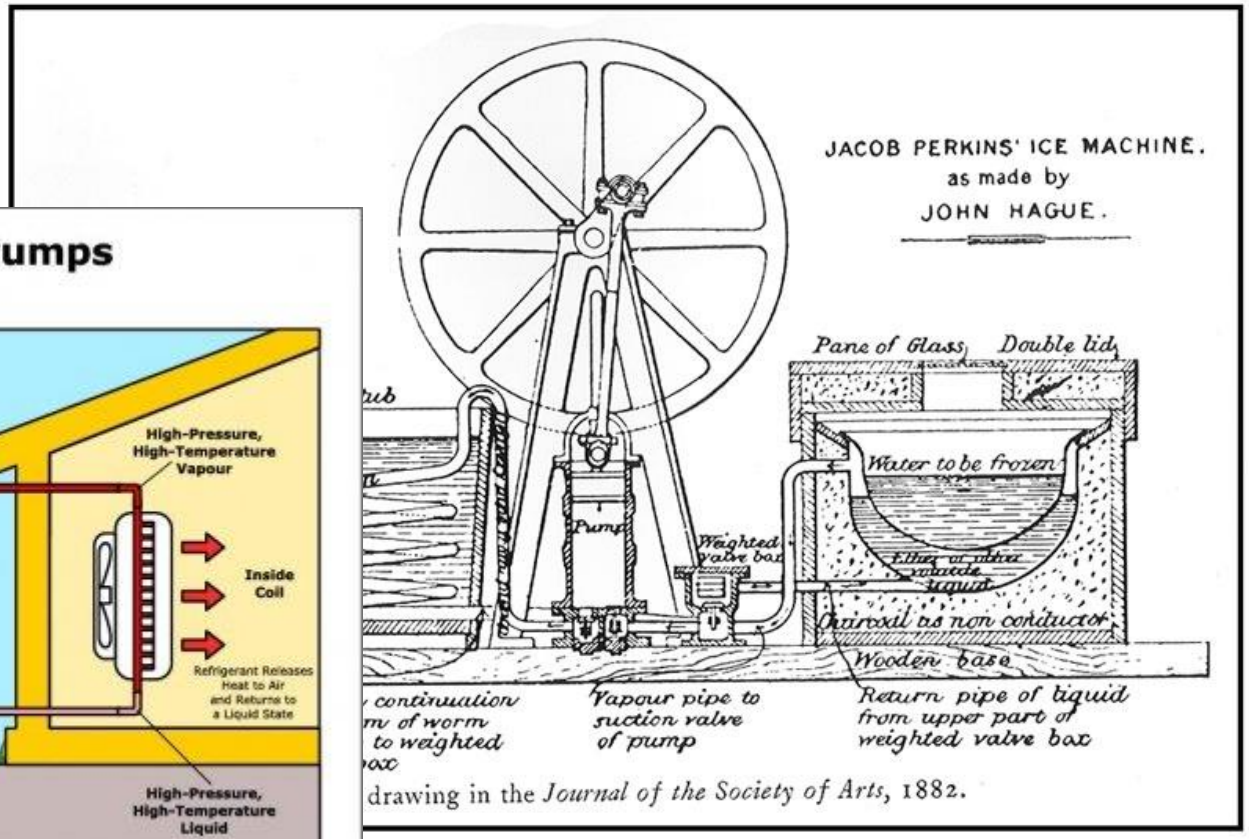




What more do we need to know?

Selection of refrigerant has always been a challenge!

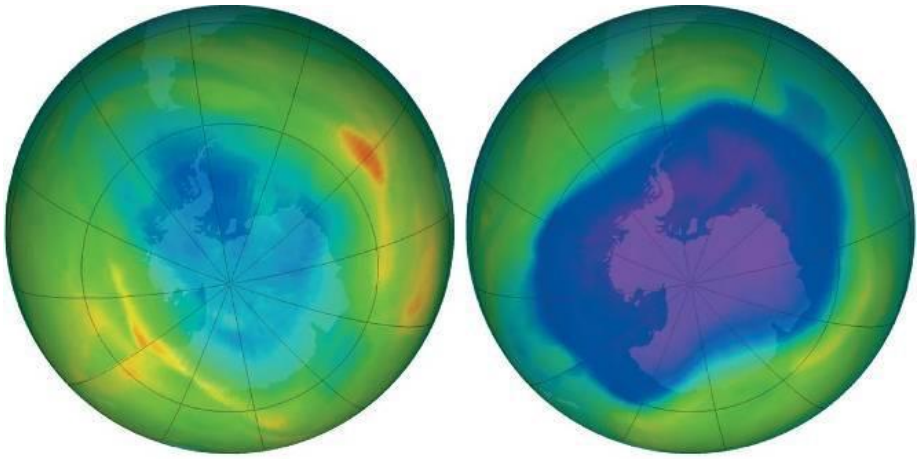
- 100 years ago: Hydrocarbons, SO_2, ethers, NH_3, CO_2, CH_3Cl
- 1930: Midgley and Henne's solution: CFC or "Freons"

Finds Non-Poisonous Refrigerant That May Be Used to Cool Homes

Scores of Chemists Inhale Fumes of New Chemical During Experiment by Dr. Thomas Midgley, Jr., Atlanta, Its Discoverer

Selection of refrigerant has always been a challenge!

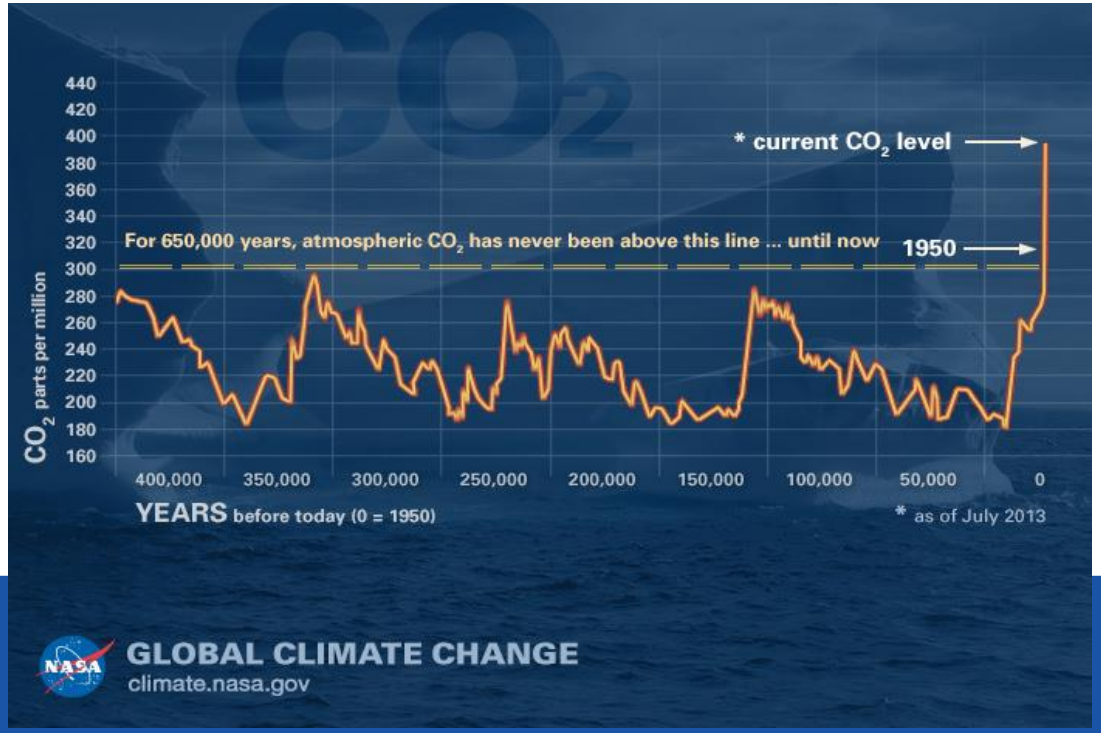
- 1970s: CFCs effect on the ozone layer discovered
  - Change to HFCs



Ozone ”hole”

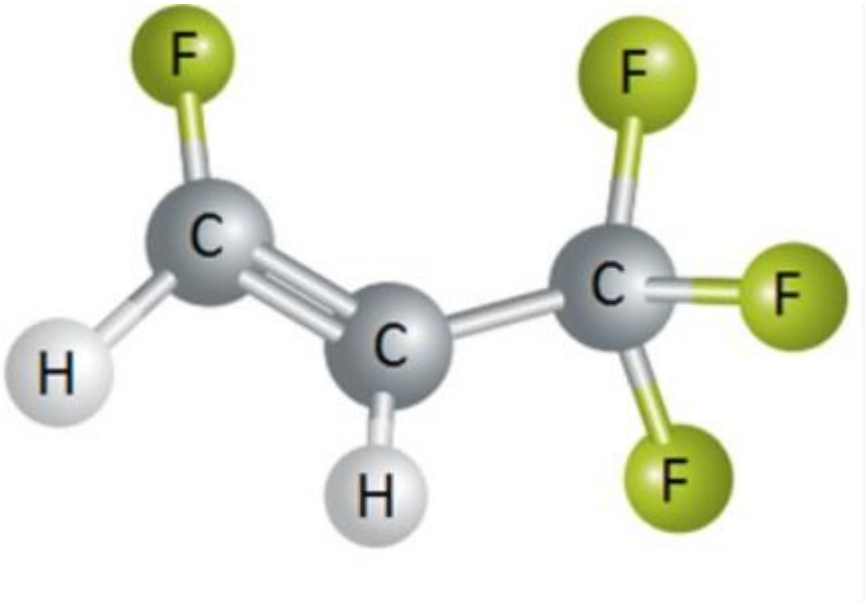
Selection of refrigerant has always been a challenge!

- 2000s, HFC´s high GWP recognized
  - Change to HFO



Selection of refrigerant has always been a challenge!

- 2020s: New threat: HFC and HFO are PFAS (forever chemicals)
  - No other synthetic substances suggested



Synthetic refrigerants are on their way out!

Back to natural fluids…

- Hydrocarbons
  - Propane, isobutane…
- CO_2
- NH_3

- In the future perhaps also water and air…

Change of refrigerant in refrigerators

- Industry in Europe changed from CFC/HFC to isobutane in about 5 years

- Safety precautions:
  - Remove from inside refrigerator:
    - Ignition sources
    - Connections and joints
    - Reduce charge
- Extremely few accidents

Safety with flammable refrigerants

- Charge reduction
  - Decrease from the normal 1 kg charge (8 kW hp) to 120g propane has already been demonstrated
  - Leads to demand for new components
    - New compressors
    - New heat exchangers

Common practice 2021

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

δ< 1 mm

< 0,4 liter/m²

Evaporator < 25g R290 Condenser < 55g R290

Traditional compressor

> 1 liter oil

>20 kg

~ 70 g propane

Compressor for electric car

< 1 dl oil

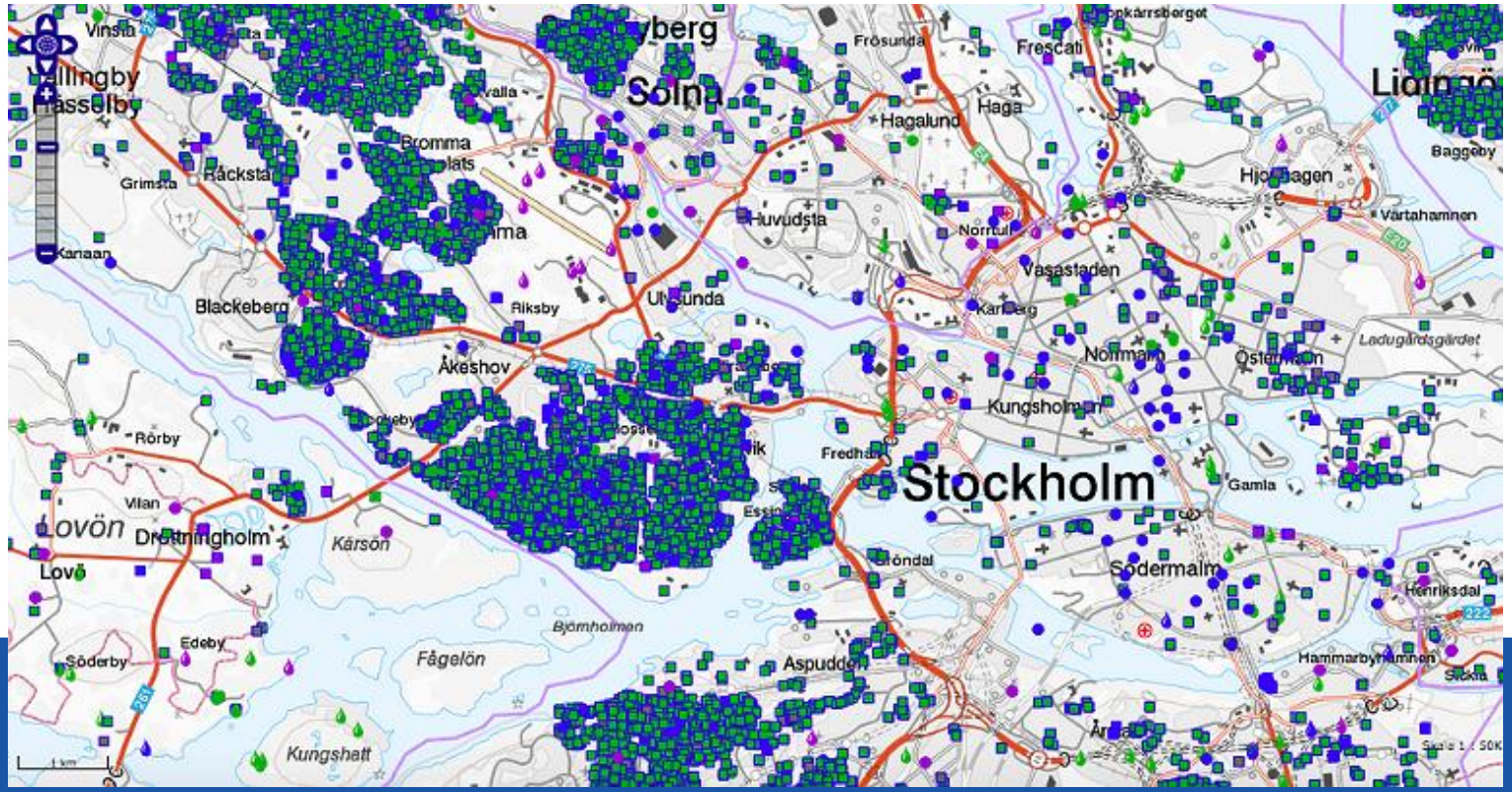
210 mm

6,8 kg

< 15 g propane

Electrification leads to new applications for heat pumps – and new research

- Electrifying the heating sector,
  - How densely can we locate the energy wells?

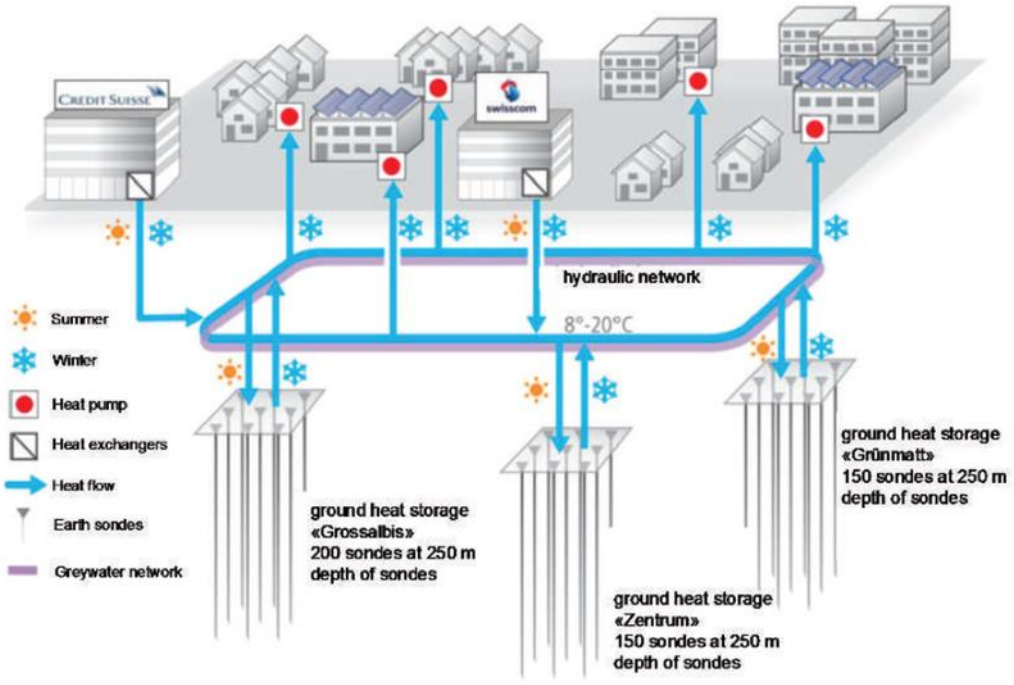


Electrification leads to new applications for heat pumps – and new research

- Electrifying the heating sector, not only heating of private houses
  - Small heat pumps for single apartments substituting gas heaters – how to integrate them?

Electrification leads to new applications for heat pumps – and new research

- Electrifying the heating sector, not only heating of private houses
  - Heat pumps in ”cold” district heating networks



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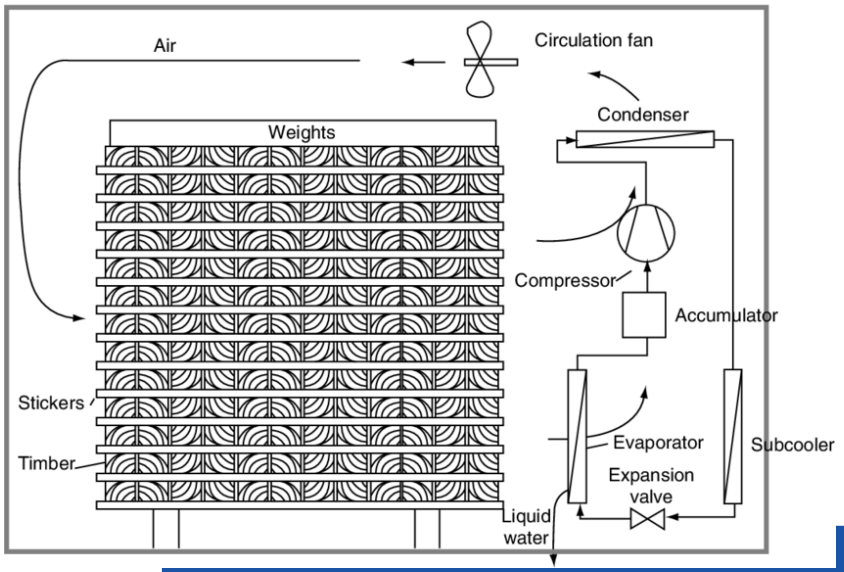
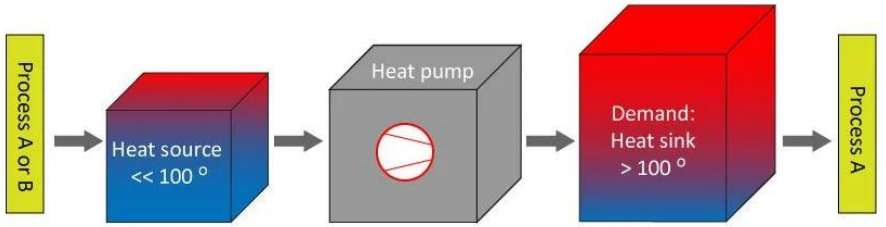
  - High temp heat pumps (Industrial applications)





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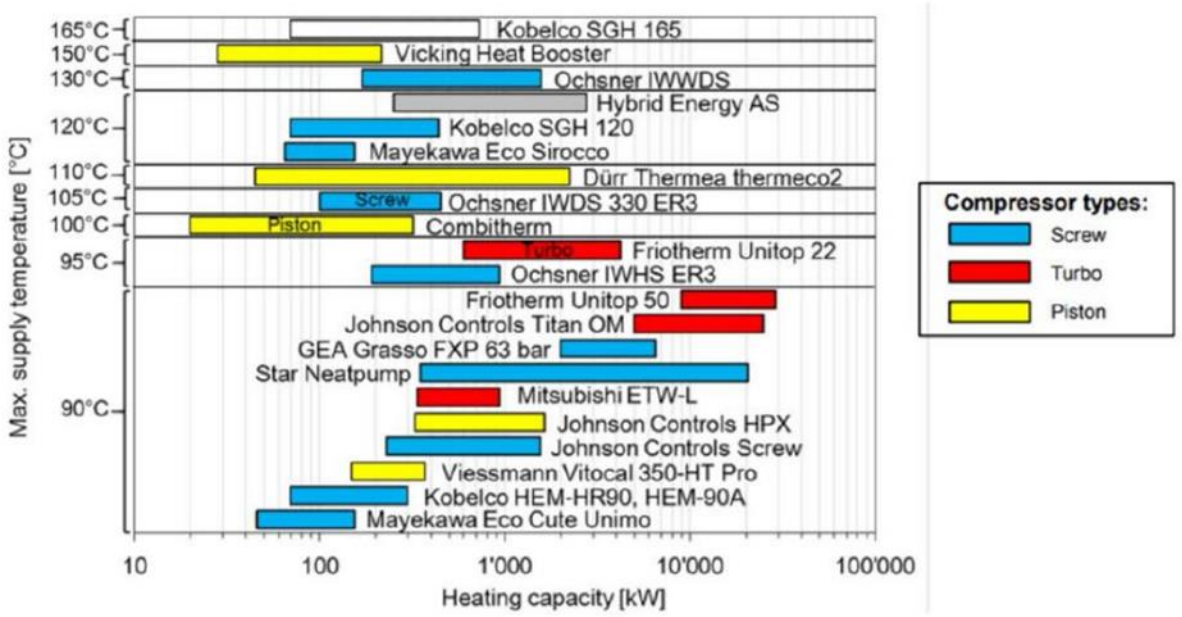


Heat pumps in the district heating systems

- Can we run large heat pumps with flammable refrigerants?

Värtan Ropsten – The largest sea water heat pump facility worldwide, with 6 Unitop® 50FY and 180 MW total capacity

Client

AB Fortum Värme samägt
med Stockholms stad
11577 Stockholm, Sweden

Stockholm's district heating system

Stockholm, the Royal Capital of Sweden, is situated on 14 islands and is considered as one of the most beautiful cities in the world. Its clean sea and air are the result of stringent environmental care. The district heating system is one vital part of the total energy supply in Stockholm.

Heat supply for District Heating

Plant	Network	Heat
Värtan	Central	2,600 GWh
Hässelby	North-Western	1,100 GWh

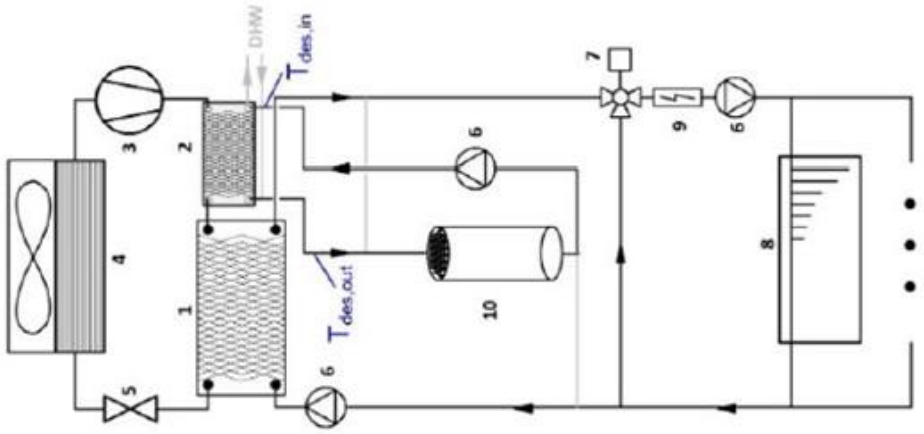
The heat pumps (total 420 MW) are used for base load production along with the bio fuel-fired plants (total 200 MW). Oil-fired plants are used in times of high energy demand only.

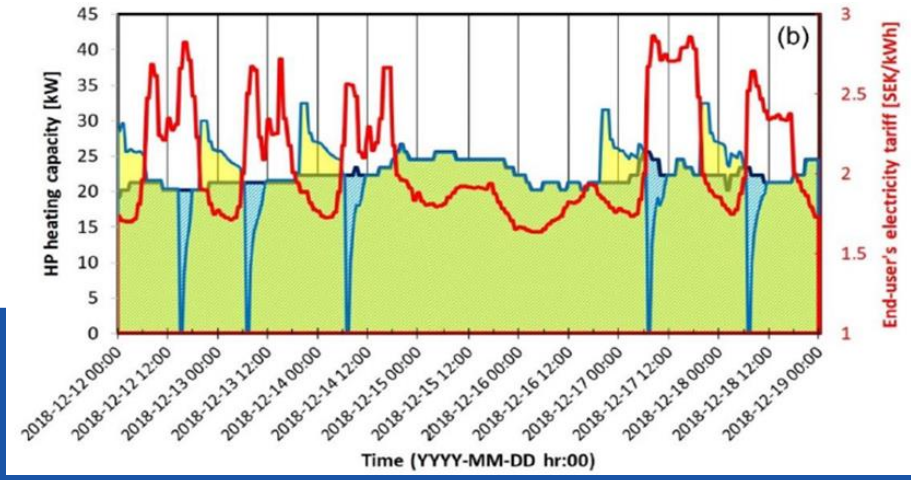
Fortums district heating production system is increasing the use of bio fuels and solar energy sources. In addition, for large heat pumps, hydro-electric power is utilized. All these measures add up to nearly 50% of renewable energy used for the production of district heat.

Värtan Ropsten district heating plant

Heat pumps as part of the energy system

- Reduce peaks in electricity demand
  - Buildings as thermal storage units
  - Separate thermal storage units connected to heat pumps
  - Smart control (Smart Grid Ready HP)





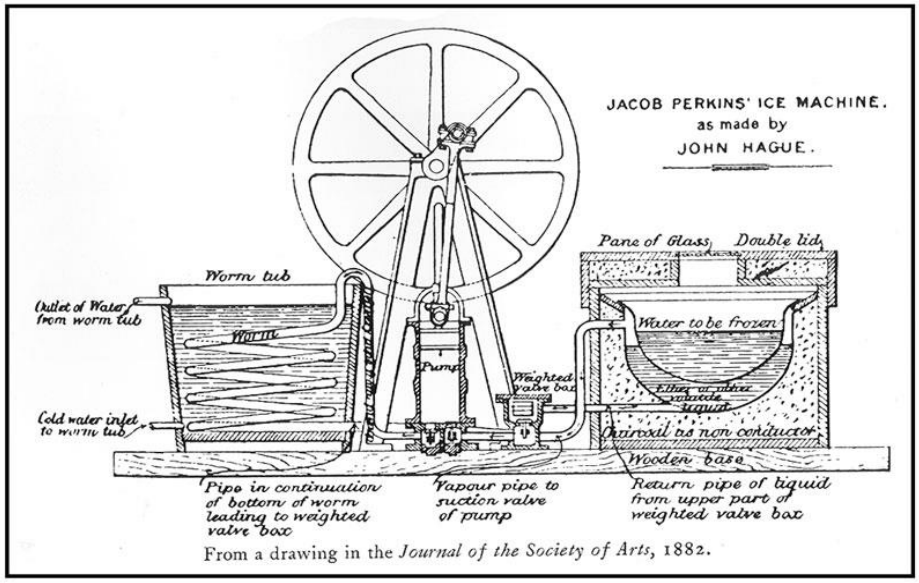
Alternative cycles for heat pumps?

- Absorption cycles
- Adsorption cycles
- Air cycles
- Thermoelectric cycles
- Stirling cycles
- Magnetocaloric cycles
- Electrocaloric cycles
- Barocaloric cycles
- Thermoacoustic cycles
- Thermoelastic cycles
- Ionocaloric cycles

None of these is likely to be able to compete with vapor compression cycles in the next 10 years.

More research is needed!

The heat pump is an old invention, but there is still need for research and development to boost the electrification of the heating sector!



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