The reverse Stirling cycle applied to SGHPs

Tor-Martin Tveit

MAKE YOUR ENERGY GREEN

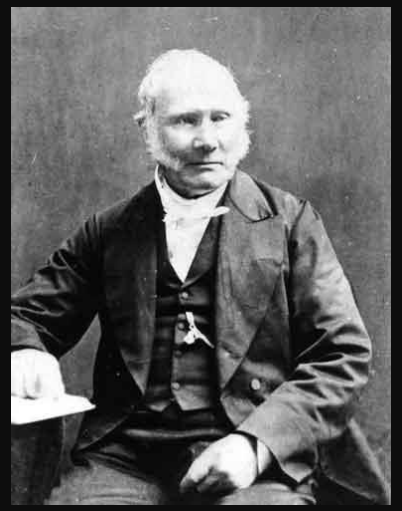
Lower your carbon footprint, increase your profit

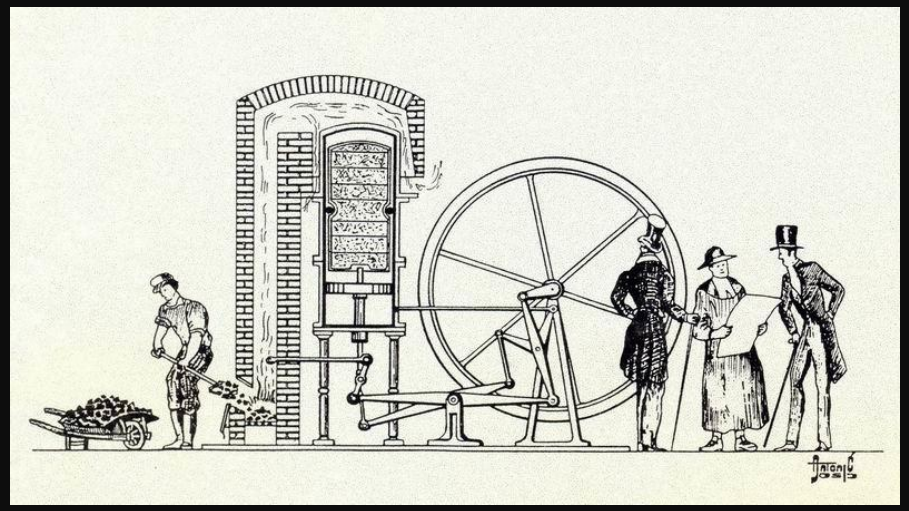
Steam-generating heat pumps, OST Webinar, 21 October 2025

Advantages of the reverse Stirling cycle

1. High efficiency (potentially)
2. High temperature lift ("single stage")
   (combined heating and cooling)
3. High (steam) temperature

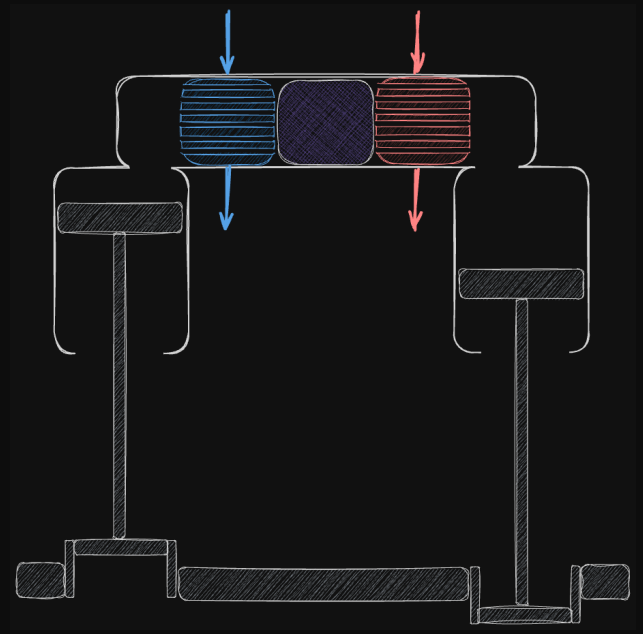
(very) Brief history of the Stirling cycle



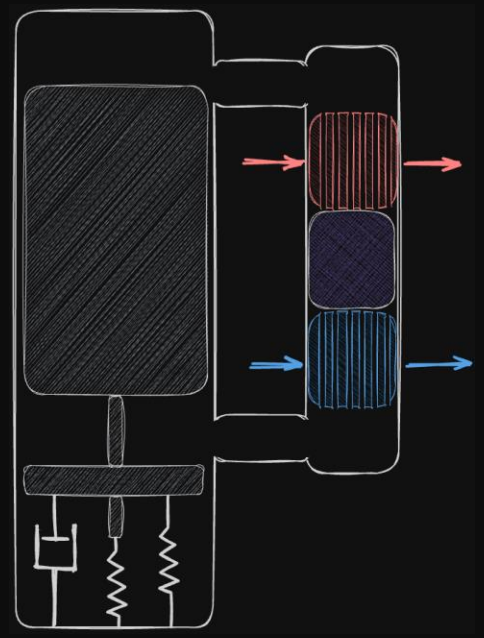


Examples of Stirling engines

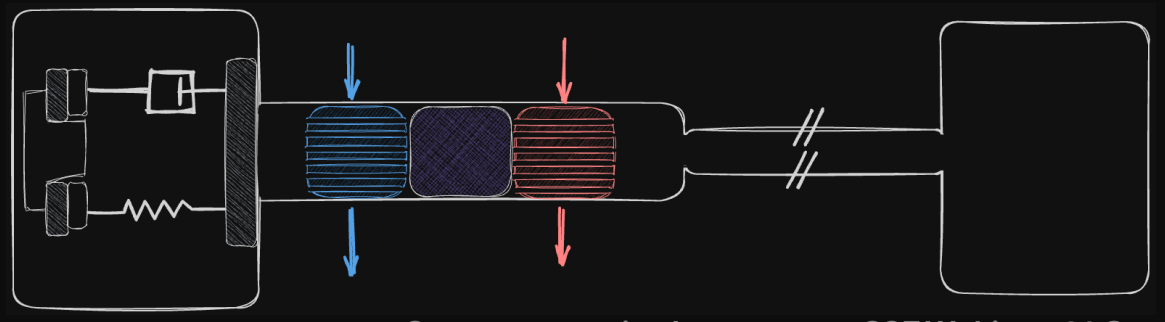
1. Kinematic
2. Free piston
3. Thermoacoustic



1.

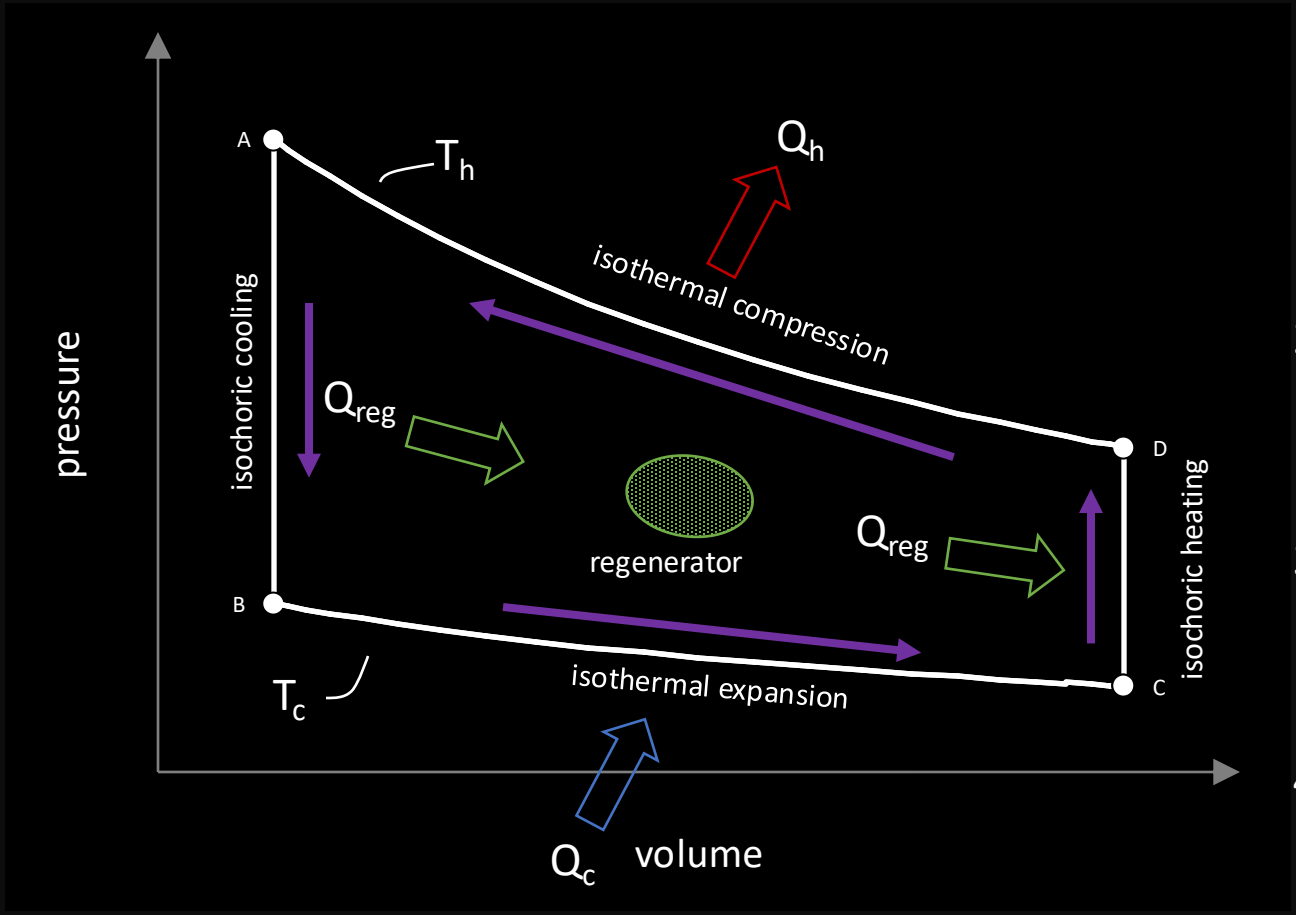


2.



3.

Thermodynamics of the reverse Stirling cycle



$$COP = \frac{T_h}{Th - Tc}$$

$$W = mR\ln\left(\frac{V_{max}}{V_{min}}\right)(T_h - T_c)$$

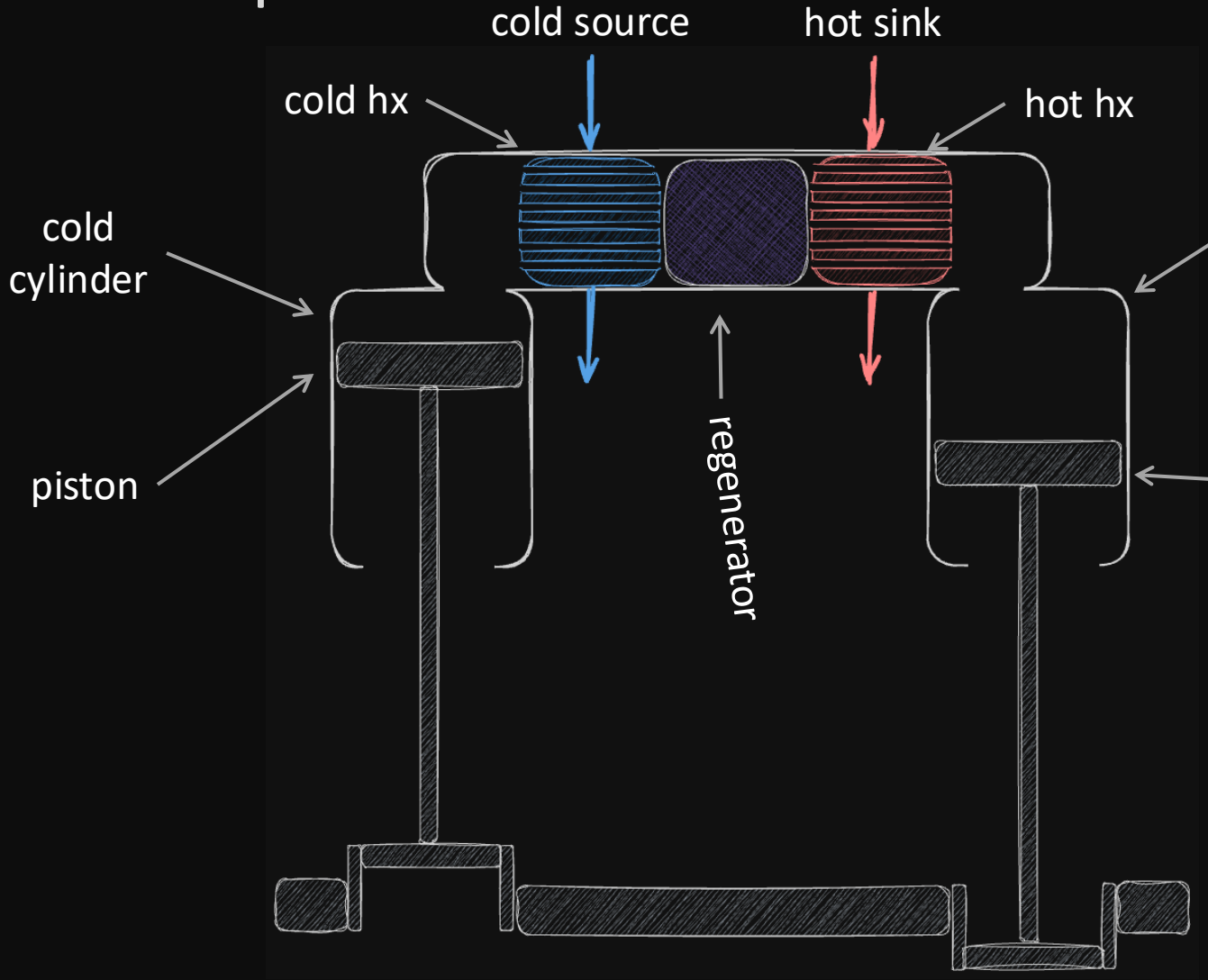
1. A – B: Isochoric cooling
   - heat is transfered to the internal heat storage at constant volume
2. B – C: Isothermal expansion
   - gas is expanded at constant temperature, heat flows into the volume

$$Q_c = mR\ln\left(\frac{V_{max}}{V_{min}}\right)T_c$$

3. C – D: Isochoric heating
   - heat is transfered from the internal heat storage at constant volume
4. D – A: Isothermal compression
   - gas is compressed at constant temperature, heat flows out from the volume

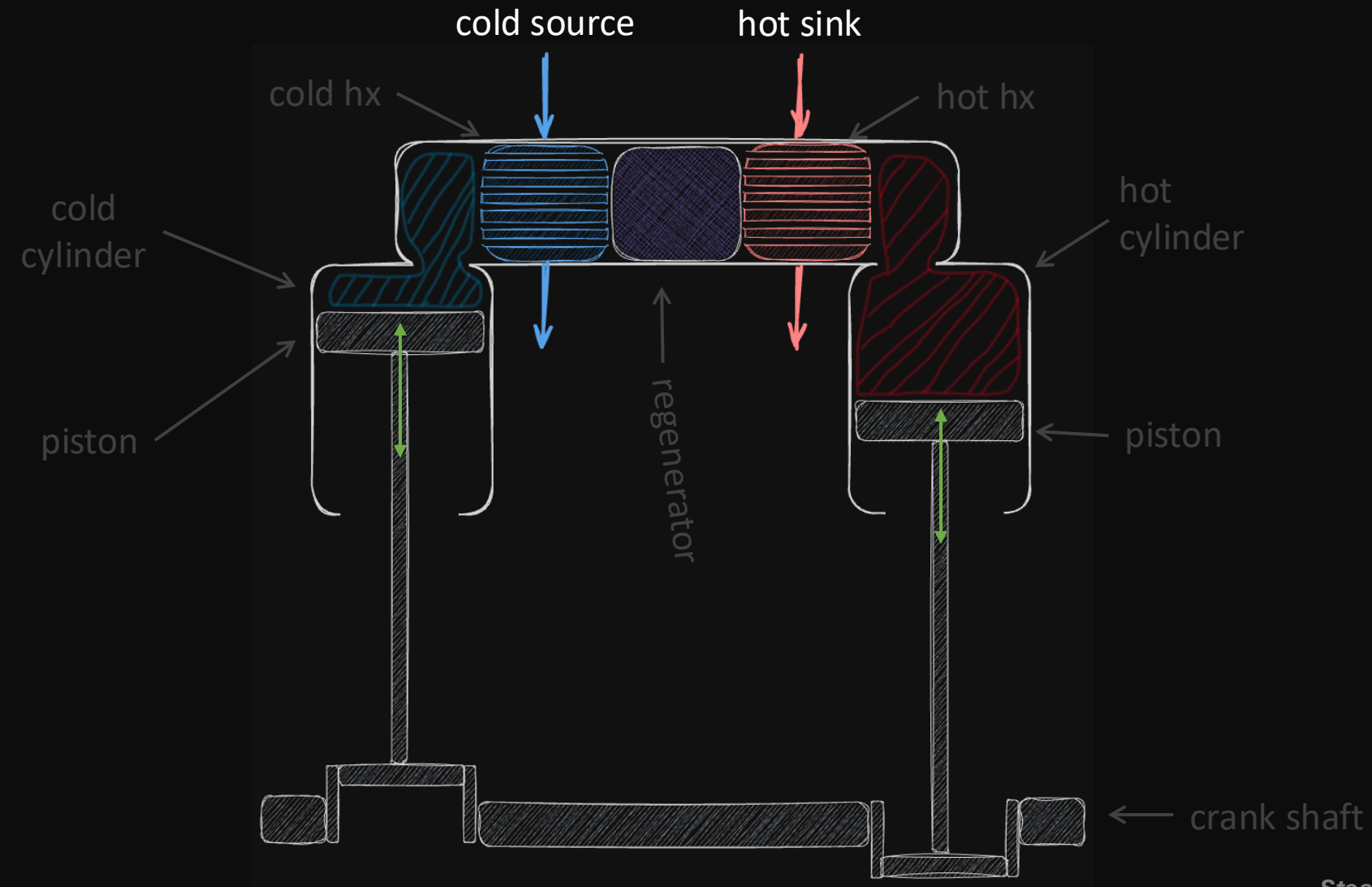
$$Q_h = -mR\ln\left(\frac{V_{max}}{V_{min}}\right)T_h$$

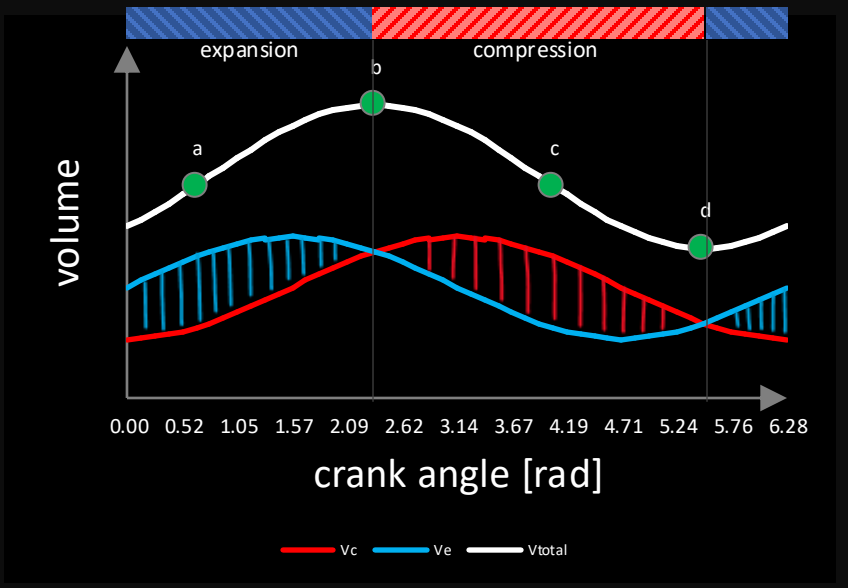
Implementation of the Stirling cycle

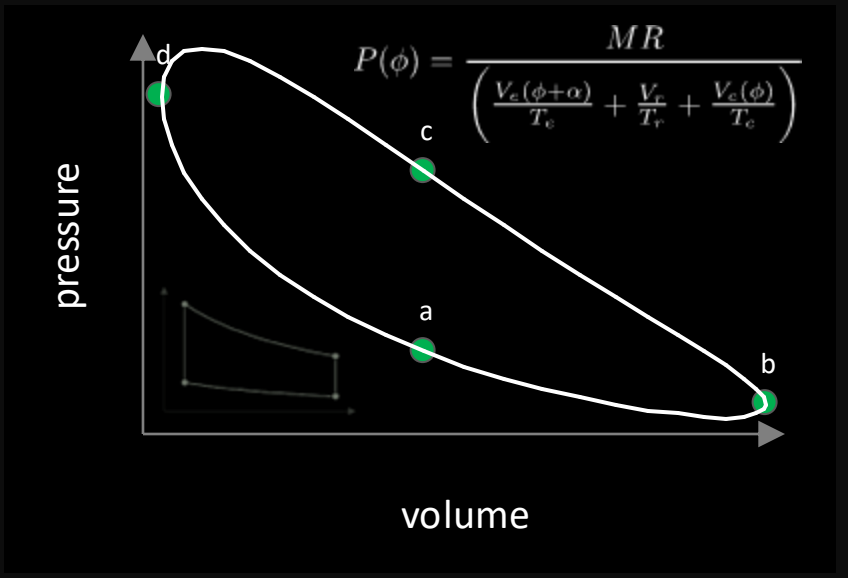


Kinematically driven configurations

- **alpha**
  - two cylinders
- **beta**
  - one cylinder (two pistons)
- **gamma**
  - two cylinders


cold source
hot sink
cold hx
hot hx
cold cylinder
hot cylinder
piston
piston
regenerator
crank shaft


expansion
compression
a
b
c
d
volume
0.00 0.52 1.05 1.57 2.09 2.62 3.14 3.67 4.19 4.71 5.24 5.76 6.28
crank angle [rad]
Vc
Ve
Vtotal


$P(\phi) = \frac{MR}{\left(\frac{V_e(\phi+\alpha)}{T_e} + \frac{V_c}{T_r} + \frac{V_c(\phi)}{T_c}\right)}$
d
c
a
b
pressure
volume

Example of steam generation

Operating conditions:

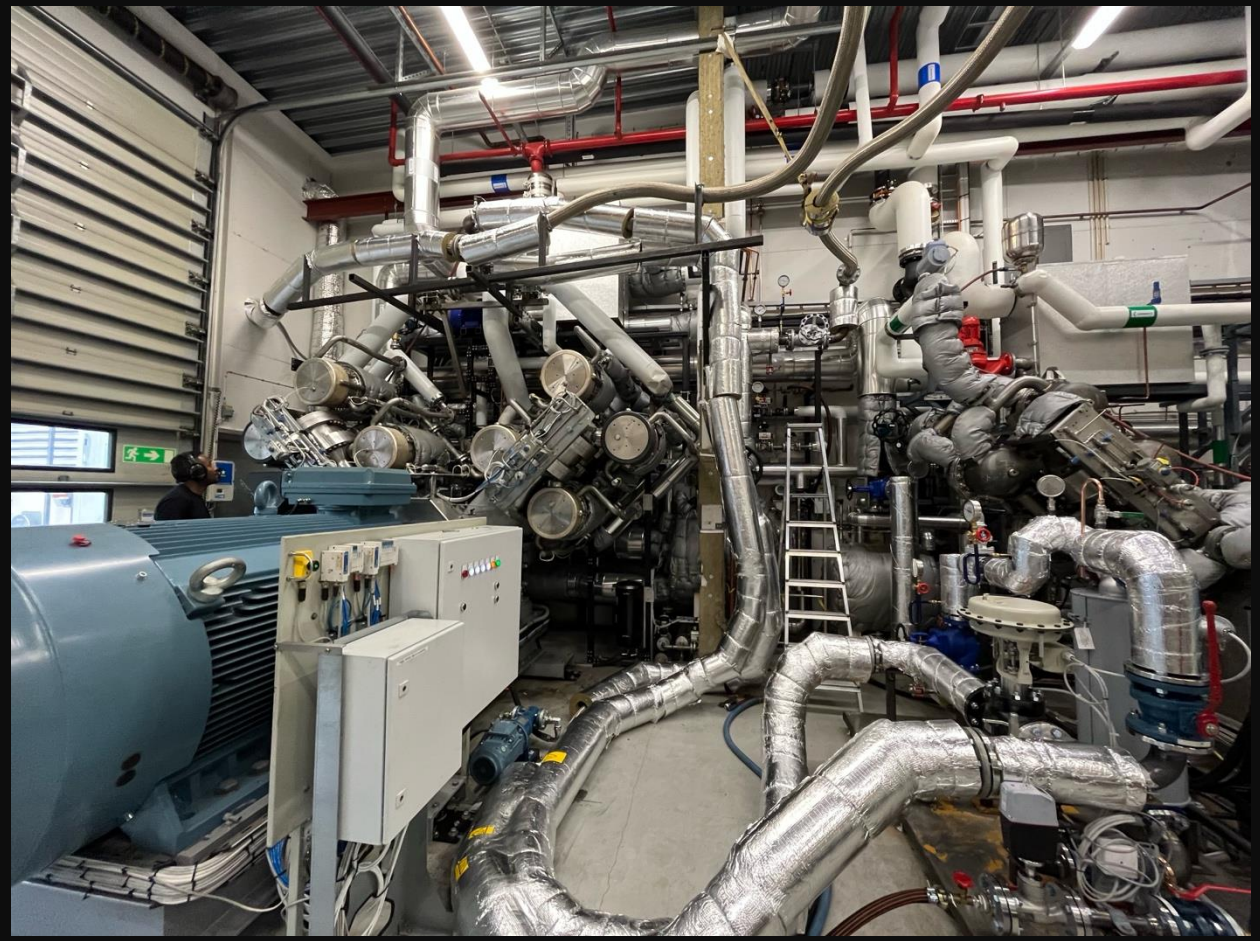
- Heat output: 300 – 740 kW
- Temperature ranges:
  - source: -5 to 120 °C
  - sink: 100 to 183 °C (steam)
- COP_h: 1.4 to 2.5

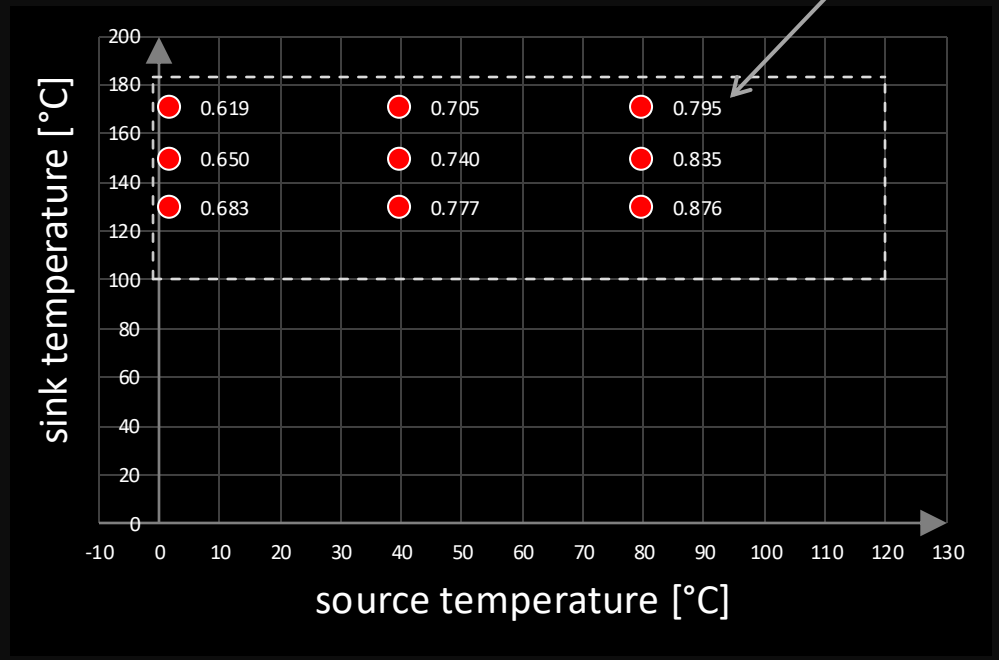
Example applications:

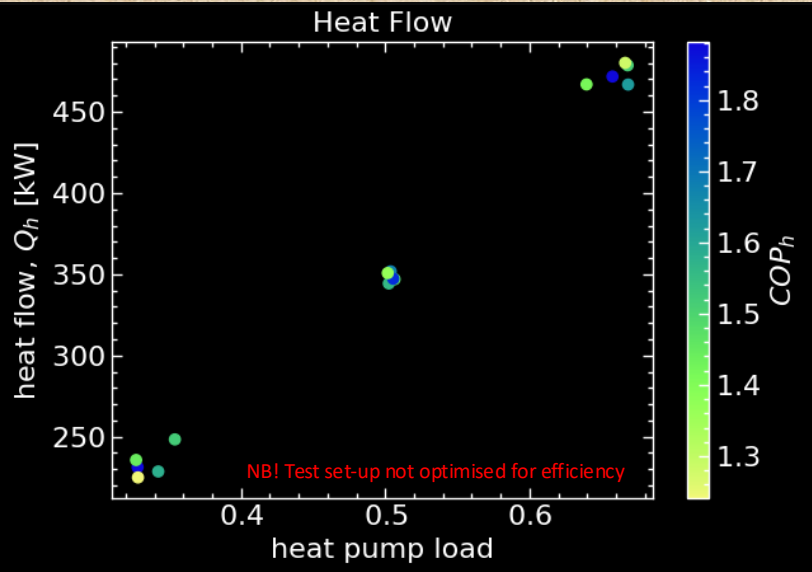
- waste heat recovery
- combined heating and cooling
- district heating (consumer)
- district heating (producer)

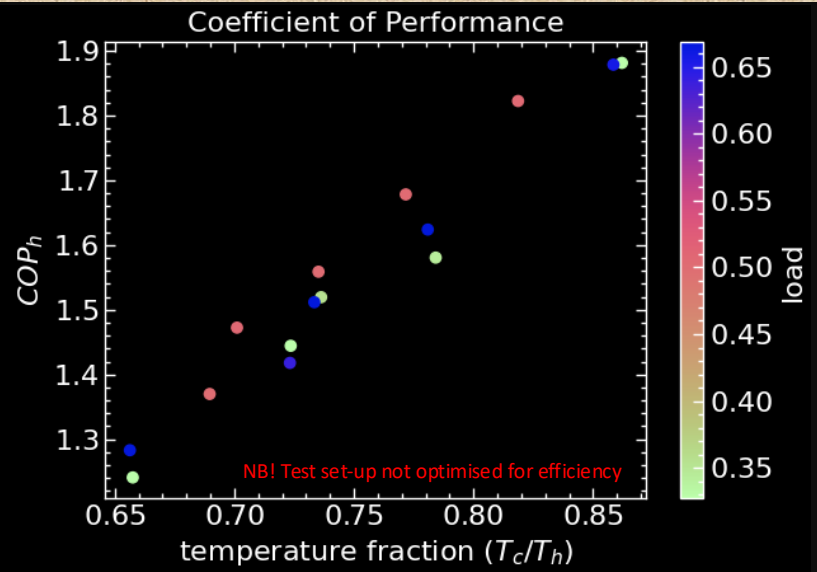
Single heat pump operation range test runs

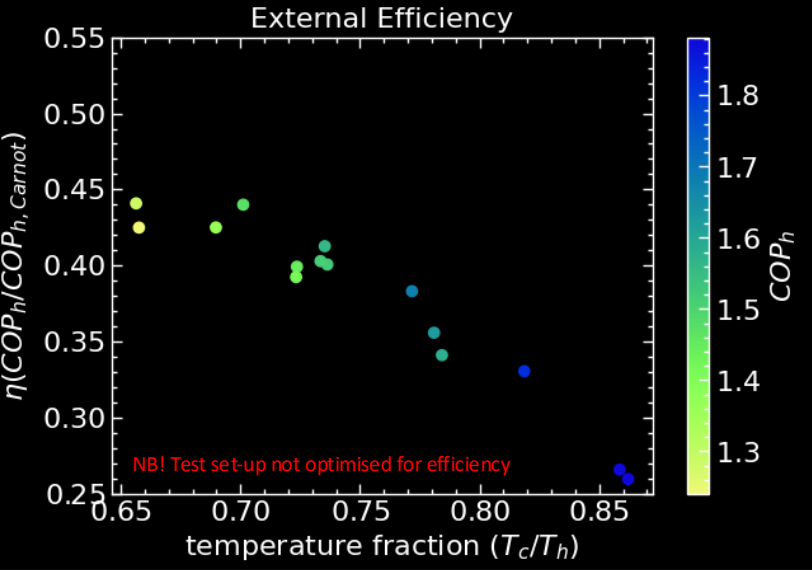
$$T_{frac} = \frac{T_c}{T_h}$$

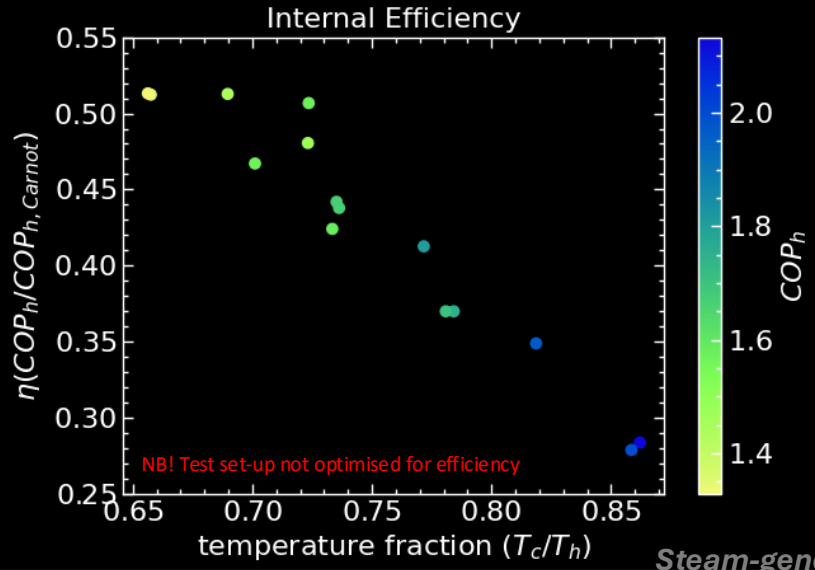






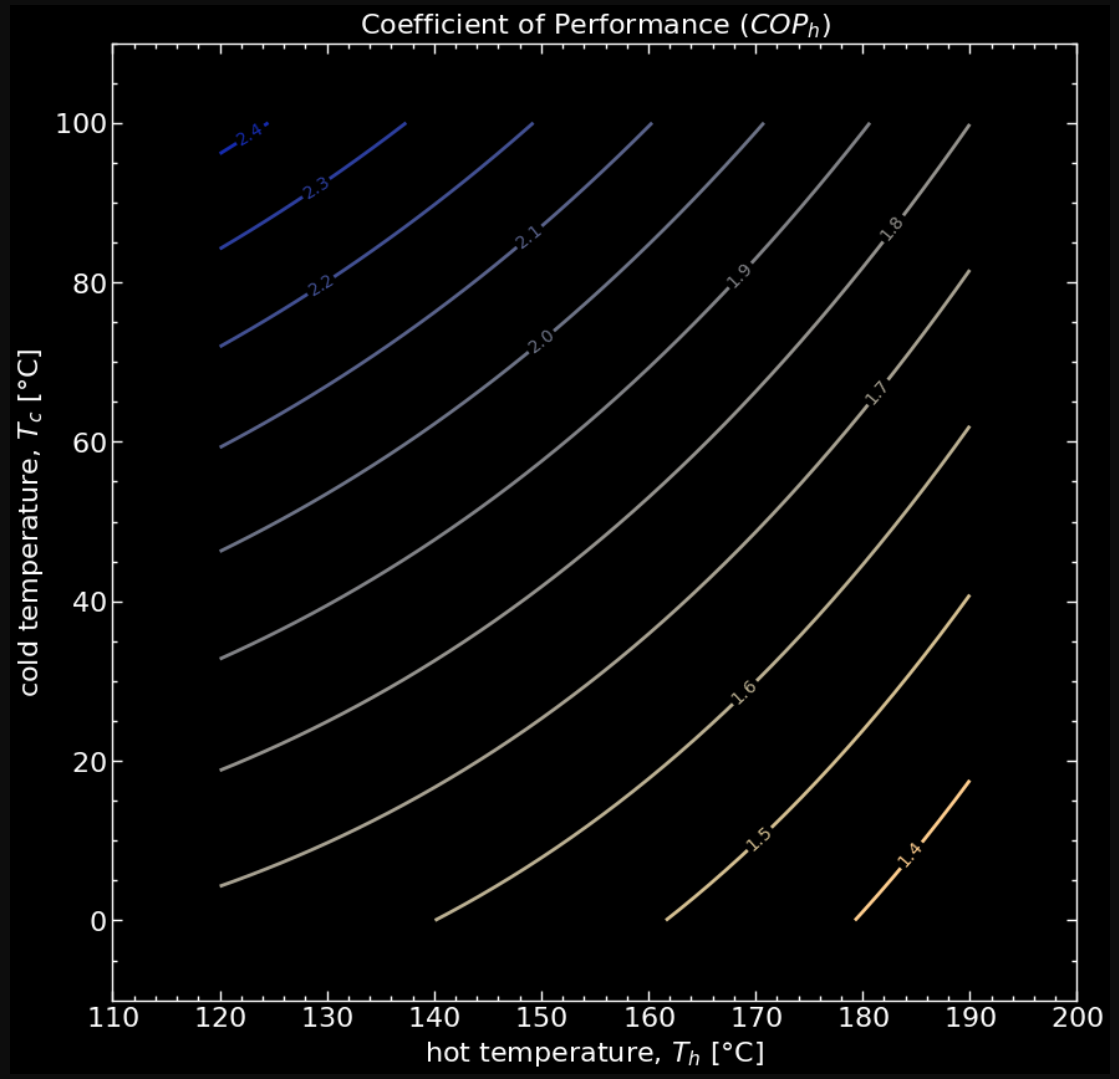


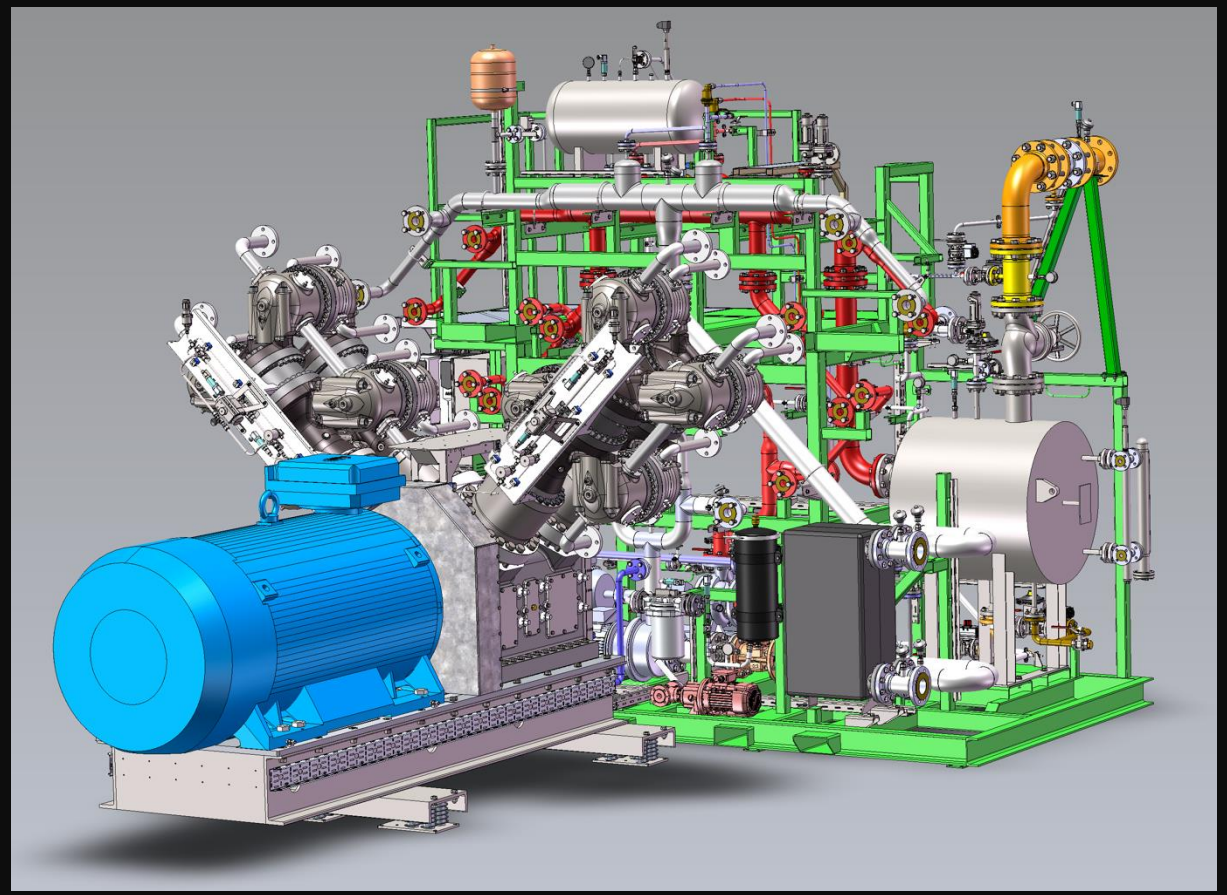




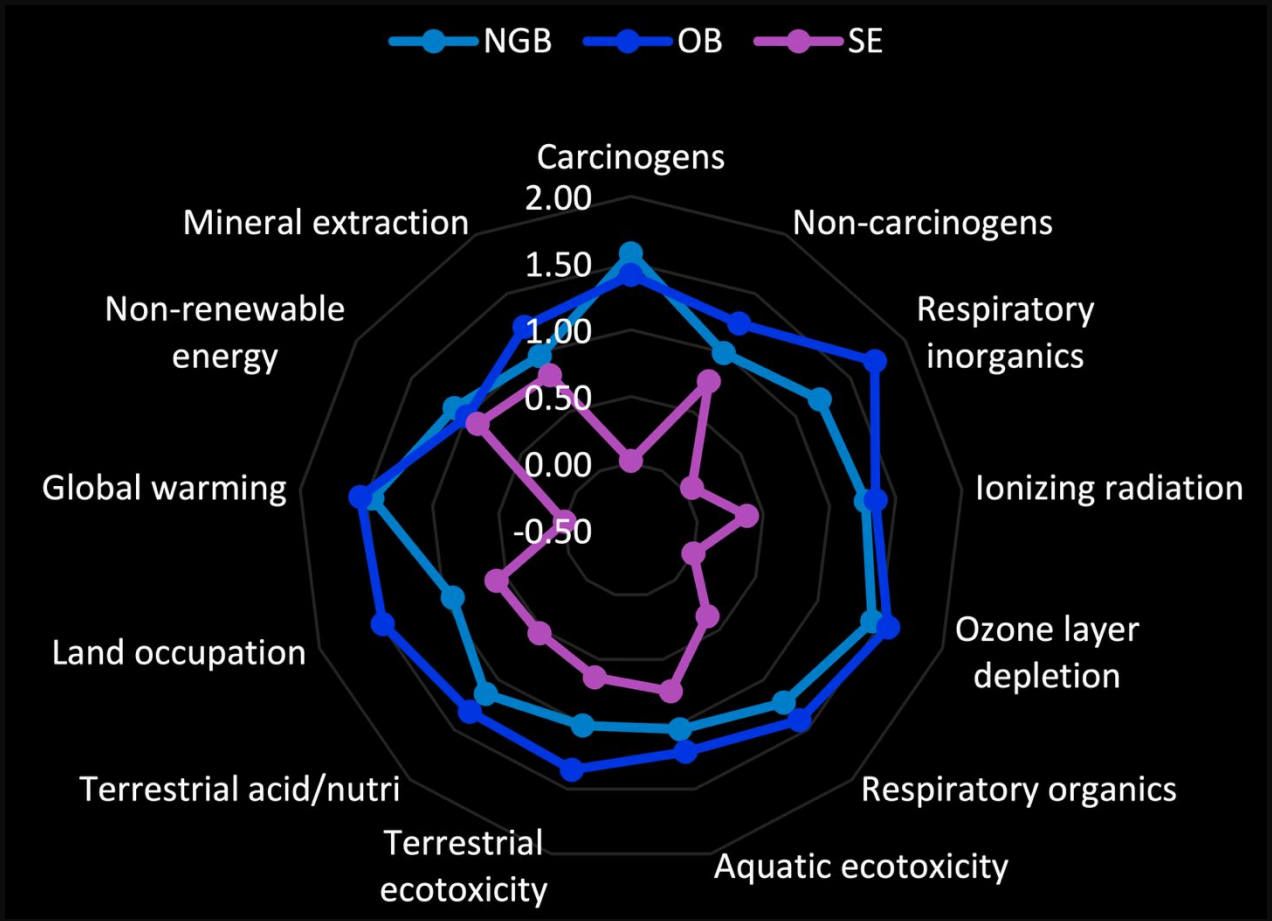
T_c [°C]	T_h [°C]	T_c / T_h [K/K]
2	171	0.619
2	150	0.650
2	130	0.683
40	171	0.705
40	150	0.740
40	130	0.777
80	171	0.795
80	150	0.835
80	130	0.876

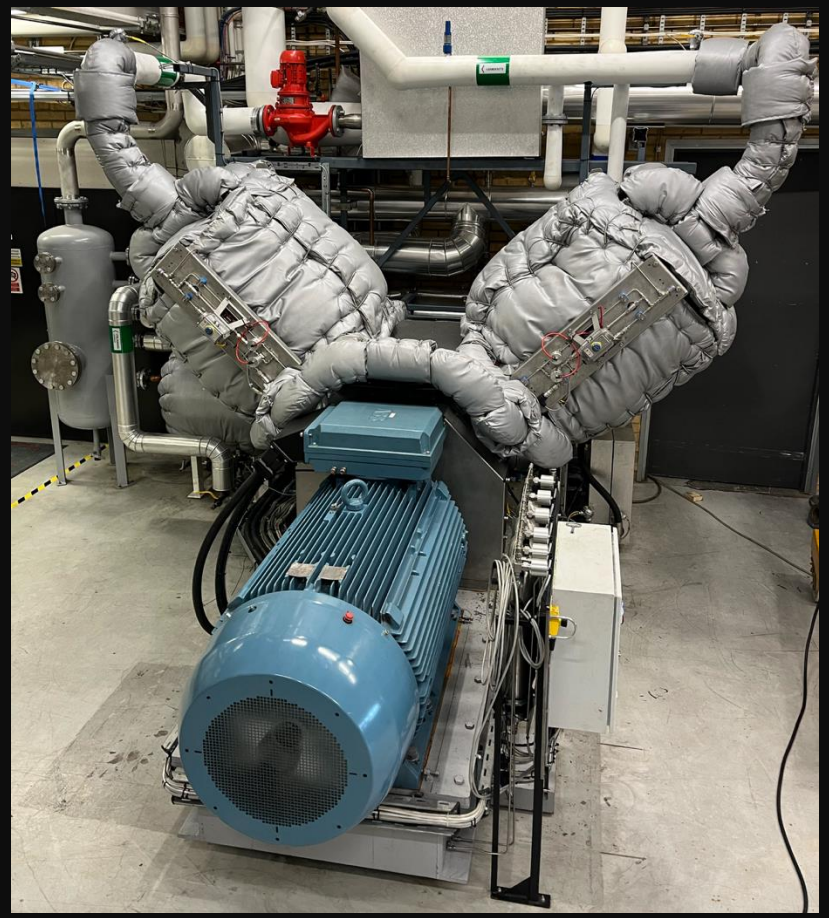
Heat pump performance





Environmental aspects

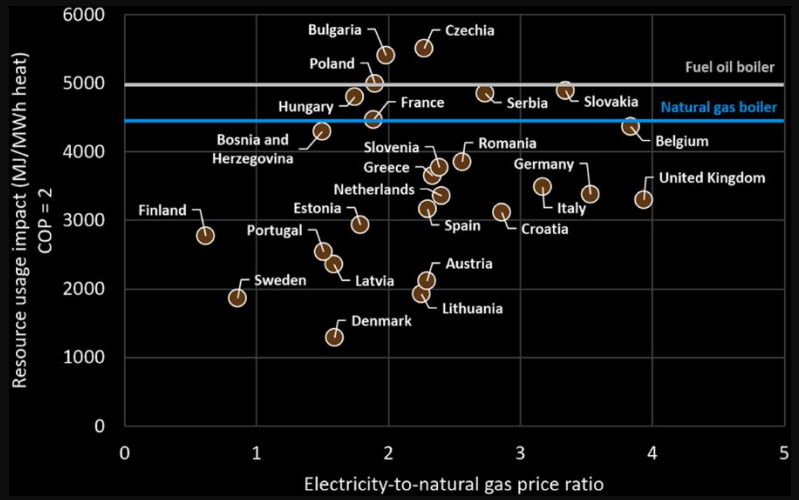


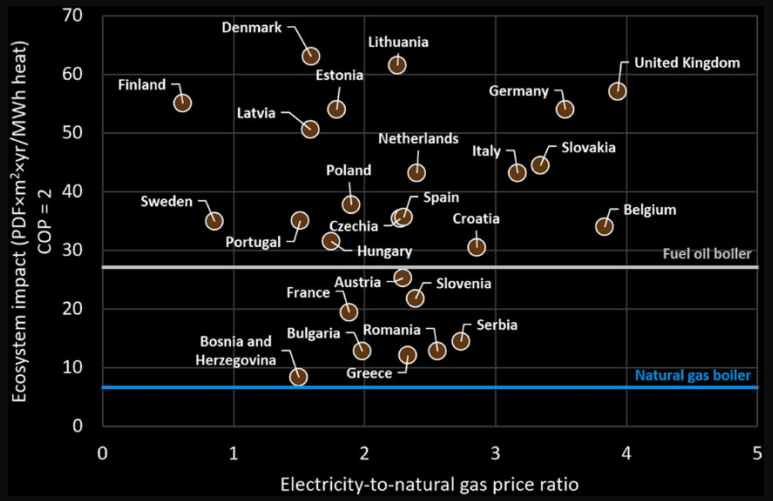


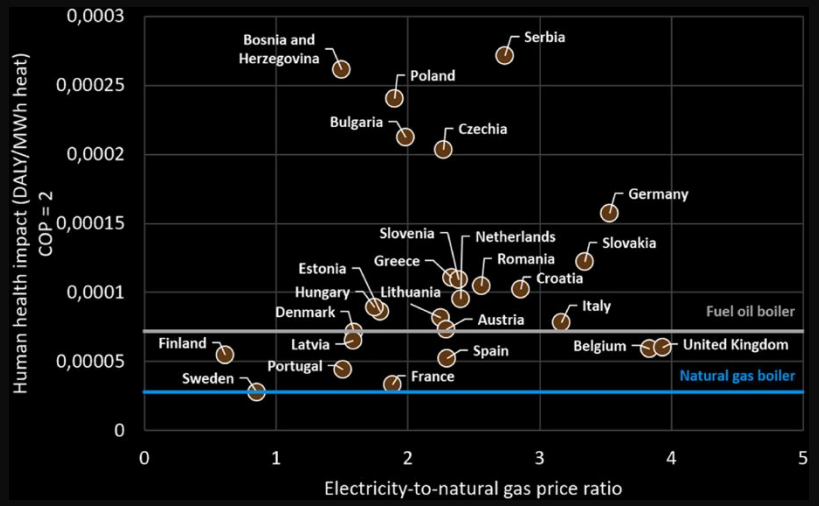
Khan U, Zevenhoven R, Tveit T-M. Evaluation of the Environmental Sustainability of a Stirling Cycle-Based Heat Pump Using LCA. Energies. 2020; 13(17):4469. https://doi.org/10.3390/en13174469

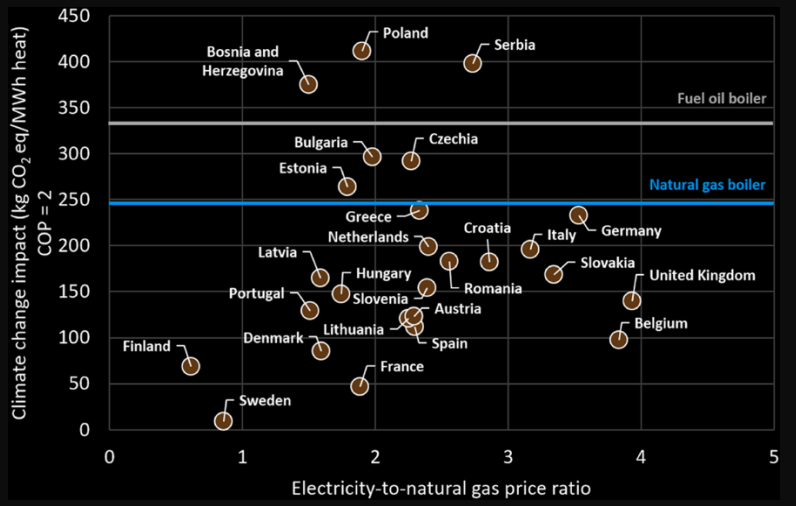
Environmental aspects

Högnabba, K., Tveit, T.-M., Vittor, S., Zevenhoven, R. Economic and environmental considerations for the deployment of industrial very high temperature heat pumps in European markets, Energy, 2024, https://doi.org/10.1016/j.energy.2024.133147.









Thank you for your attention!

http://www.olvondotech.no