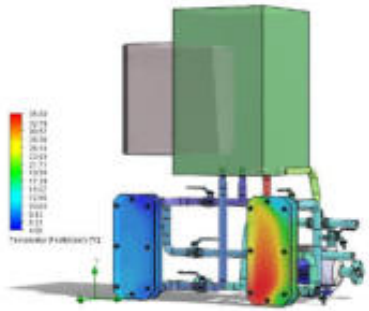
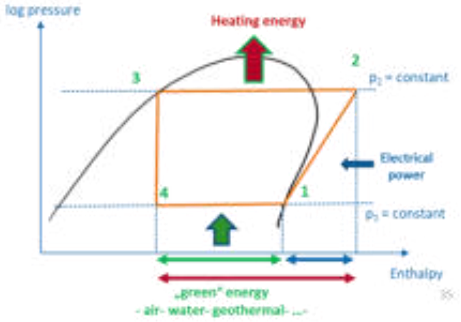
Heat Pump And Utilisation





Tom Ebel, Thomas Grab, Timm Wunderlich, Lukas Oppelt

Supported by

10.05.2023

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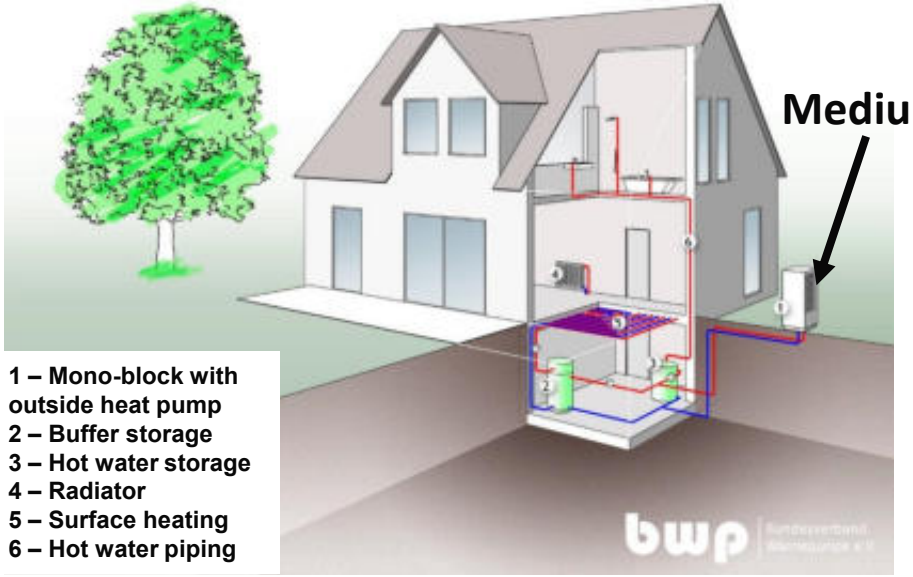
Structure

1. Heat sources and systems
2. Heat Pump Process
3. Refrigerants
4. Practical Heating Systems
5. Market Outlook

1. Heat sources and systems

Air as a heat source

Air heat pump, mono-block type

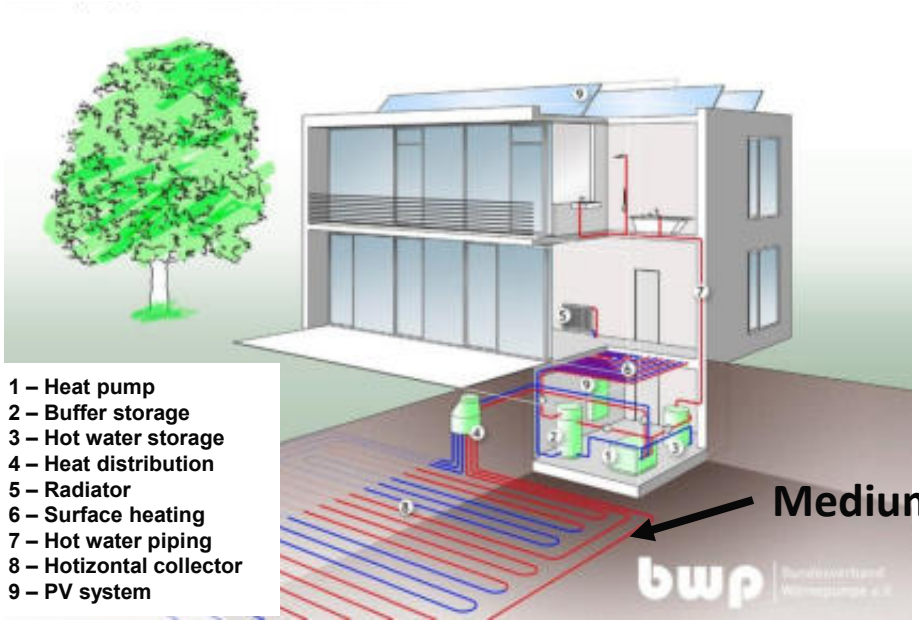


https://www.waermepumpe.de/presse/mediengalerie/grafiken/

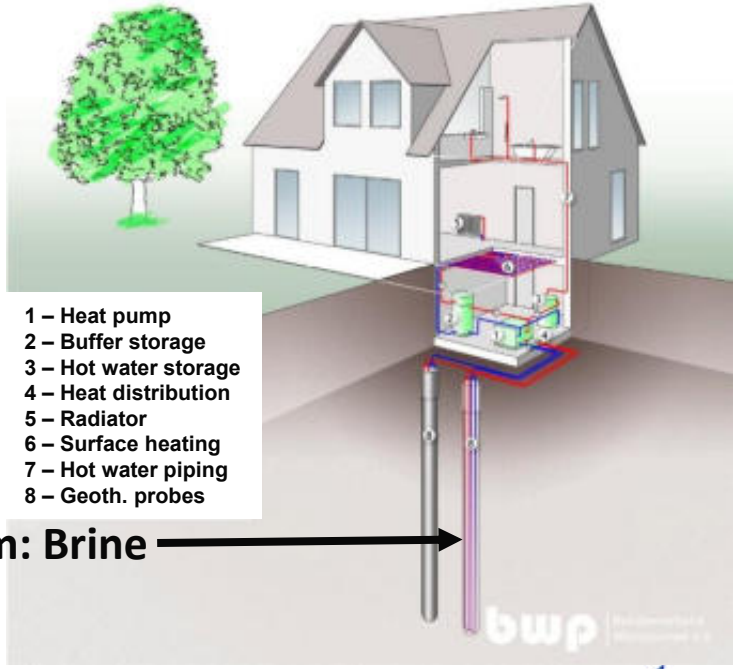
https://www.capital.de/immobilien/der-grosse-waermepumpen-hype-32647838.html

Shallow geothermal energy

Horizontal collector, surface collector



Geothermal probe



Medium: Brine

https://www.waermepumpe.de/presse/mediengalerie/grafiken/

Shallow geothermal energy

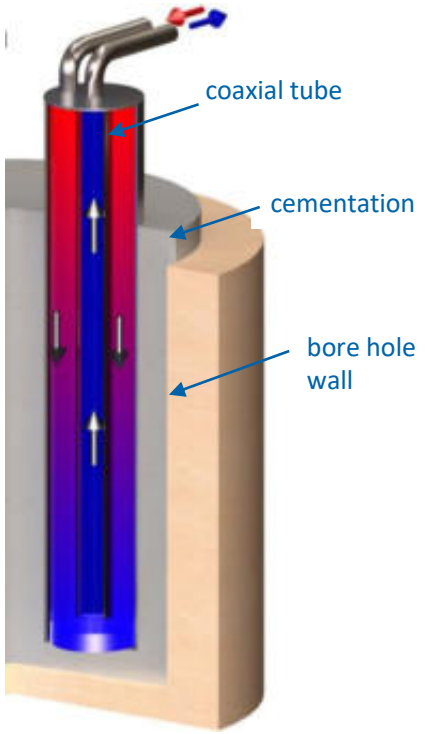
Geothermal Probes:

Pros:
- High efficiency, low operation cost
- Not visible, no noise
- Cooling and heating

Cons:
- Higher initial costs
- Drilling area needed

In general:
- Increasing temperature with depth (3K/100m)
- U-tube, double U-tube or coaxial tube
- 80-200m deep (for households)
- 12-15°C in 100m depth
- rule of thumb: ~40-60W/m depth or ~10-40W/m² collector

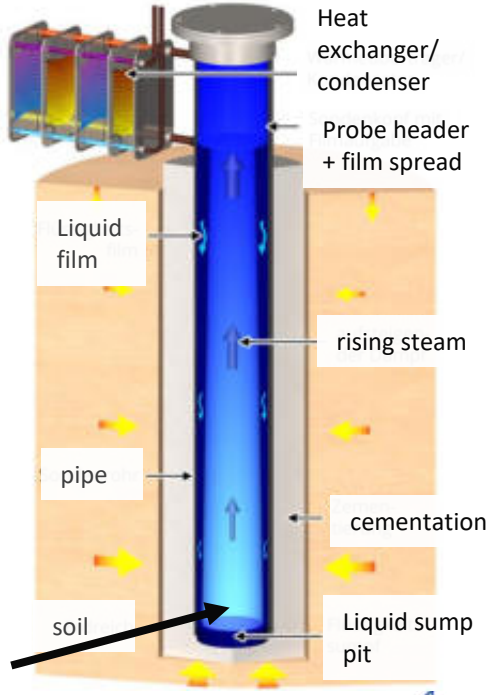
→ Heat Pump is needed for heating!



Shallow geothermal energy

Heat Pipes:

- Liquid film (propane) wets the inner surface of the pipe
- Evaporation due to absorbed geothermal heat
- Uplift of the steam to the probe head
- Condensation of the refrigerant in the heat exchanger and transfer of the heat to the heat pump circuit.
- Continuous backflow of the propane liquid film on the probe wall



Medium: Propane

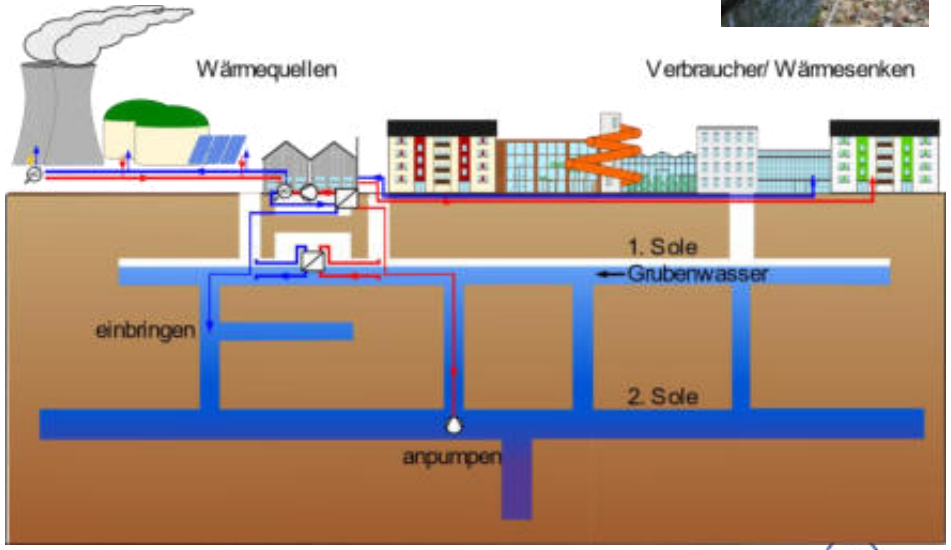
Geothermal mine water systems

Pros:
- Constant temperature
- Large energy reservoirs
- Post-mining land use
- Cooling and heating

Cons:
- Only at former mine sites
- Only big power plants suitable
- Fouling!

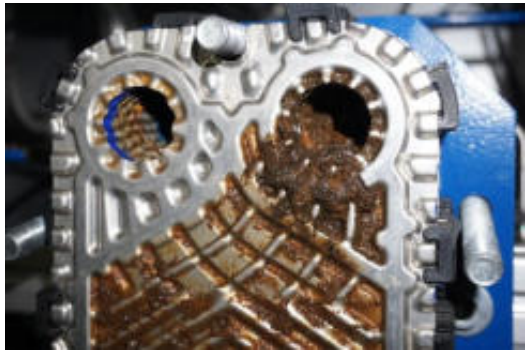
http://www.gupf.tu-freiberg.de/bilder_allgemein/bergbaufrs_m_450x600px.JPG

➢ Heat Pump is needed for heating (in most cases)!



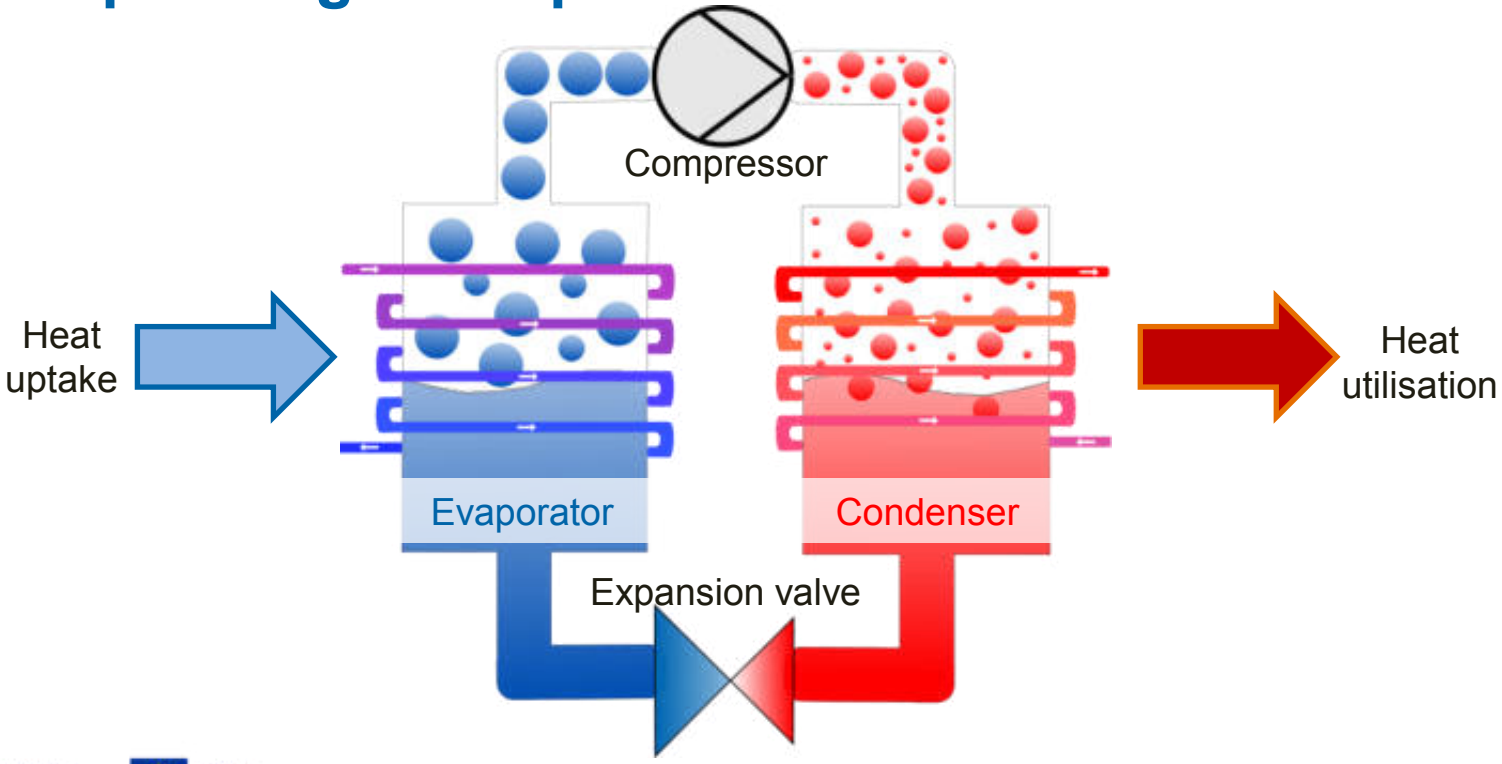
Fouling: Small-scale test rig trials

Deployment at a water treatment plant for radioactive mine water (T = 26 °C !)

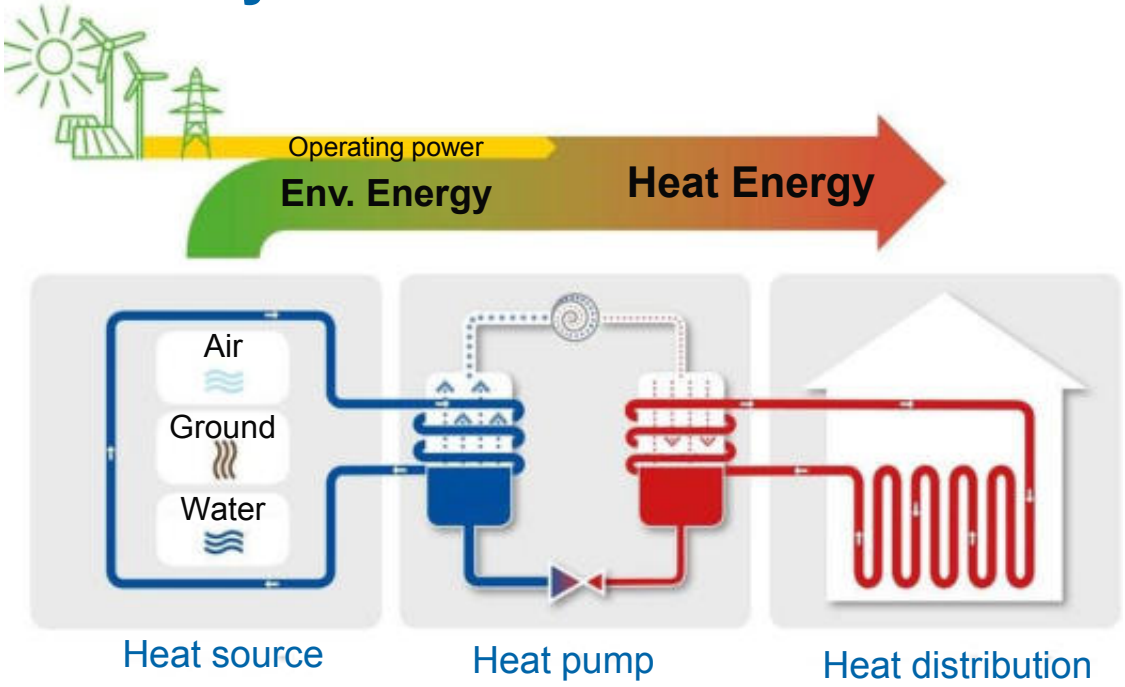


2. Heat Pump Process

Operating Principle

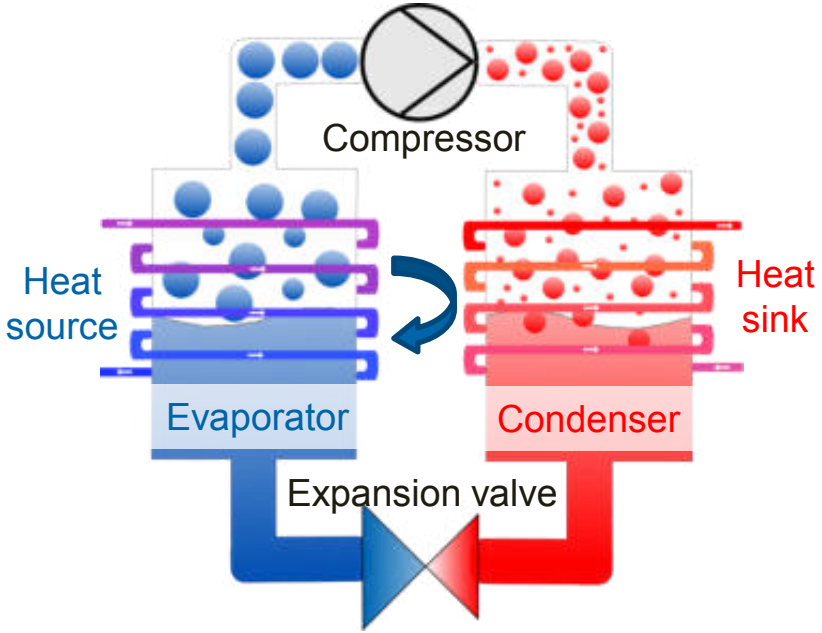


Sustainability



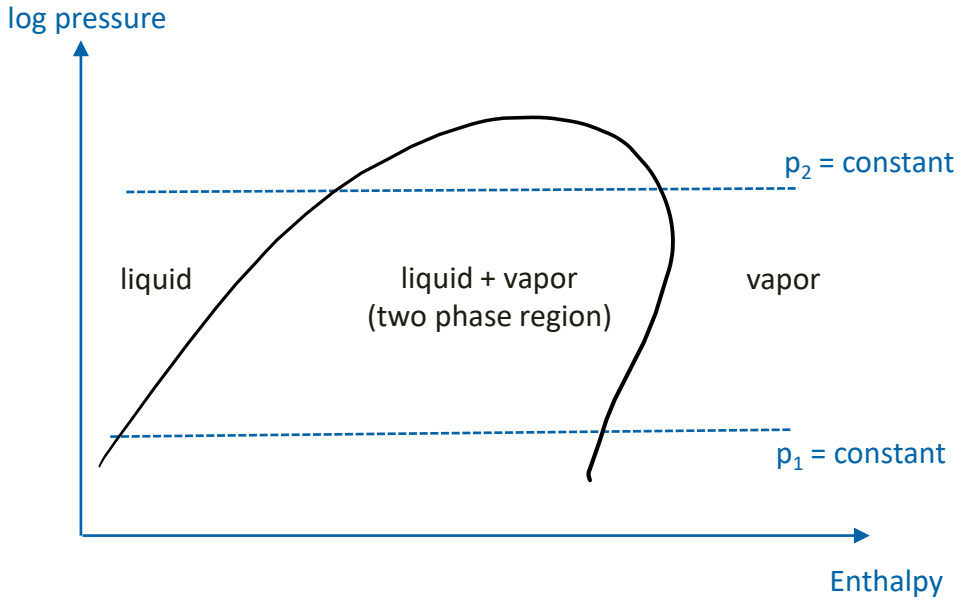
Picture from: https://www.waermepumpe.de/waermepumpe/funktion-waermequellen/

Heat Pump Cycle

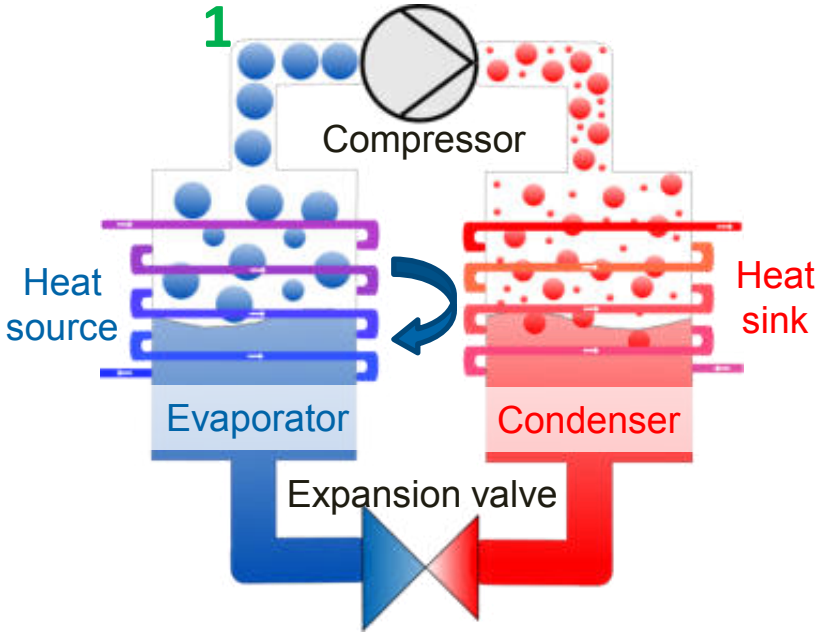


https://www.waermepumpe.de/waermepumpe/funktion-waermequellen/

log p/h diagram from refrigerant
- with ideal heat pump cycle -



Heat Pump Cycle



https://www.waermepumpe.de/waermepumpe/funktion-waermequellen/

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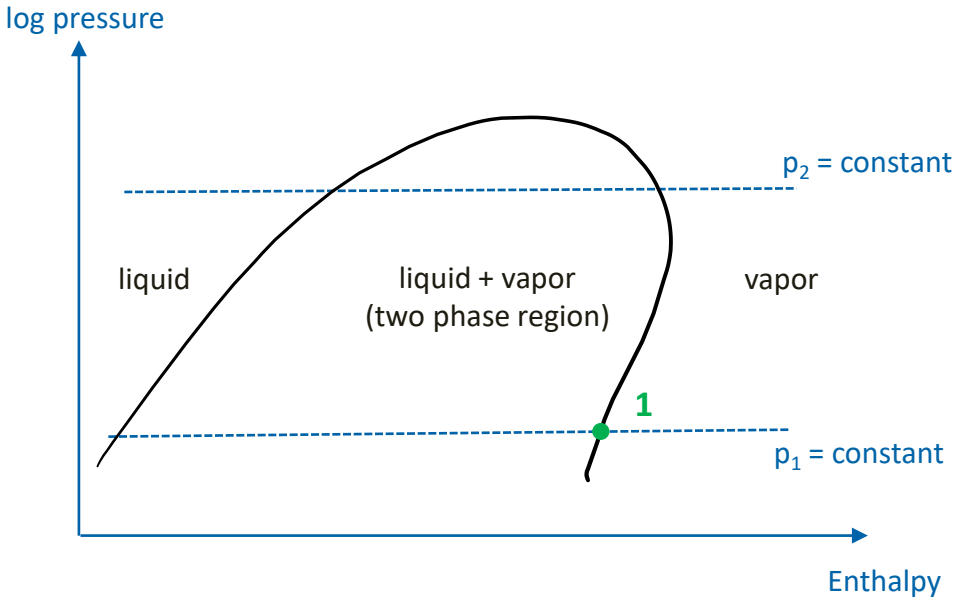
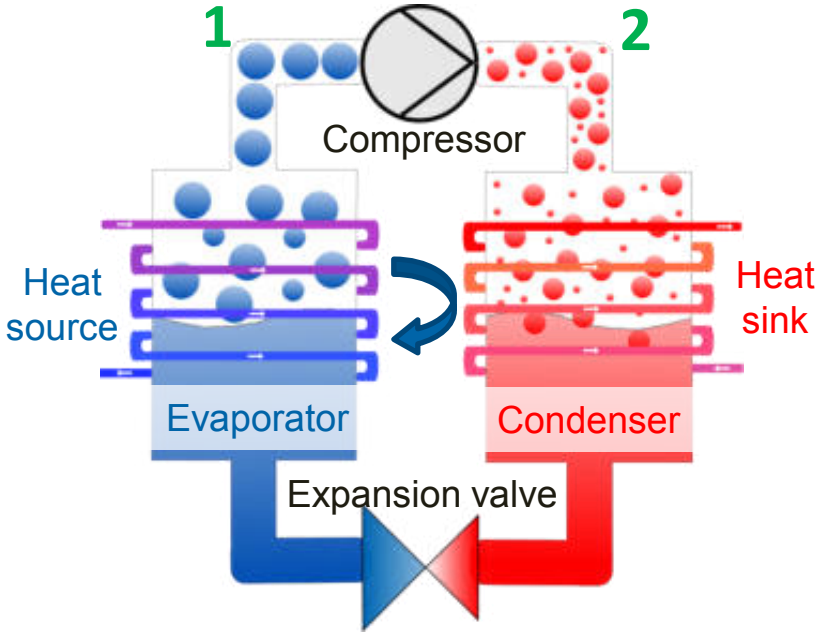


Heat Pump Cycle



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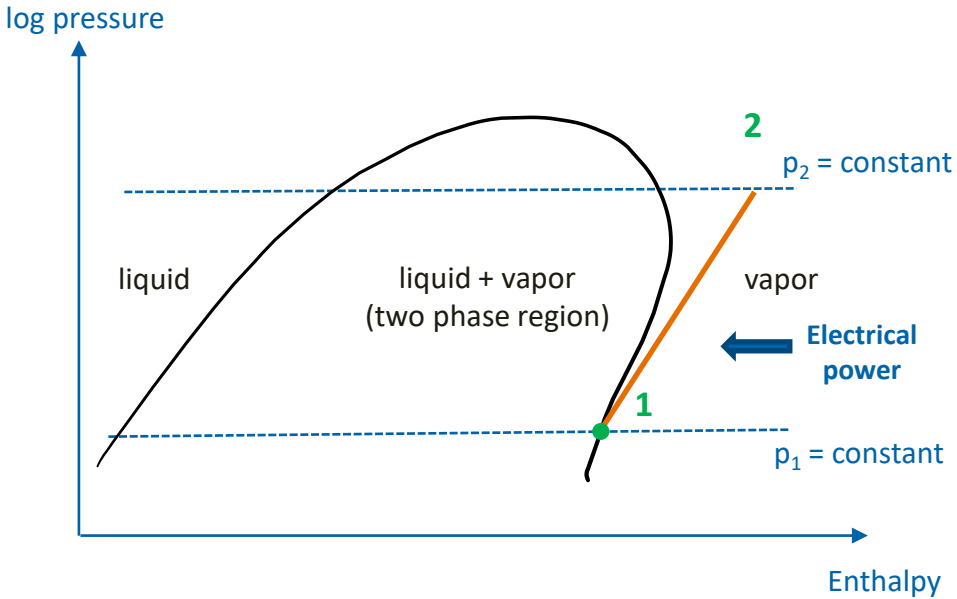
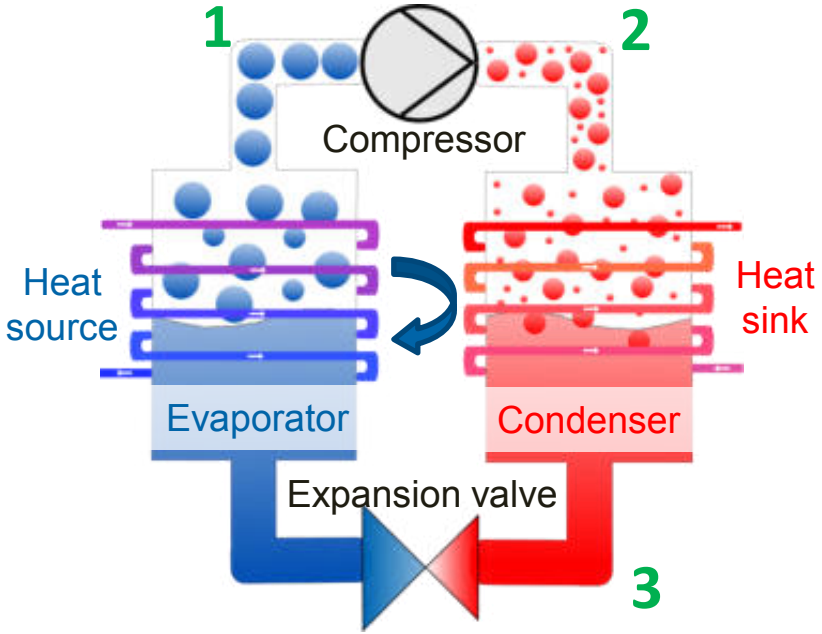


Heat Pump Cycle



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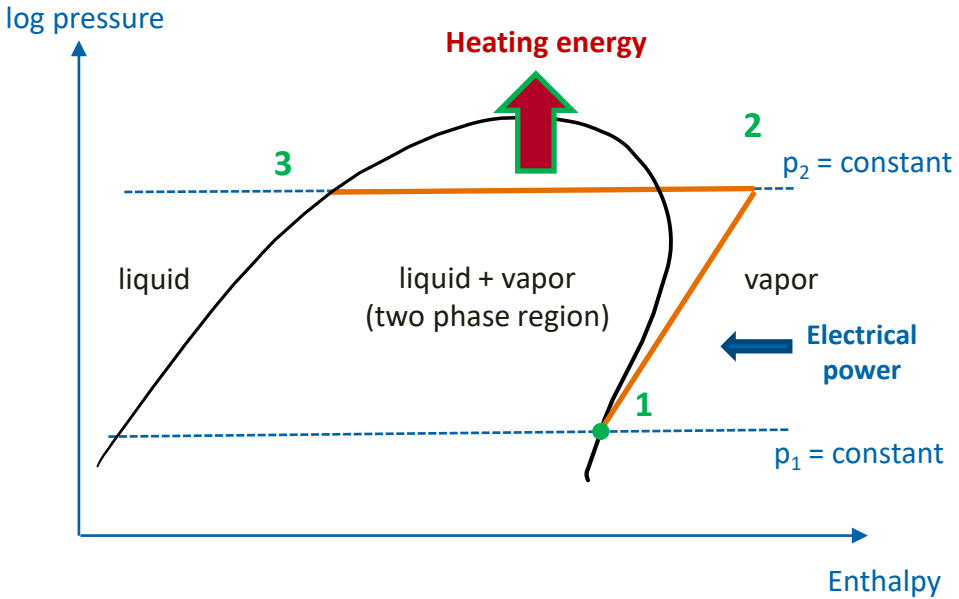
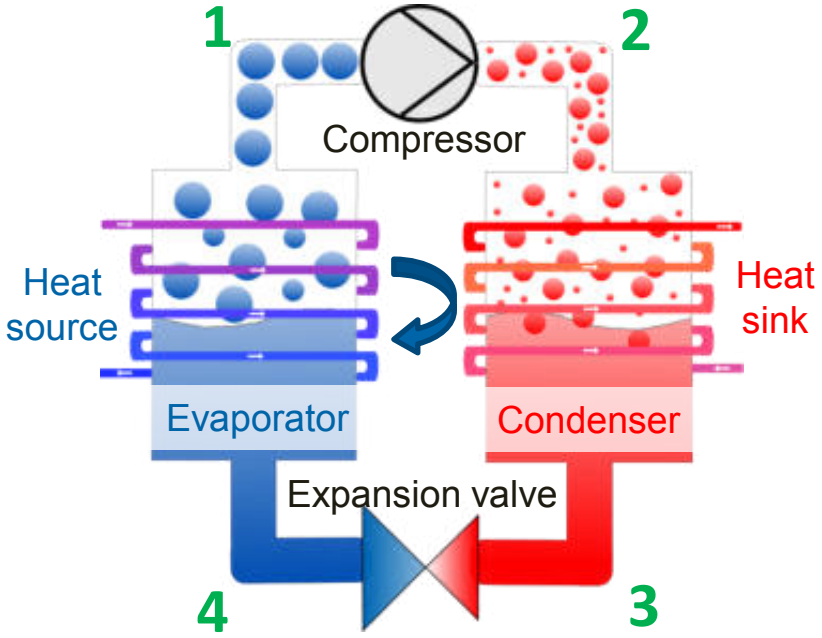
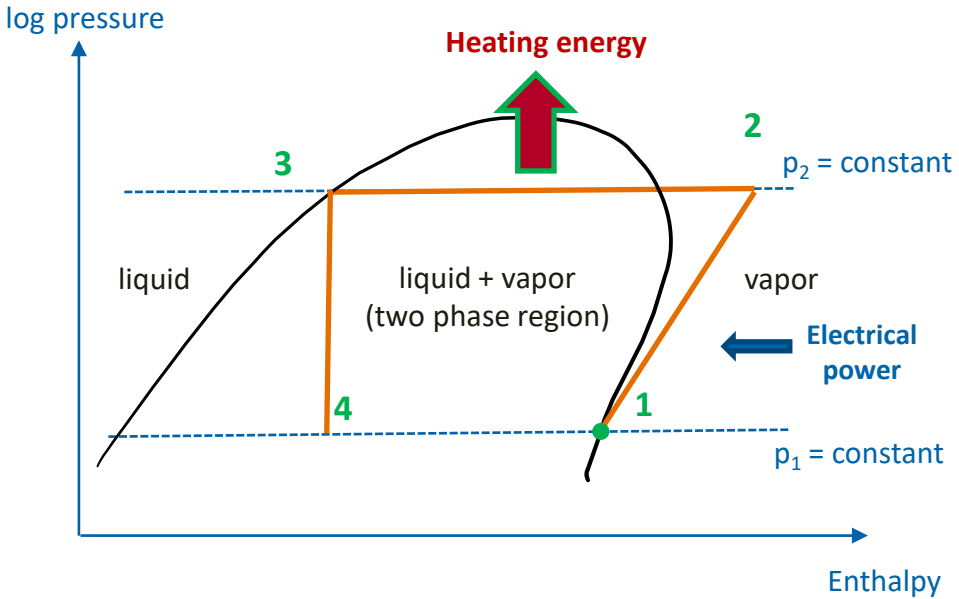


Heat Pump Cycle

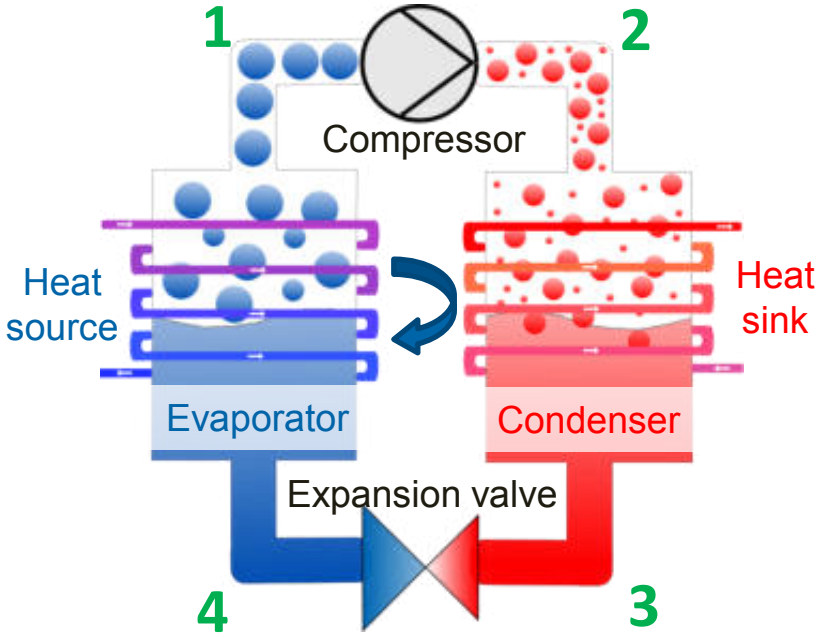


https://www.waermepumpe.de/waermepumpe/funktion-waermequellen/

log p/h diagram from refrigerant
- with ideal heat pump cycle -



Heat Pump Cycle



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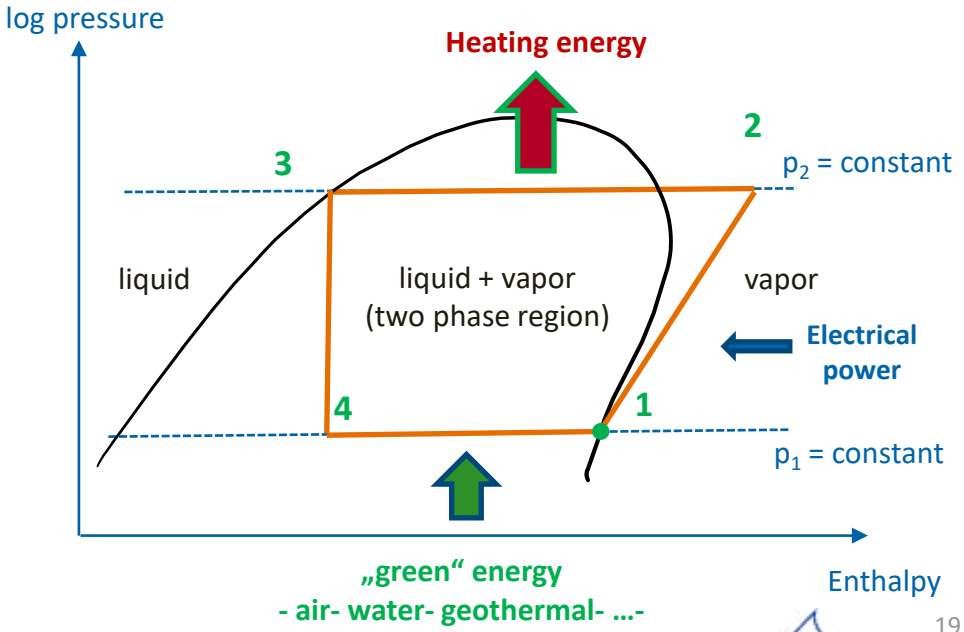


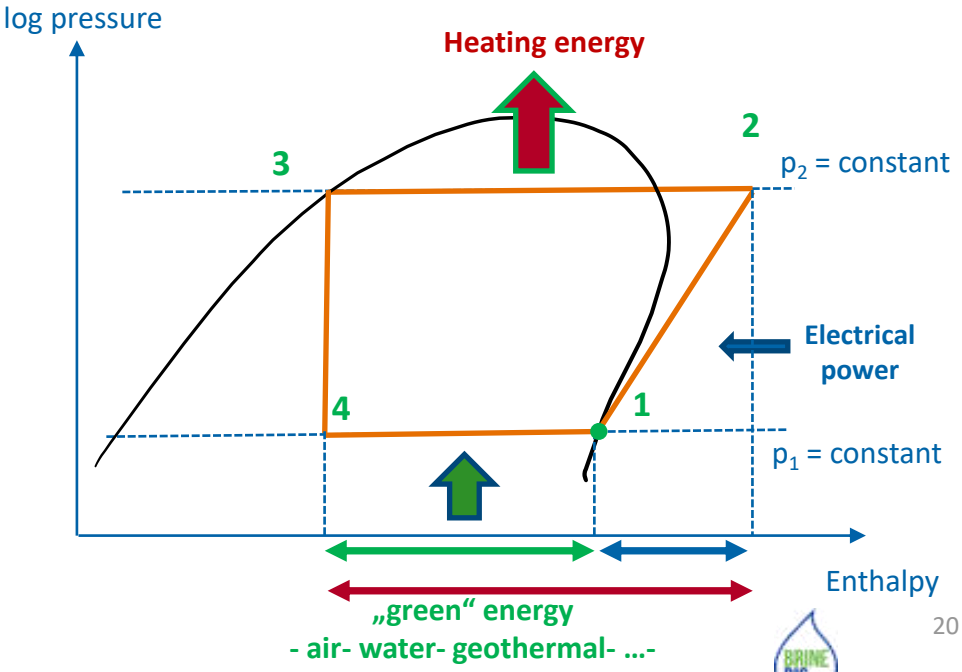
Heat Pump Cycle

Performance:

$$COP = \frac{\text{Heating Energy}}{\text{Electrical power}} \quad > 3 \text{ to } 6 \text{ !!!}$$

Out of 1 kWh **electricity** you can get 3-6 kWh **heat** or **cold**. The main part of energy is coming from the **environment !**

log p/h diagram from refrigerant
- with ideal heat pump cycle -



COP: Coefficient of performance

3. Refrigerants

Overview

- Designation: R-XYZ (i.e. R-290)
  - R = Refigerant; X, Y and Z indicate the composition of the substance
- Specificical property requirements:
  - Physical (i.e. heat conduction, evap. enthalpy …)
  - Chemical (stability, no corrosiveness …)
  - Physiological (no toxicity, no smell, not flammable)
  - Ecological (no ozone depletion, no GWP, no harmful degradation substances)

- Improved technology & ecological awareness

→ Commercial and private paradigm shift in refrigerant use!

1: www.istockphoto.com
2: www.shutterstock.com

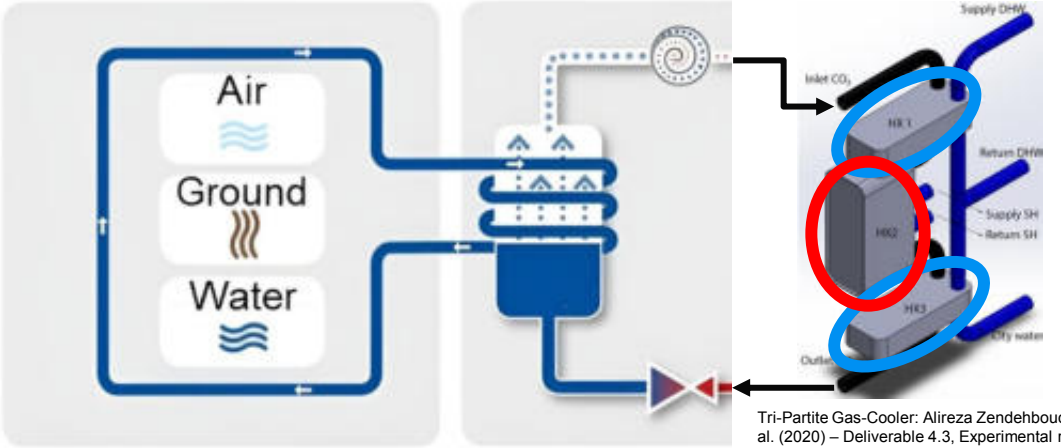
Refrigerant development

Original refrigerants	Transition refrigerants	Medium/long term refrigerants
FCKW R-11 R-12 HFCKW R-401A	FKW/HFKW R-23 R-32 R-404A R-407C	Natural ref. R-170 (Ethan) R-290 (Propan) R-744 (CO_2) R-717(NH_3)
New use prohibited	Restricted use allowed	No use limitations

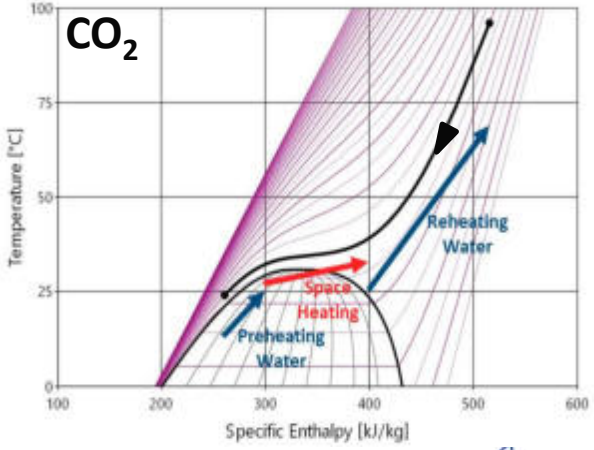
Natural refrigerants

Ammonia NH_3	(R-717)	=	-33,0 °C at 1,00 bar
Propane	(R-290)	=	-42,0 °C at 1,00 bar
Carbondioxid CO_2	(R-744)	=	-57,0 °C at 1,00 bar
Water	(R-718)	=	+100 °C at 1,00 bar

Natural refrigerants = high pressure = high temperature 65 °C to 75°C possible!



Tri-Partite Gas-Cooler: Alireza Zendehboudi et al. (2020) – Deliverable 4.3, Experimental results of a tri-partite gas cooler



4. Practical Heating Systems

Range of Application

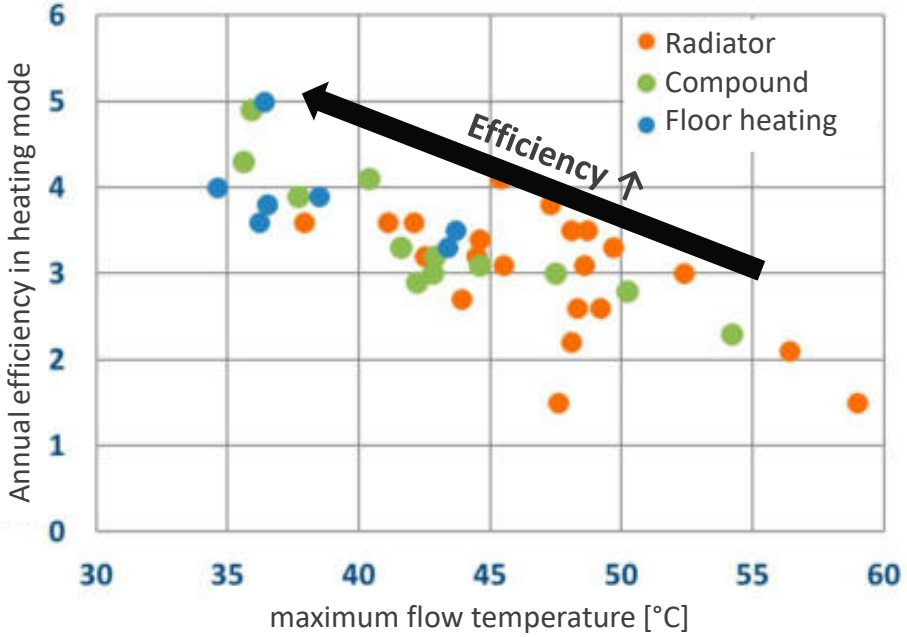
1 to 5 kW

https://www.nieters-haustechnik.de/marke_hersteller_produkte/nibe/neuheiten/abluft-waermepumpe-foerderfaehig

> 20.000 kW

https://tlk-energy.de/projekte/grosswaermepumpe

Household Applications - Efficiency



https://tga.at/errichten/nicht-nur-im-neubau-effizient/ Dr. Marek Miara, Fraunhofer ISE

Household Applications - Radiators

Important:

- Size, Surface, Material
- Inlet temperature
- Field of application

Pro:

- Common, cheaper
- Simple control

Con:

- Efficiency
- Heat dispersion!!
- No cooling
- Maintanance

https://www.ibc-heiztechnik.de/produkte/gussheizkoerper

https://de.wikipedia.org/wiki/Heizk%C3%B6rper

https://www.energie-experten.org/heizung/heizungstechnik/heizkoerper/mit-geblaese

Low temperature radiators

Household Applications – Floor Heating

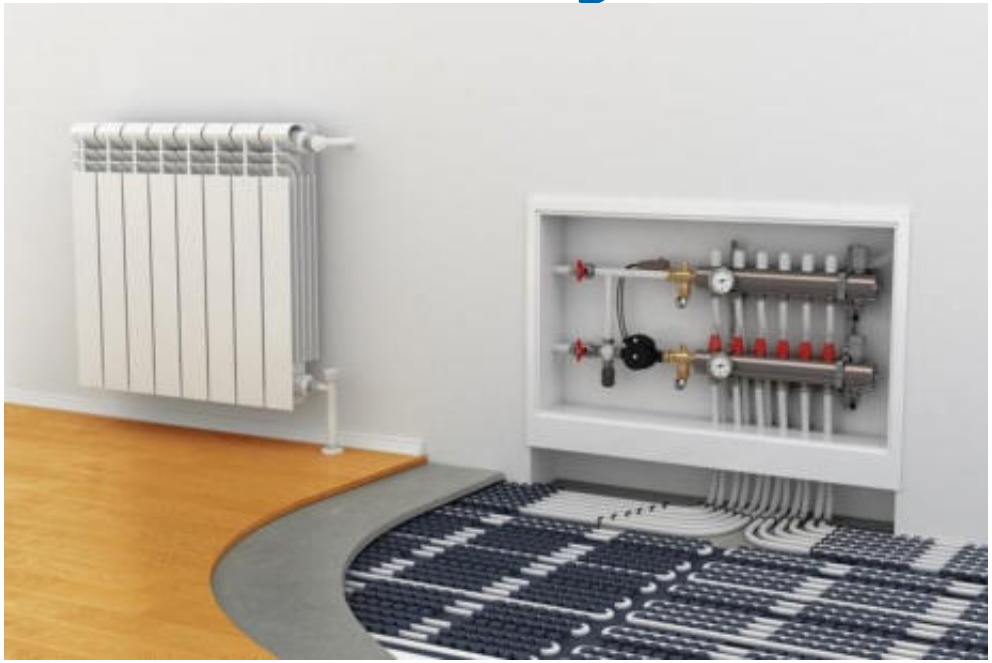
Rising popularity because of synergy with heat pumps.

Pro:

- Heat Source
- Efficiency
- Cooling possible

Con:

- Mostly in new buildings
- Thermal response
- Precise design calculations



https://www.waermepumpe.de/waermepumpe/kuehlen-mit-der-waermepumpe/

Household Applications – Ceiling Heating

Tubes or tube mats in ceiling create thermally active surface.

Pro:

- Retrofitability
- Heat Dispersion (Radiation)
- Cooling efficient
- Thermal response
- No furniture obstruction

Con:

- More expensive
- Less efficient

https://www.waermepumpe.de/waermepumpe/kuehlen-mit-der-waermepumpe/

Sarbu I. 2018: Performance of Radiant Heating Systems of Low-Energy Buildings

Large Scale Applications – Sector coupling

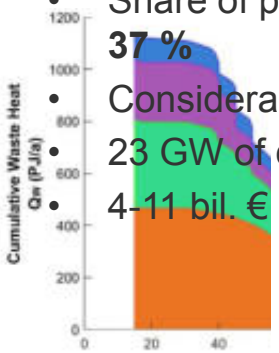
- Heat pumps enable efficient utilization of energy peaks (wind, PV)
- Direct use of electricity already in practice (i.e. Nechlin village in Brandenburg)
  - Large water tanks (1000 m³)
  - heating rod activated on peak days
  - Hot water up to two weeks
  - Minimal cost

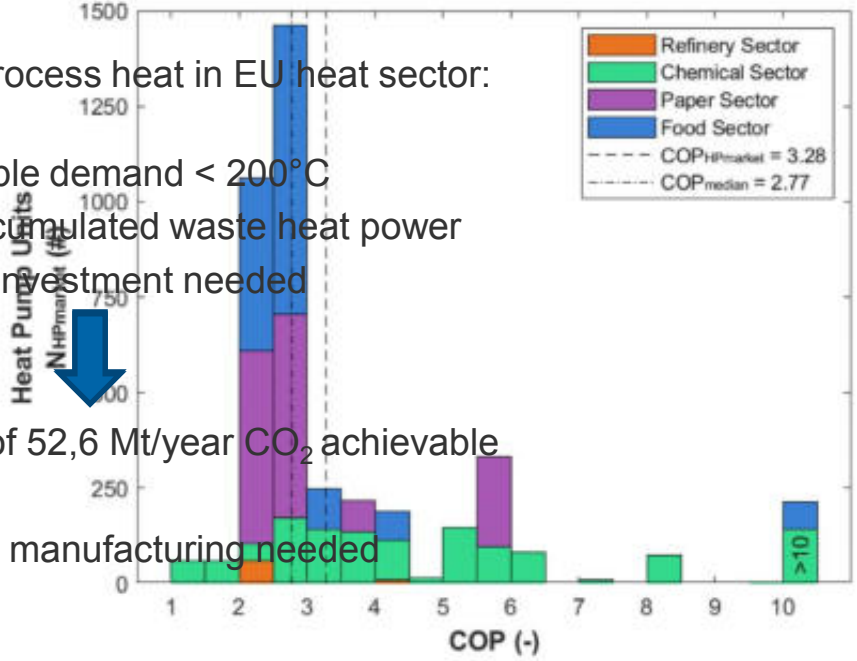
→ Combination with **heat pumps** enables even larger and more efficient energy supply

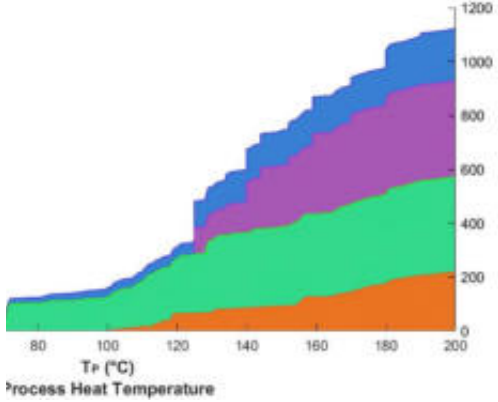
https://enertrag.com/en/products/wind-based-thermal-energy

Large Scale Applications - Process Heat

- Share of process heat in EU heat sector: **37 %**
- Considerable demand < 200°C
- 23 GW of cumulated waste heat power
- 4-11 bil. € Investment needed







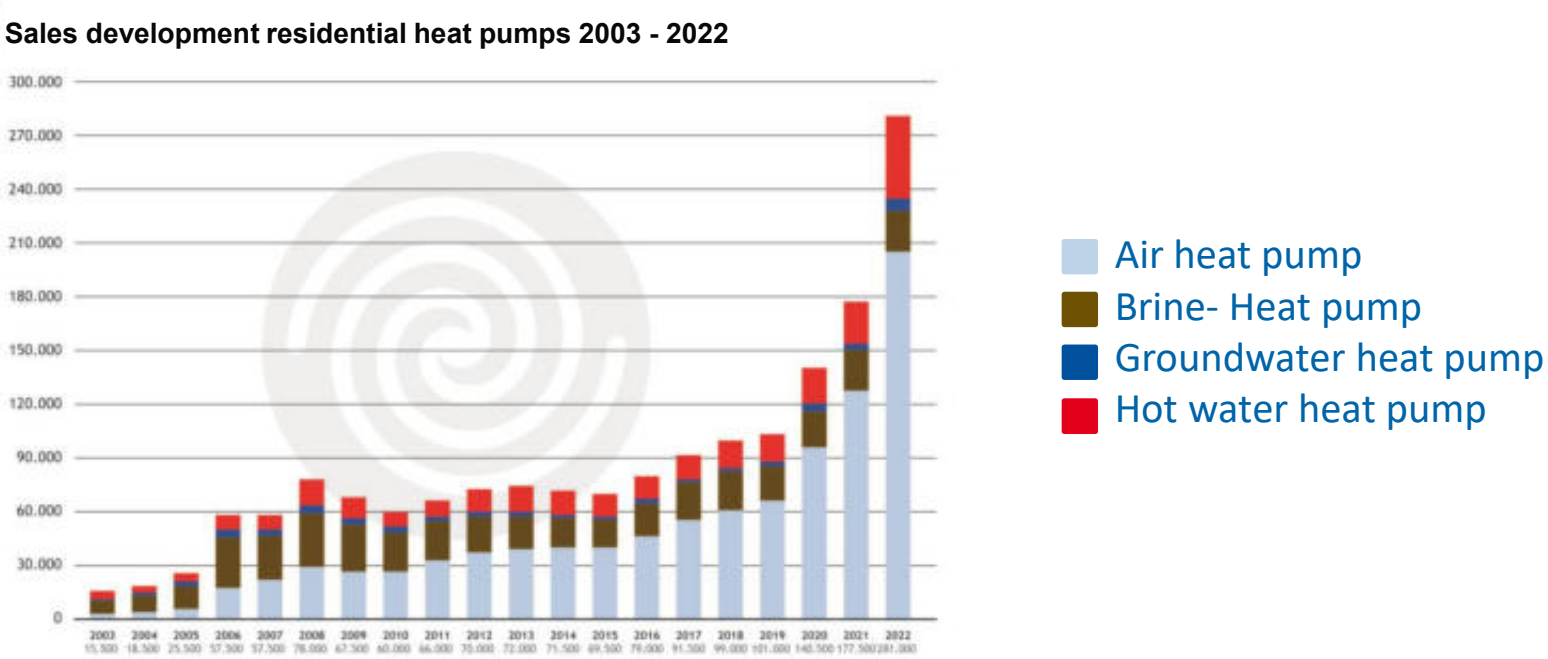
Savings of 52,6 Mt/year CO_2 achievable

→ Large scale manufacturing needed

Marina A. 2021: An estimation of the European industrial heat pump market potential https://heatroadmap.eu/wp-content/uploads/2019/03/Brochure_Heating-and-Cooling_web.pdf

5. Market Outlook

Sales development of heat pumps in Germany 2002-2022

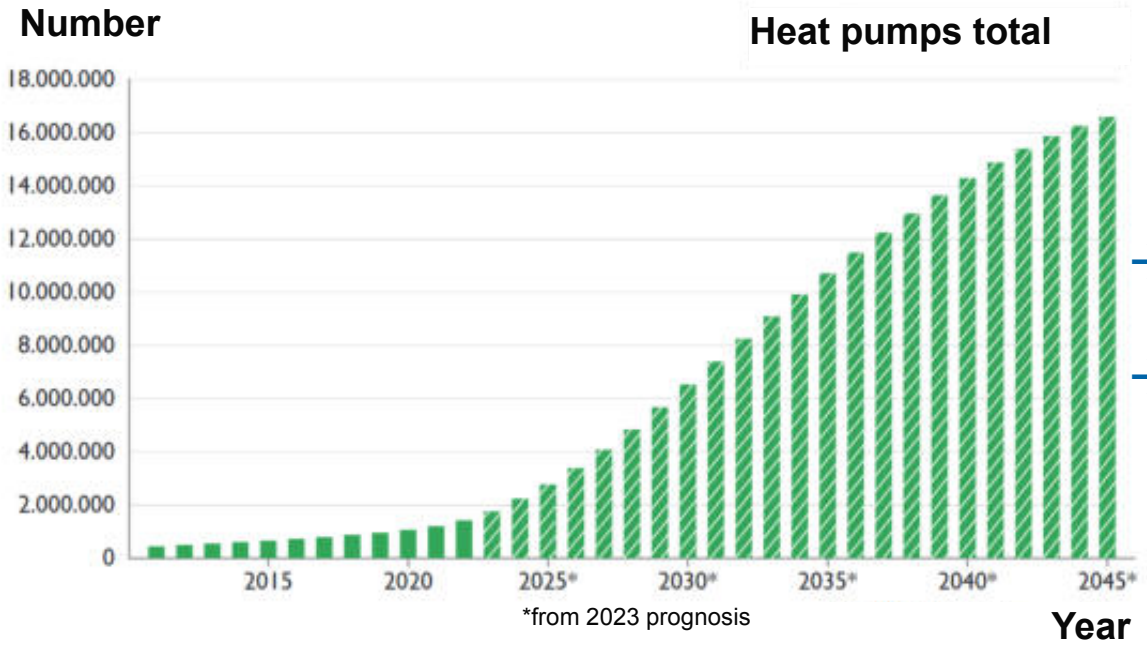


Sales development Q1 2022 compared to the same period of 2021 (Germany)

	Sales 2022	Comparing 2021	Source share
Total number of heat pumps	**236.000**	**+53 %**	
Soil	**31.000**	**+14 %**	**13 %**
Brine	23.500	+ 2 %	
Groundwater and other	7.500	+ 84 %	
Air	**205.000**	**+ 61 %**	**87 %**
Type: Mono block	140.000	+ 67 %	
Type: Split	65.000	+ 49 %	
Total number of warm water heat pumps	**45.500**	**+ 93 %**	

BWP e.V.

Sector survey HP Sales (2022-2045) GER

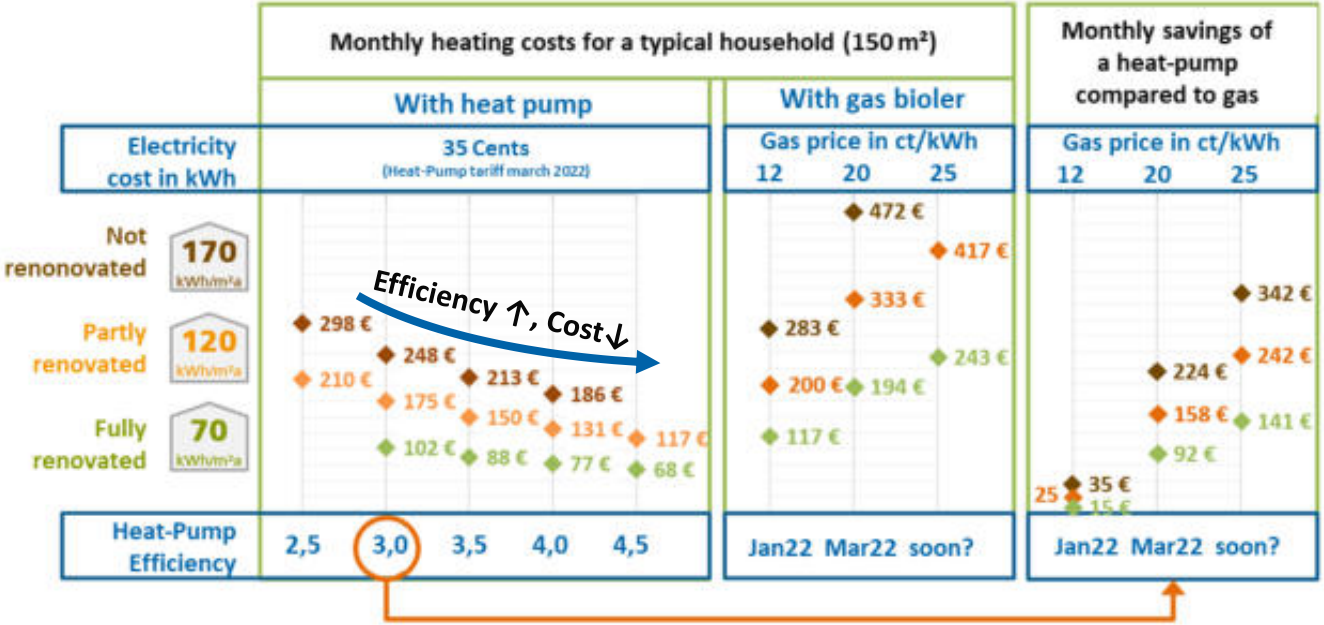


→ 6 Mio. HP in 2030

→ 17 Mio. HP in 2045

https://www.waermepumpe.de/fileadmin/user_upload/waermepumpe/05_Presse/01_Pressemitteilungen/BWP_Branchenstudie_2023_DRUCK.pdf

Cost Comparison Gas / Heat Pump



https://blog.innovation4e.de/2022/04/08/warmepumpen-oekonomische-betrachtung-der-betriebskosten-neue-sichtweise/

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geothermie.iwtt.tu-freiberg.de

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