Large scale heat pumps

Integration of multiple heat sources & flexibilisation of DH-systems

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LowTEMP training package - OVERVIEW

Introduction

- Intro Climate Protection Policy and Goals
- Intro Energy Supply Systems and LTDH
- Energy Supply Systems in Baltic Sea Region

Energy Strategies and Pilot Projects

- Methodology of Development of Energy Strategies
- Pilot Energy Strategies – Aims and Conditions
- Pilot Energy Strategy – Examples
- Pilot Testing Measures
- CO_2 emission calculation
- LCA calculation

Financial Aspects

- Life cycle costs of LTDH projects
- Economic efficiency and funding gaps
- Contracting and payment models
- Business models and innovative funding structures

Technical Aspects

- Pipe Systems
- Combined heat and power (CHP)
- Large Scale Solar Thermal
- Waste & Surplus Heat
- Large Scale Heat Pumps
- Power-2-Heat and Power-2-X
- Thermal, Solar Ice and PCM Storages
- Heat Pump Systems
- LT and Floor heating
- Tap water production
- Ventilation Systems

Best Practice

- Best Practice I
- Best Practice II

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Overview I

- **General information**
  - heat pump dimensions
  - terminology
  - distinction by temperature level
  - heat pump designs
- **Possible Heat Sources** (air, water, ground & sewage water, geothermal, industrial waste and surplus heat)
- **Summarization of different heat sources & usage**
- **Coefficient of Perfomance indicator**

Overview II

- **Integration of heat pumps into DH-systems**
  - Supply-pipe feed-in
  - return flow temperature increase
- **Refrigerants – Research & environmental issues**
- **Economic viability**
- **General benefits of LHP in DH-systems**

General information - terminology

- Difference between heat pumps and large heat pumps is yet **<u>not</u>** clearly defined
- Large heat pumps could be described as…
  - Heat pumps that energetical power and reached temperature level are able to feed a heat network
  - Power and temperature level also depends on the size / heat demand of the heating grid
  - Terminologically will be **<u>no distinction</u>** between both terms

General information – distinction by temperature level

Generally heat pumps can be distinguished or rather described as

- **High-temperature heat pumps**
- **Low-temperature heat pumps**

- Both types are used within housing units & the DH-sector
- **However, no clear definition or distinction possible!**
  - High-temperature heat pumps are usually used **within the DH-sector**
  - Low-temperature heat pumps **in single-family houses & apartment buildings**

General information – heat pump designs

- Heat pumps using different natural heat sources
- Heat pumps use heat sources on low temperature levels → raising temperature levels

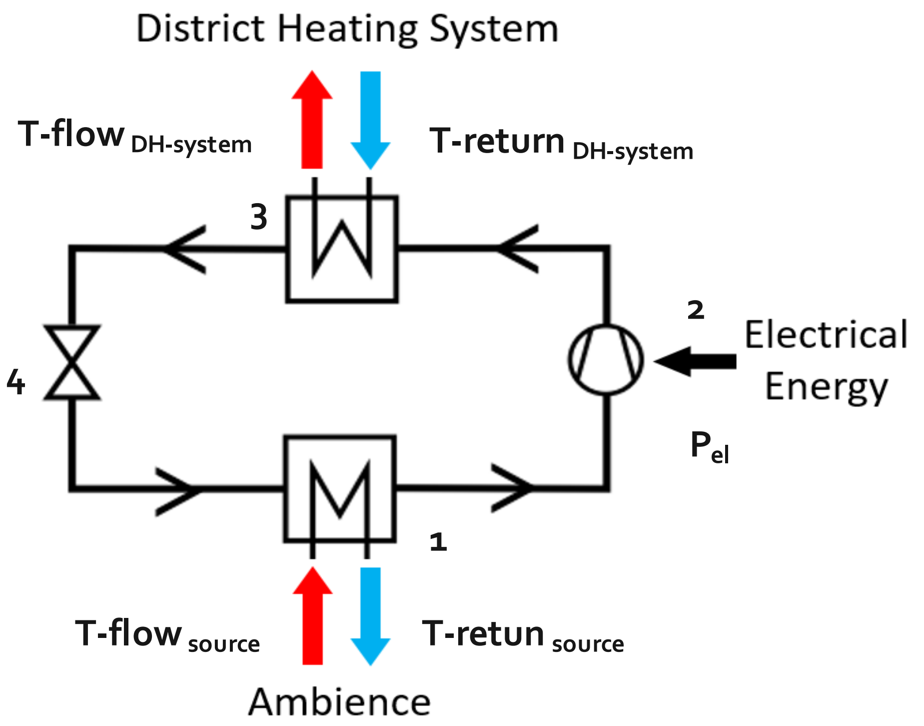
Difference between most common implementations

- Operating energy
- Driving power (electricity, gas / steam, combustion engine)
- Thermical compression / mechanical compression
- Open or closed heat pump circuit

Compression heat pump (electrical)

- Mostly used within the heat sector
- Other heat pump technologies (Adsorption heat pump, absorption heat pump, rotary heat pump)

- 1) evaporation refrigerant
- 2) pressure & temperature increase through compression
- 3) condensation refrigerant & energy transfer
- 4) pressure reduction



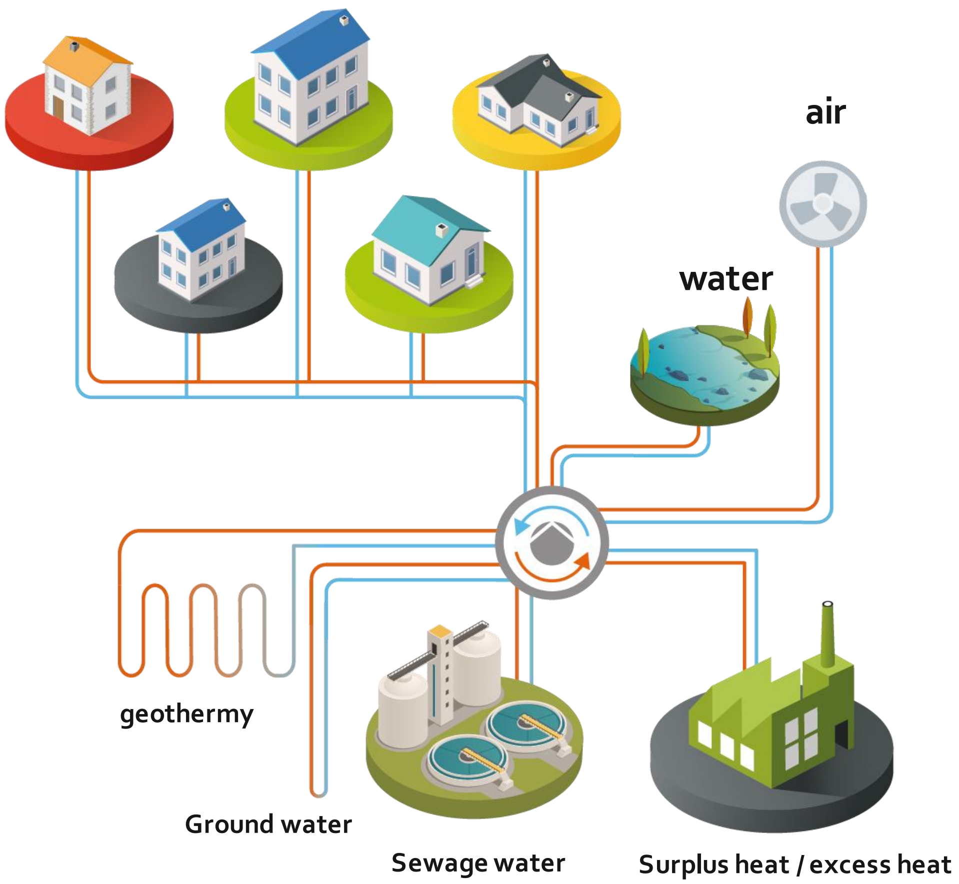
Working principle of compression heat pumps (based on AGFW, 2017)

Possible heat sources

- Heat pumps rely on an **existing heat source**
- Most important considerations are the **high availability** on-site and the range of **technical exploitation possibilities**
  - High source temperature
  - constant availability

→as lower the Δ T between heat source and heat sink as higer the efficiency of the heat pump

In general, there is a wide range of CO_2-neutral heat sources available!



Source: AGFW-Project GmbH

Possible heat sources - air

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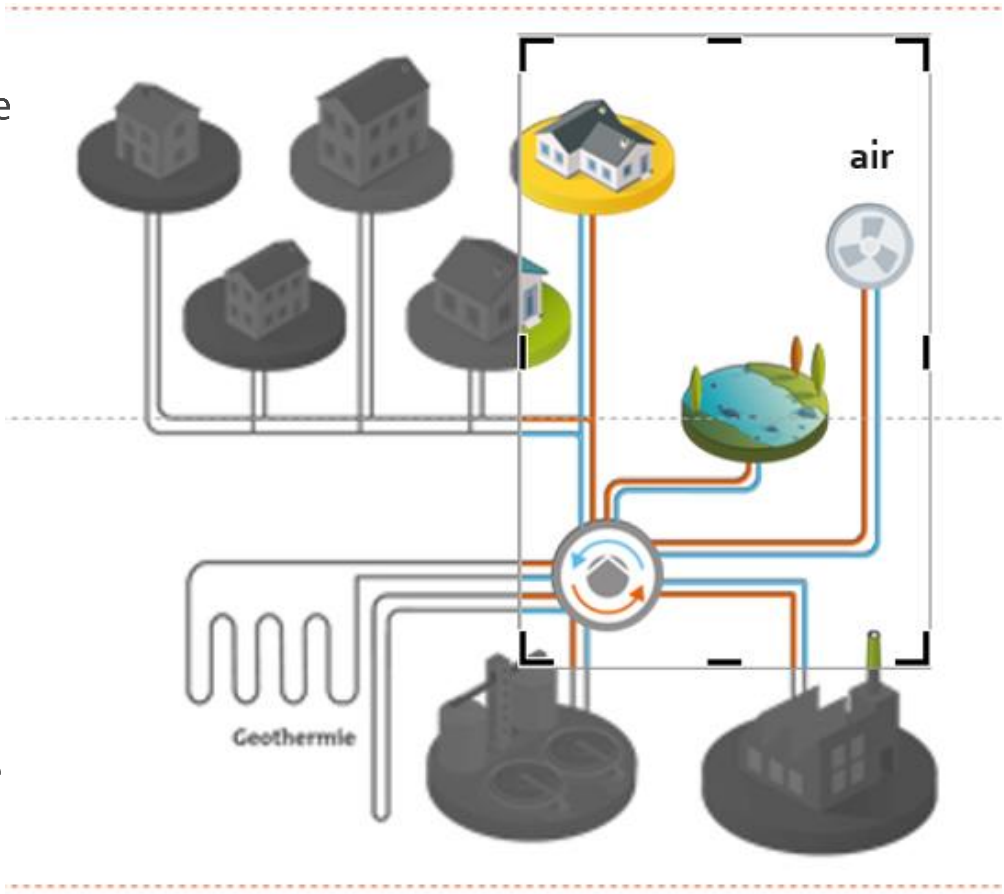
- Operate with ventilators that suck in air > thermal energy is transmitted to a heat exchanger > processed air is led back into the environment
- Unlimited heat source, **but volatile & seasonal dependent**
- **Fluctuations** caused by weather (daily & seasonal)

- Heat production is opposed to heat demand
  - > Highest COP (Coefficient of Perfomance) in summer
  - < Highest heat demand of DH-systems in winter

→ **heat pumps using air as heat source are usually used for base loads during summer**



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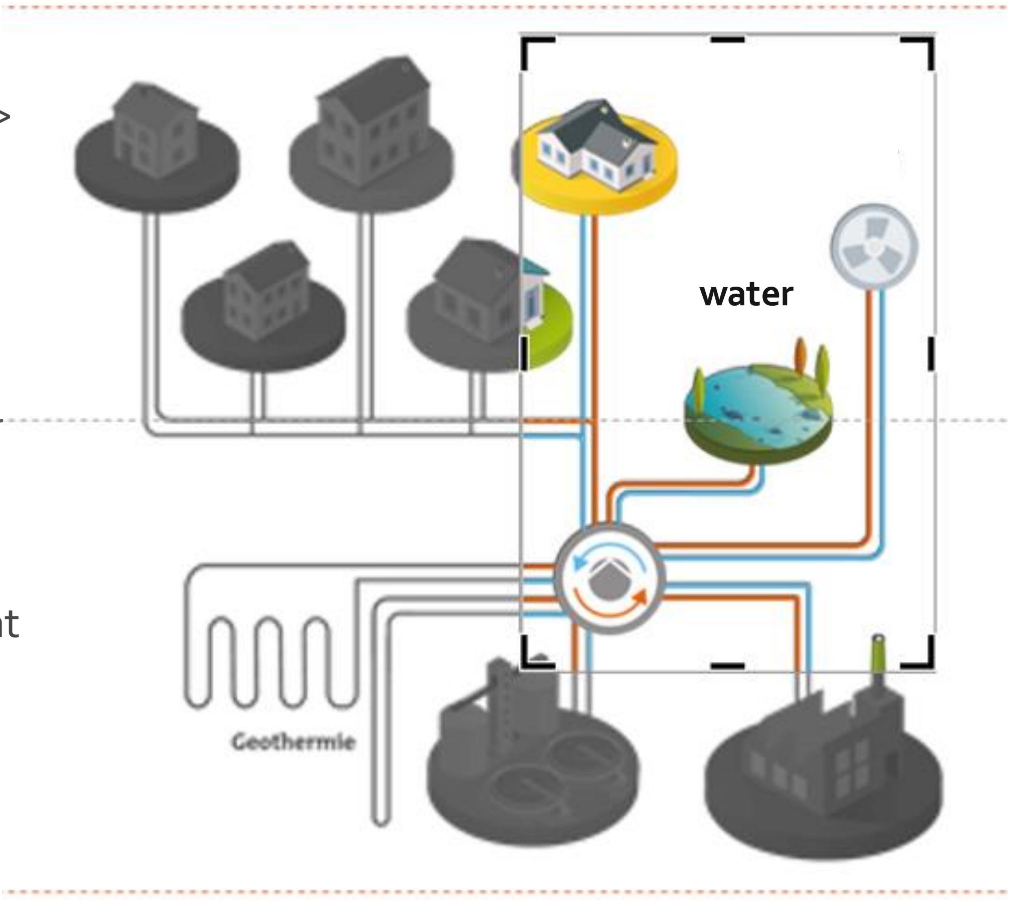
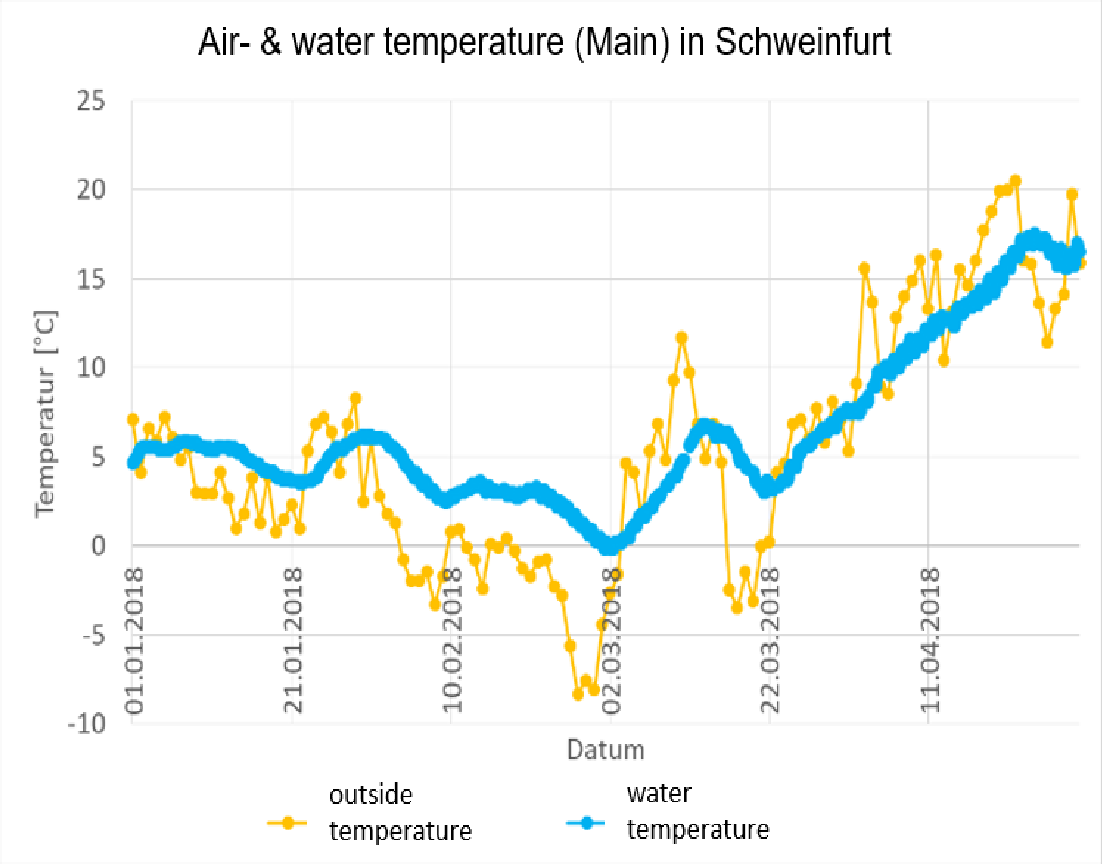
Possible heat sources – river & lake water

- Flowing waters, lakes are used as heat sources
- Pumps extract a certain amount of water from the heat source > heat is removed and transmitted > water is led back into the source
- **fluctuations** caused by weather and season
  - Less than air due to the higher heat storage capacity of water
  - Water heat sources usually have a higher availability than air heat sources
- Lake water extraction and return is limitied – cooling of the heat source is restricted
- **Example: For at least heat source temperature of 7° C, different sites in Germany could use river water heat sources for 6.000-6.500 h/a**



Possible heat sources - river & lake water



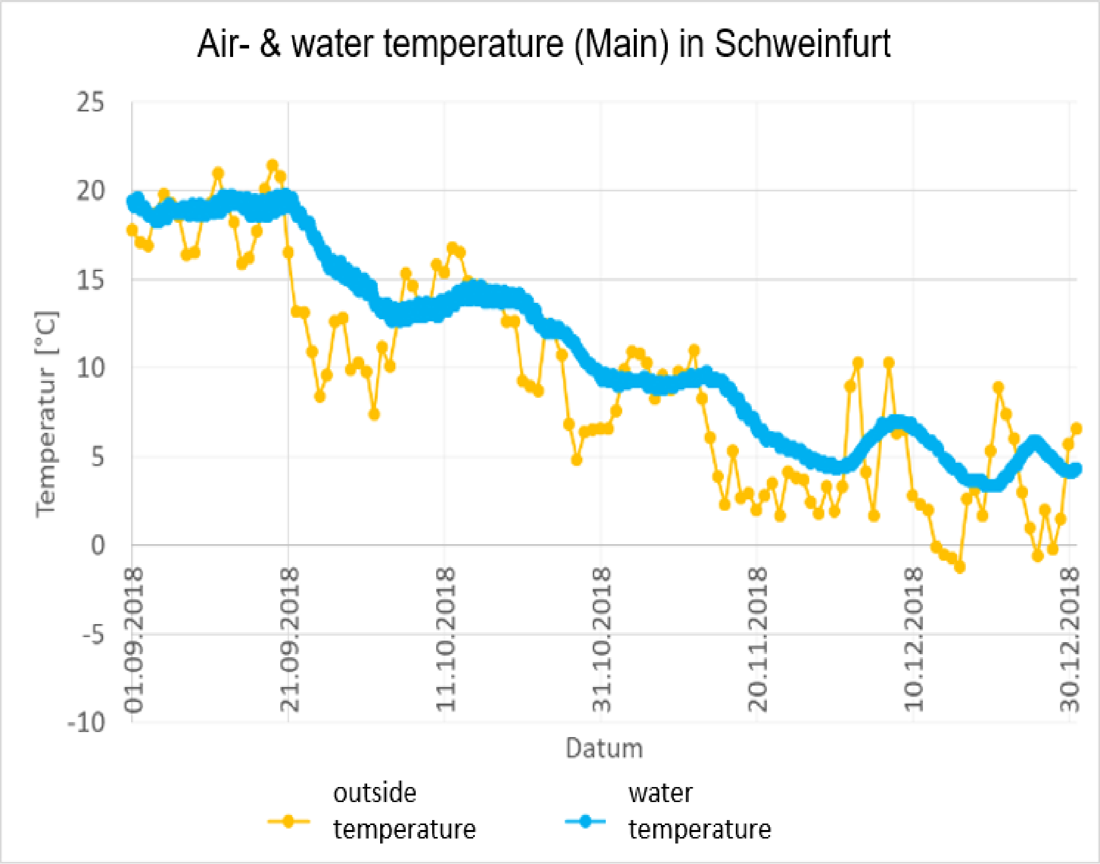
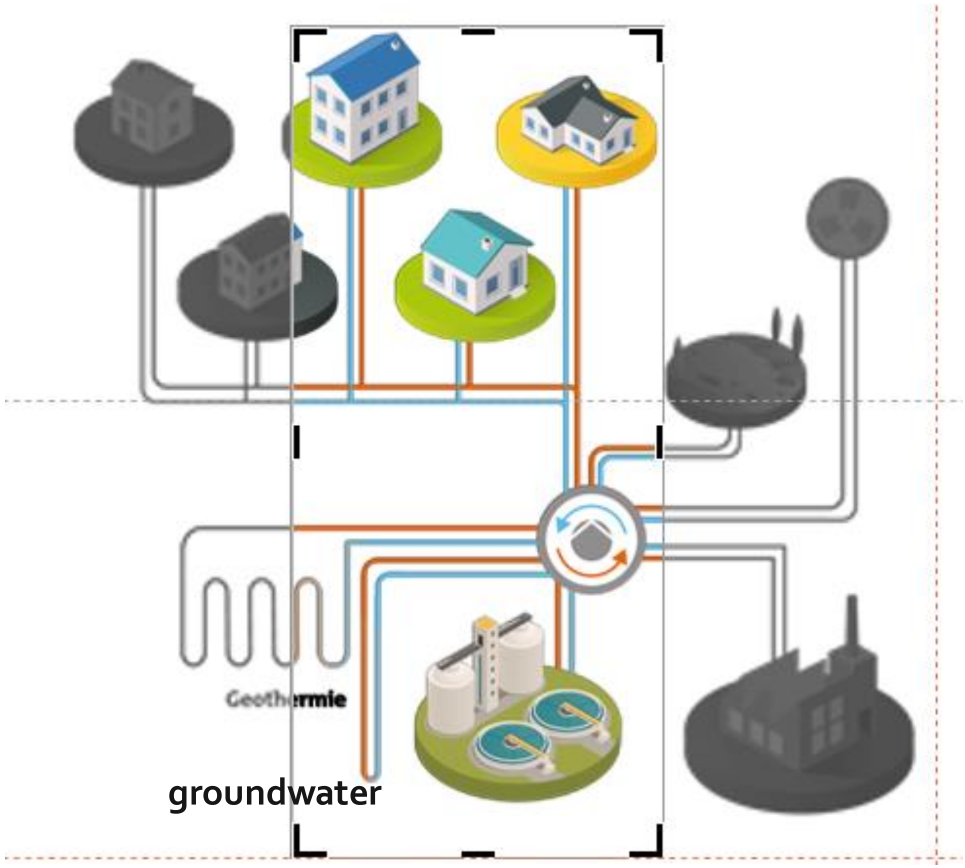


Figure 2 Comparative air and water temperature (of the river Main) in Schweinfurt in 2018 (from 1 January to 30 April and 1 September to 31 December) [Eselshöhe weather station and Bavarian State Office for the Environment]

Possible heat sources – ground water

- Groundwater-heat pumps using the thermal energy of water similar to lake and river-water heat pumps
- Two wells are required (usually between 5-20 m)
  - A feed pump transports the ground water from the withdrawal- or **suction well** to the heat pump
  - afterwards the processed water is fed back into the soil **via an absorption well**
- **As deeper the groundwater usage as more constant is the heat availability**



Possible heat sources – ground water

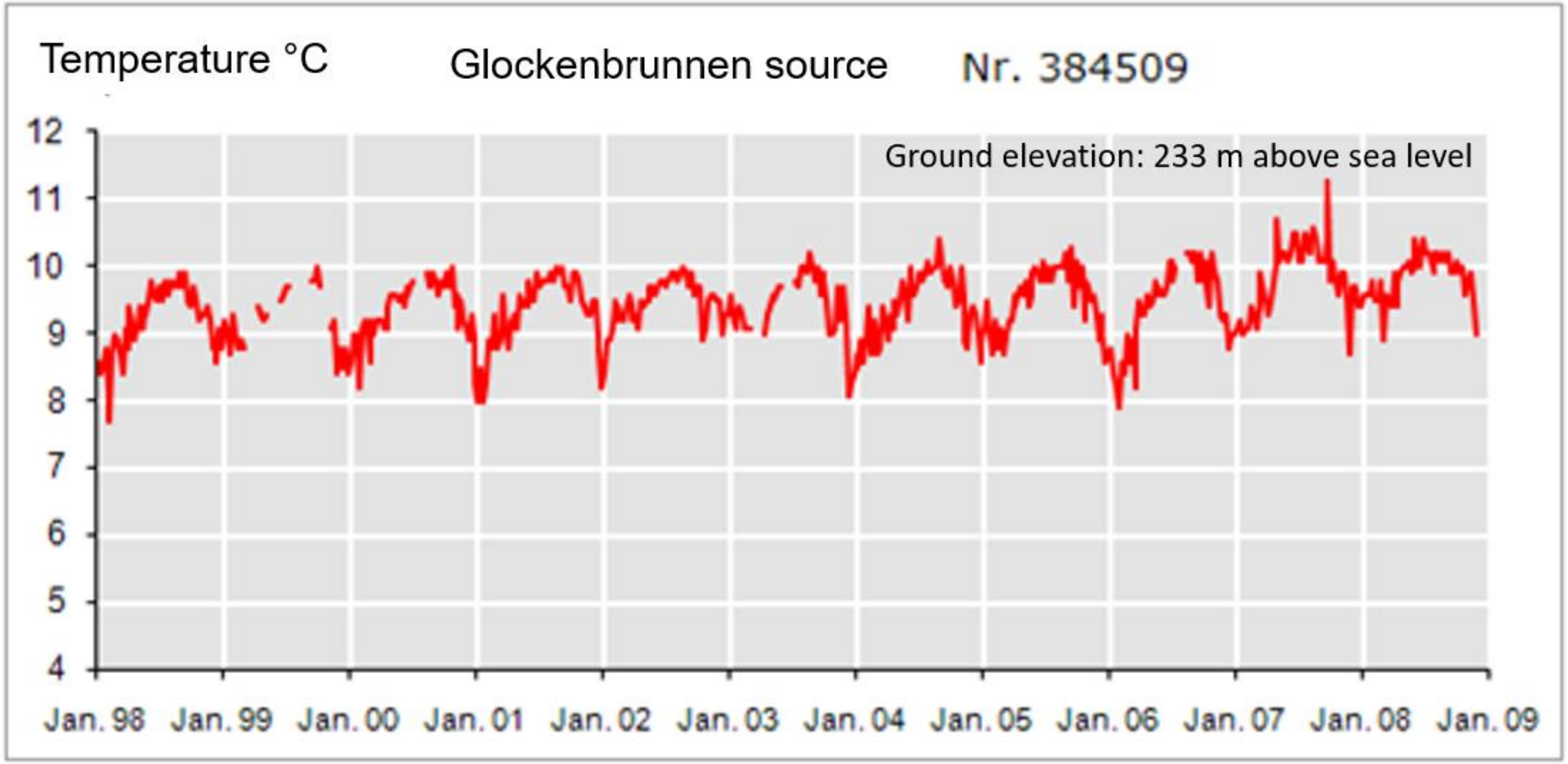
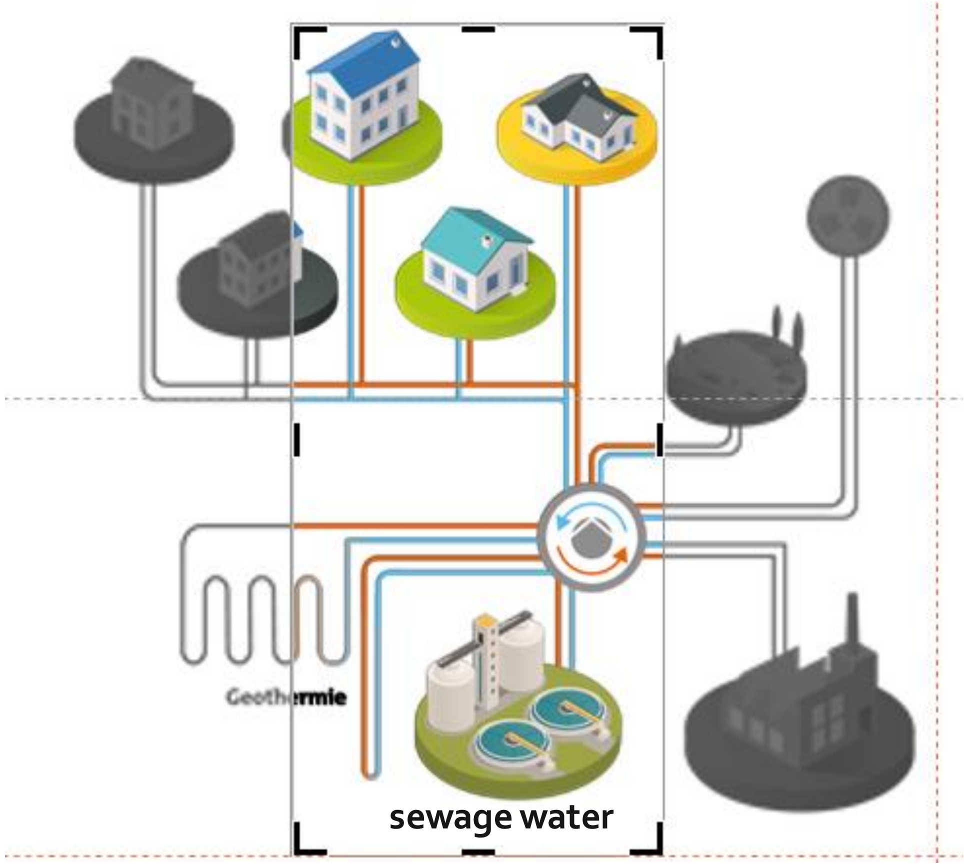


Figure 3 Groundwater temperature between 1998 and 2009 in Bad Soden am Taunus [Hessian State Office for Environment and Geology]

- Between 1998 and 2009 the average temperature **fluctuation was in the range of +/- 1 K** as the example shows

Possible heat sources – sewage & pure water

- Residual heat of cleaned sewage water in sewage treatment plants is used as heat source
- Issue for **water legislations** / **authorisation** for operator required
- **Cooling** of the sewage water is **often restricted** due to environmental legislations
- Quality of cleaned sewage water is important
  - e.g. iron phosphate deposits on the heat exchanger
  - Filter systems or special cleaning processes required (e.g. plate heat exchangers rather unsuitable)



Possible heat sources – sewage & pure water

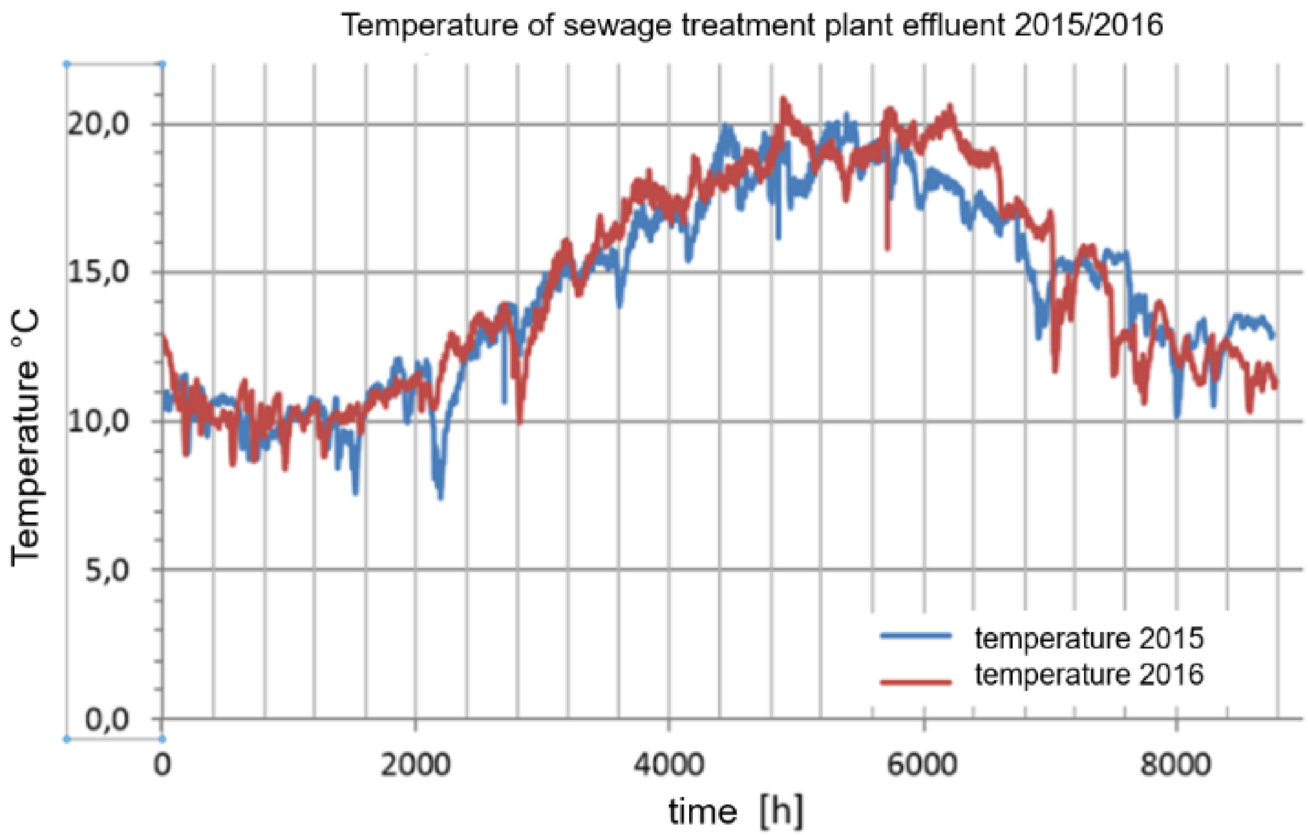


Figure 4: Illustration of the temperature curve of the wastewater treatment plant outflow of a combined wastewater sewer [Stadtwerke Lemgo]

Possible heat sources - near-surface geothermal energy

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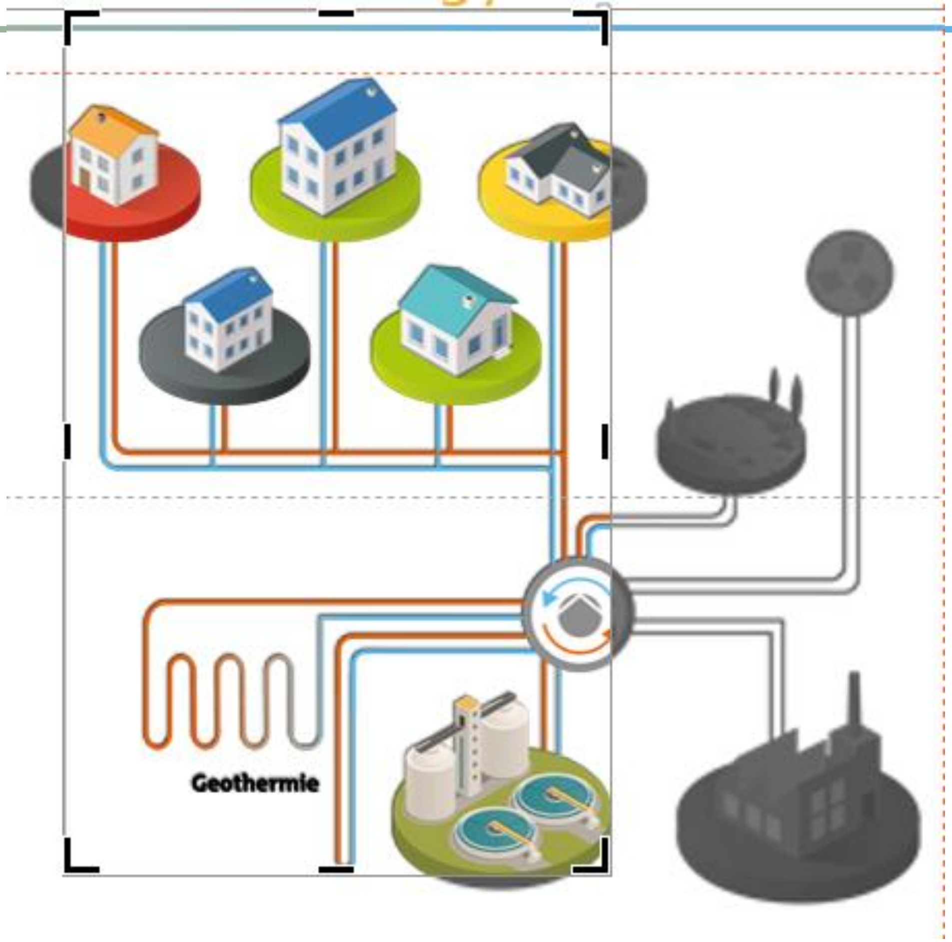
- Heat pump is using heat that is stored in the ground
- For extracting the heat a **comprehensive installation of heat exchangers** in the ground is required
- Heat exchangers are usually as **ground collectors** installed
- Heat source temperature is **dependant on the depth** of installation
- As **deeper** the installed heat exchangers as more **constant** the heat availabilty
- **Low heat source temperature** > heat yield per m² collector surface comparatively low > exploitation of vast areas necessary
- **Further use of this area** above ground resticted (e.g. agriculture usually still possible)



Possible heat sources - near-surface geothermal energy

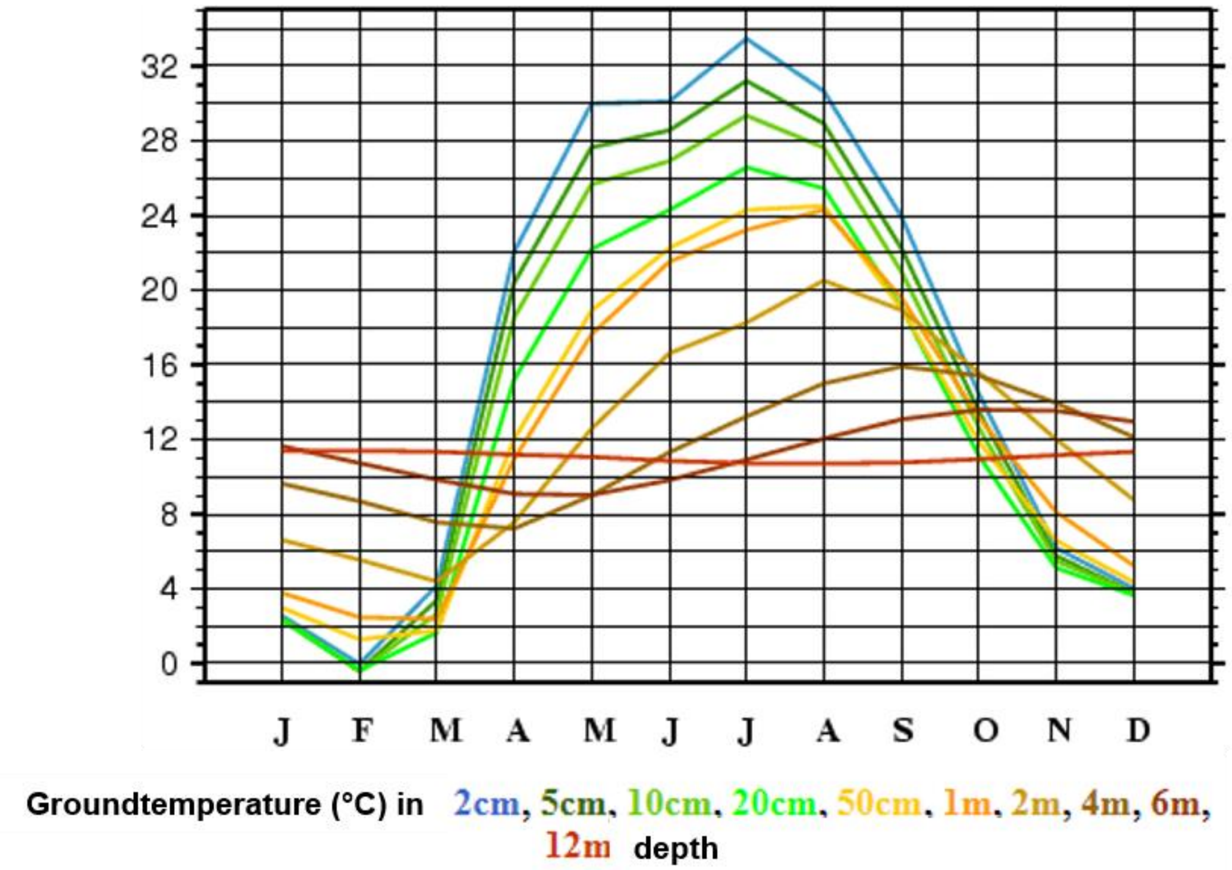
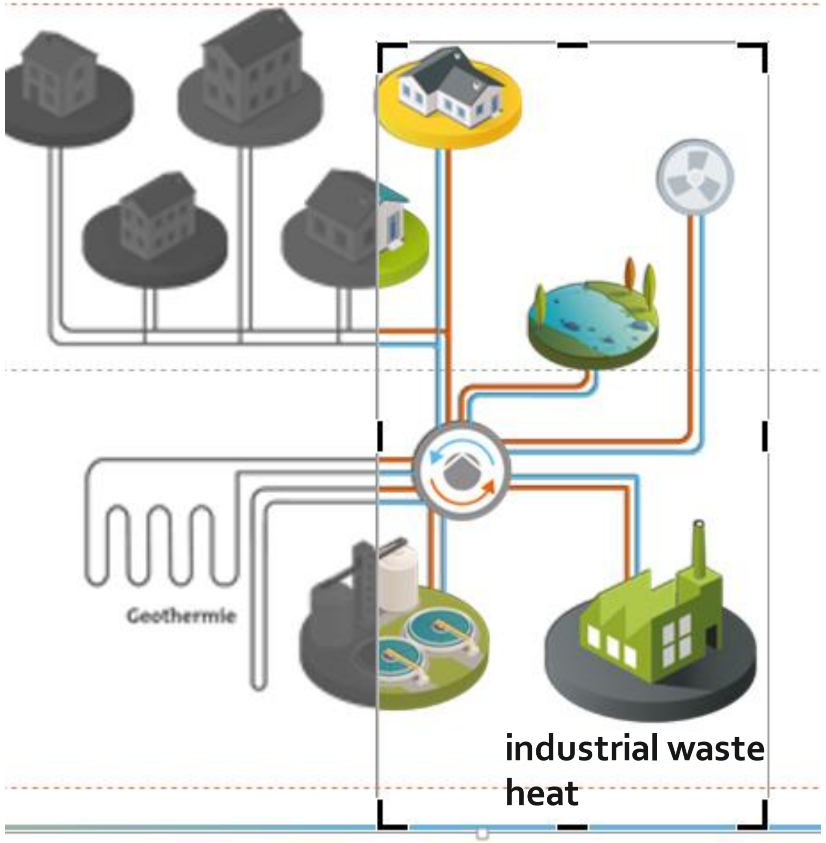


Figure 5 Soil temperatures at different depths [Potsdam Institute for Climate Research]

Possible heat sources – industrial waste & surplus heat

- Ideal heat source for heat pumps (if the heat extraction is plannable due to regular occurrence regarding heat amount / thermal output)
- **Each form of waste heat** from industrial processes usable if technologically exploitable (e.g. cooling water, cooling air, etc.)
- **Active recooling** possible
- Also the use / combination of industrial flue gas with heat pumps is possible



Summarize of different heat sources

Heat source	Typical source temperatures	Temperature fluctuations	Typical availabilities	Further information
Ambient air	0 °C – 40 °C	High	April – September	Local (own) weather stations
Lakes and rivers	2 °C – 20 °C	Medium	April – October	Local, competent water authority
Groundwater	3 °C – 15 °C	Low	All year round	Competent water authority
Wastewater/ pure water	7 °C – 20 °C	Medium	All year round[4]	Operator of the relevant sewage treatment plant
Shallow geothermal energy	0 °C – 19 °C	Medium	All year round	-
Industrial waste heat	14 °C – 50 °C	Individual	Individual	Corresponding industrial enterprise
Industrial flue gas/waste gas	30 °C – 50 °C	Low	Individual	Corresponding industrial enterprise

Table 1 Overview of heat sources [large heat pumps, supplemented] (AGFW)

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Coefficient of Perfomance

... Defines the efficiency of heat pumps – it describes the **provided useful thermal energy** divided by the **consumed electrial energy**

$$COP = \frac{|\dot{Q}_{use}|}{P_{electrical}}$$

- Heat sources like air, geothermal energy, water and surplus heat are estimated as freely available

→Consumption is not considered in efficiency calculation → Efficiency values higher than 1 possible

→Use is considered cost-free – **Heat pumps can be very energy-efficient and cost-efficient**

→General rule: The smaller ΔT- the higher the COP

Integration of Heat pumps into DH-systems

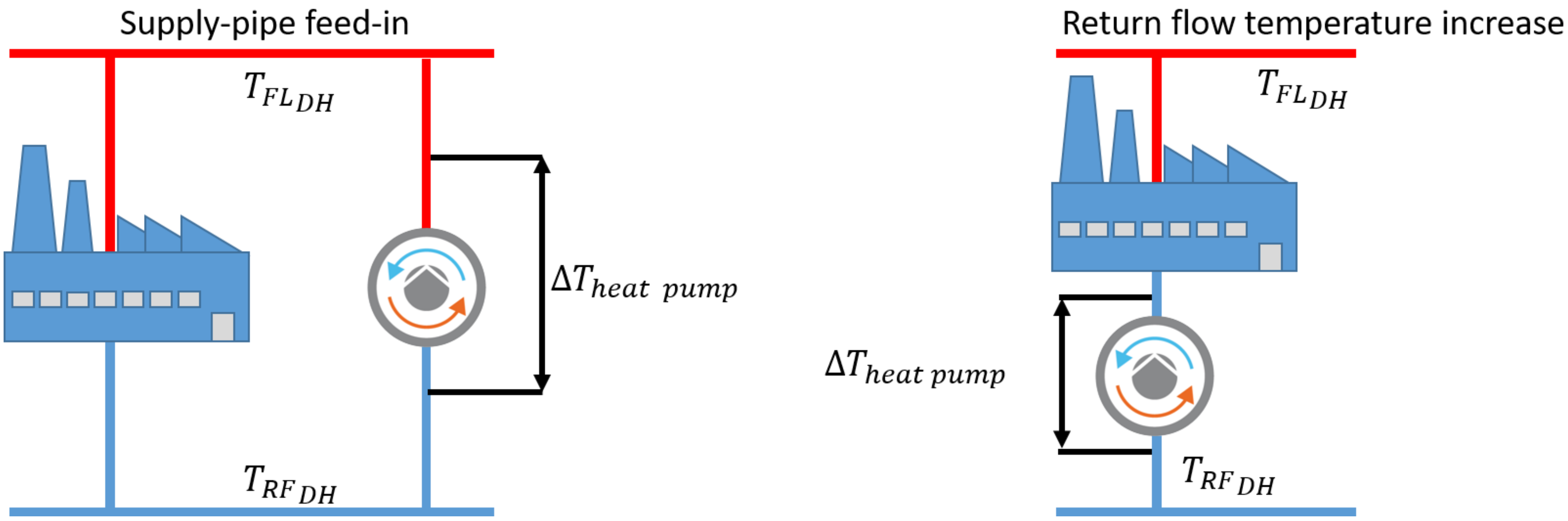


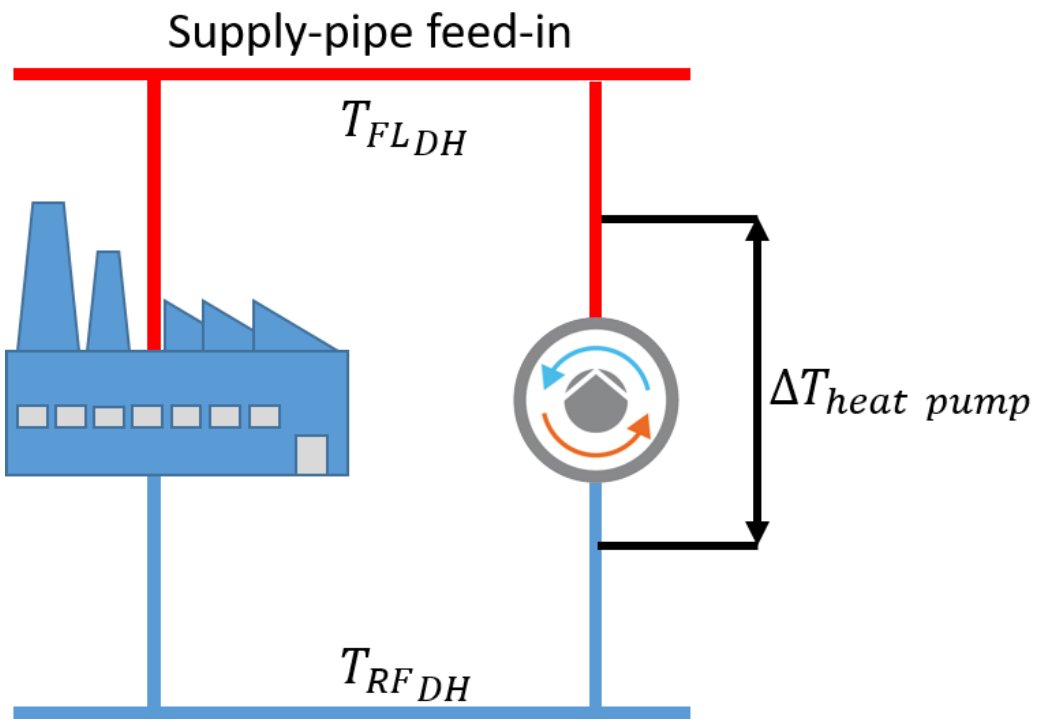
Figure 8 Different possible ways to integrate a large heat pump supply-pipe feed-in (left) and return flow temperature increase (right) [own illustration]

Source: AGFW

Integration possibilities – Supply-pipe feed-in

- Generally, **LHP can feed directly** in the supply pipe of a DH-System, if **required Δ T** can be met
- Heat pump must be designed for the max. flow temperature*

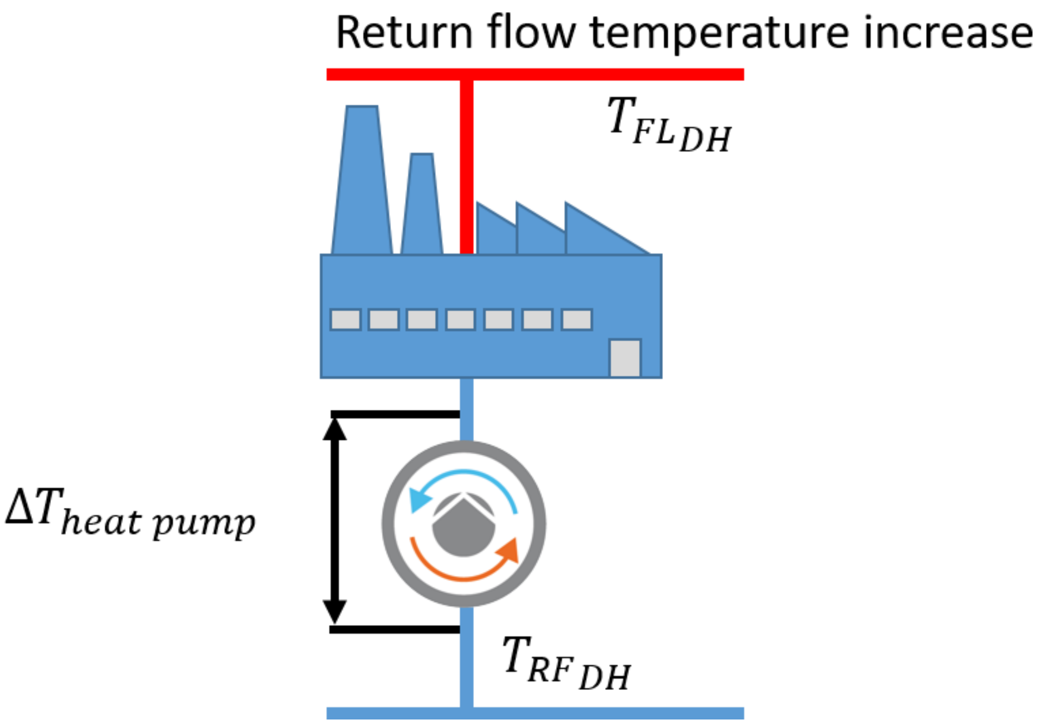
(*since T_{FL} is increasing when outside temperature decreases)



Source: AGFW

Integration possibilities – return flow temperature increase

- In case, the performance of a heat pump is too low, return flow integration could be an alternative
- **Benefits:**
  - integration into an **existing generation** of a DH-system more easy
  - Possible **future use** for feed-in scenario into supply pipe, since there is a general tendency to reduce T_{FL}



Source: AGFW

Refrigerants - overview

- Refrigerants are essential working medium and can be distinguished in:

Natural

- NH_3 (ammonia) and CO_2
- Very low global warming potential (GWP)
- Non-existent ozone-depleting potential (ODP)
- Only few or non environmental restrictions
- Not commonly used as refrigerant

Synthetic

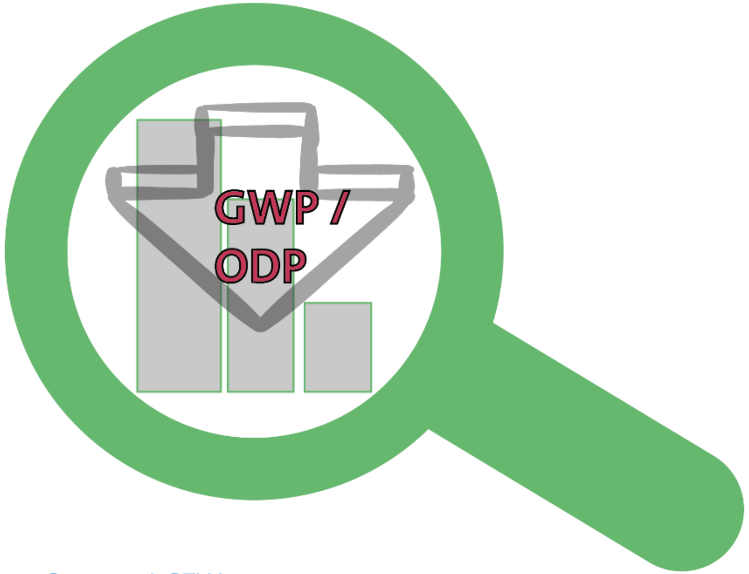
- R-134a, R-152a and R-245fa
- Mainly hydrofluorocarbon (HFC)
- Several ecological issues
- Mainly used

Right now there is no restriction on the use of HFC for large-scale applications, but high GWP level refrigerants are restricted by the latest EU F-gas regulation.

→ In general, policy pushes forward the transiton towards natural refrigerants!

Refrigerants – Research & environmental issues

- Due to the temperature requirements of a district heating network only a limited number of possible refrigerants available
- **Decisive requirements in that regard are:**
  - the available heat source temperatures
  - the necessary feed-in temperature
  - the required heat output
  - the necessary COP
  - the heat pump technology

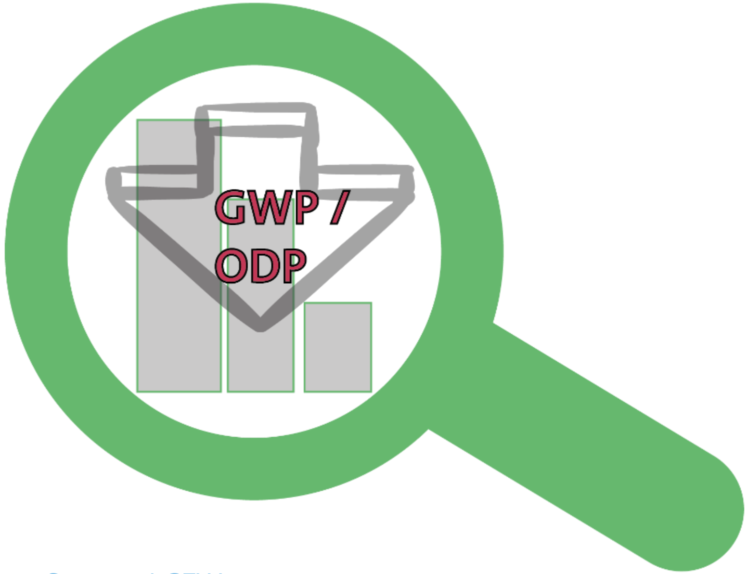


Source: AGFW

Refrigerants - Research & environmental issues

- Regarding environmental issues following aspects can be taken into account:
  - Detrimental effects on the climate
  - Environmental impacts
    - ozone depleting potential (ODP)
    - global warming potential (GWP)

  - Other aspects:
    - Safety precautions
    - Operating costs



Source: AGFW

Economic viability

Breakdown of the total investments:

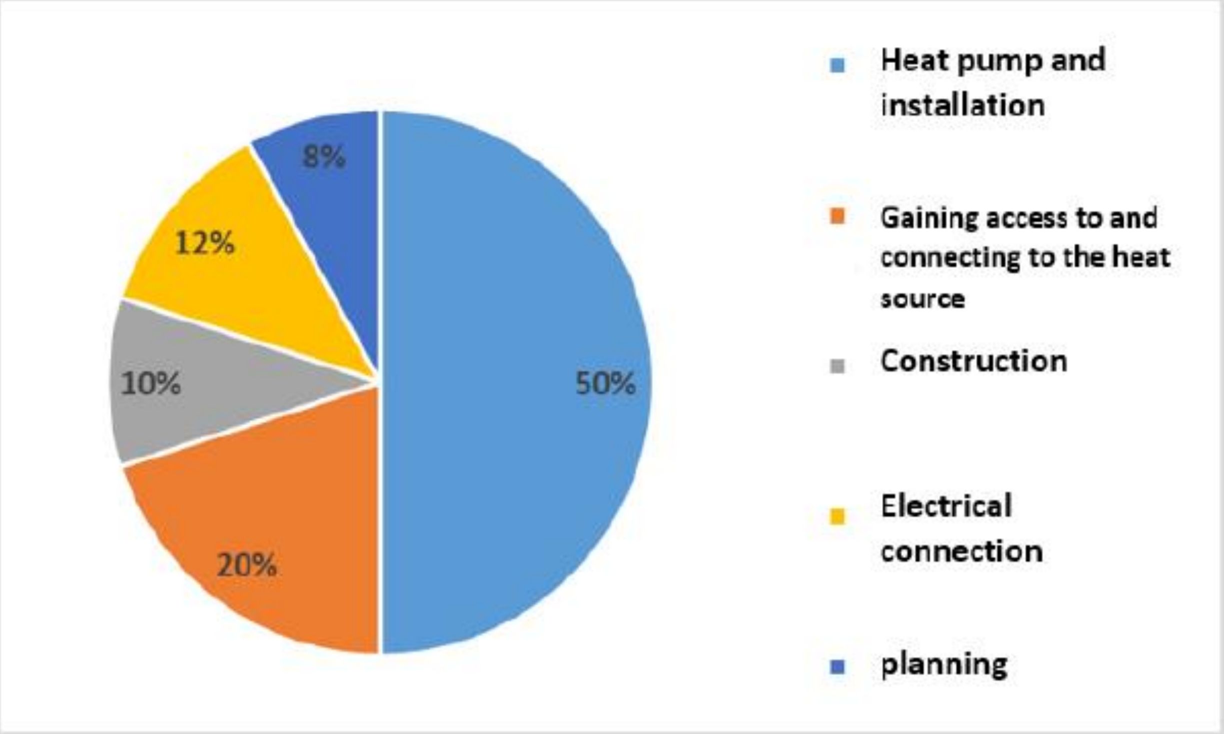
Items taken into account in a large heat pump project:

- Large heat pump
- Gaining access to and connecting to the heat source
- Connection to the district heating network
- Electrical connection
- Construction costs
- Costs for planning and permissions

Economic viability

Breakdown of the total investments:

- The heat pump unit will account for approximately 50% of the total investment
- Costs to make the heat source usable from a technical point of view depend heavily on the heat source itself and the associated general conditions, such as…
  - accessibility
  - structural conditions
  - maintenance intensity
- Attention must be paid to the way in which the integration is designed (e.g. network temperatures & pressures or distance to the heating network, etc.)



Breakdown of the total investment into individual items
Source: own presentation after Pieper and Energinet

Economic viability

Breakdown of the total investments and their variation towards the used heat source

Table 3 Specific amounts of the total investment in the case of large heat pumps, depending on the heat source used according to [Pieper]

Specific investment (total) in million €/MW_{th}	Flue gas	Wastewater	Waste heat	Groundwater	Air
0.5 – 1 MW_{th}	0.53 – 0.63	1.23 – 1.91	0.97 – 1.3	1.18 – 1.72	0.9 – 1.12
1 – 4 MW_{th}	0.46 – 0.53	0.72 – 1.23	0.72 – 0.97	0.77 – 1.18	0.73 – 0.9
4 – 10 MW_{th}	0.44 – 0.46	0.62 – 0.72	0.67 – 0.72	0.69 – 0.77	0.7 – 0.73

Source: AGFW

General benefits of LHP in DH-systems

Increased flexibility of the DH-system	• Quick + cheap start-ups • Optimized runtime of base load plants
Better utilization of surplus heat production	• Utilization of low temperature and other redundant heat sources
Protection against (market) risks	• Hedge against price fluctuation of electricity and fuel costs • Failure protection & Combination of DH & DC
Increase of renewable heat production	• No local emissions • Positive boost for DH-image

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References

[Eselshöhe weather station and Bavarian State Office for the Environment]; quoted in AGFW 2020: "Praxisleitfaden Großwärmepumpen" p. 5

[Hessian State Office for Environment and Geology]; quoted in AGFW 2020: "Praxisleitfaden Großwärmepumpen" p. 6

[Stadtwerke Lemgo]; quoted in AGFW 2020: "Praxisleitfaden Großwärmepumpen" p.7

[Potsdam Institute for Climate Research]; quoted in AGFW 2020: "Praxisleitfaden Großwärmepumpen" p.7

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Further literature

[AGFW1] AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK, Arbeitsblatt AGFW FW 309 Teil 1, Energetische Bewertung von Fernwärme – Bestimmung der spezifischen Primärenergiefaktoren für Fernwärmeversorgungssysteme -, 2014

[AGFW2] AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK, Arbeitsblatt AGFW FW 309 Teil 6, Energetische Bewertung von Fernwärme – Bestimmung spezifischer CO2-Emissionsfaktoren -, 2016

[Agrothermische Wärmeversorgung] Dr. Pietruschka und Dr. Kluge, Kalte Nahwärme: agrothermische Wärmeversorgung einer Plusenergiesiedlung, bauma 2013 [BDI] Gerbert, P. et al.: Klimapfade für Deutschland, 2018.

[EnEff:Wärme] Andreas Christidis et al, EnEff:Wärme, Einsatz von Wärmespeichern und Power-to-HeatAnlagen, AGFW | Der Energieeffizienzverband für Wärme, Kälte und KWK e. V., 2017

[Energinet] Danish Energy Agency, Technology Data for Energy Plants for Electricity and District heating generation, 2016

[Large Heat Pumps] A. Davis, Large Heat Pumps in European District Heating Systems, 2016 zitiert in Grosse, R., Christopher, B., Stefan, W., Geyer, R. and Robbi, S., Long term (2050) projections of techno-economic performance of large-scale heating and cooling in the EU, EUR28859, Publications Office of the European Union, Luxembourg, 2017, ISBN 978-92-79-75771-6, doi:10.2760/24422, JRC109006

[Literaturstudie NTB] Dr. Cordin Arpagaus et al, Hochtemperatur Wärmepumpen, Literaturstudie zum Stand der Technik, der Forschung, des Anwendungspotentials und der Kältemittel, Interstaatliche Hochschule für Technik Buchs, 2017 [OLG Düsseldorf] OLG Düsseldorf, Beschluss vom 29.06.2016 – VI-3 Kart 95/15(V)

[Pieper] Pieper et al, Allocation of investment costs for large-sclae heat pumps supplying district heating, CONECT 2018

[WKO und ÖKKV] Informative Zusammenfassung von Kältemittel-Alternativen, WKO Berufsgruppe Kälte- und Klimatechnik und Österreichischer Kälte- und Klimatechnischer Verein (ÖKKV), 2018