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District Heating Integration of a River Water Heat Pump at a CHP Plant in Germany

Feasibility Study and Techno-Economic Evaluation

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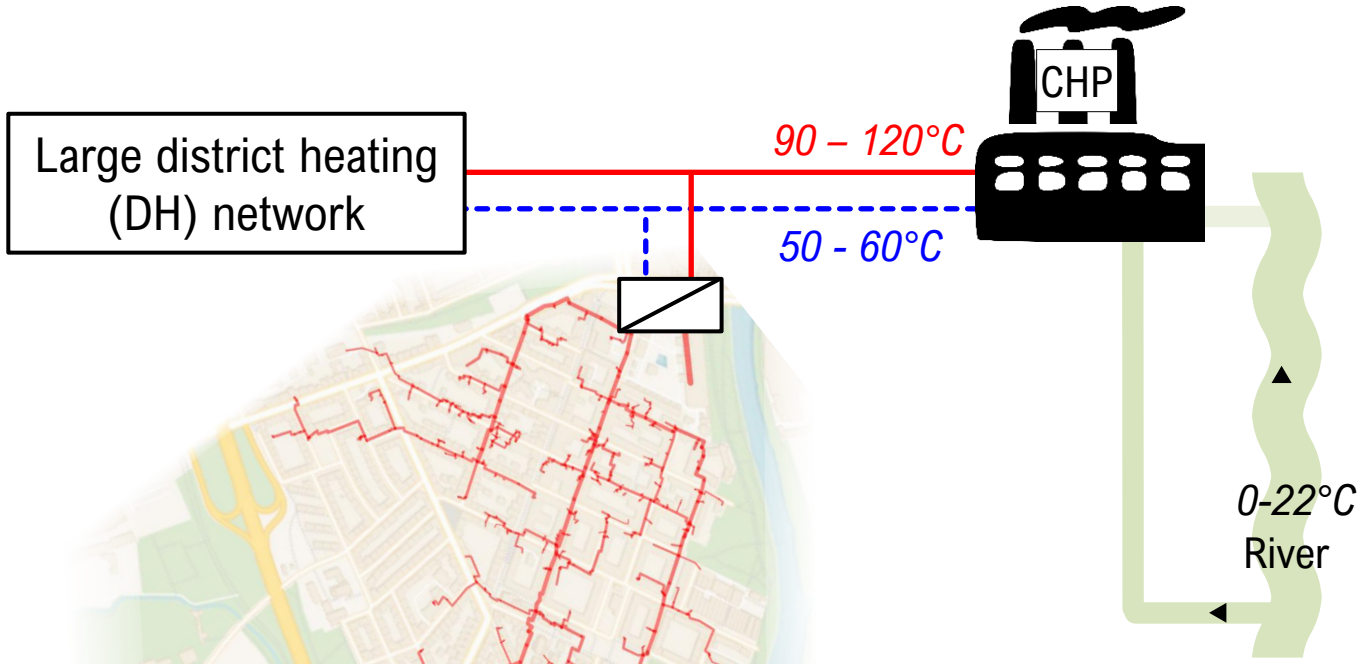
Status quo of urban district heating systems in Germany



Map: © OpenStreetMap-Contributors

CHP plant:
Main heat source for urban district heating systems

River water cooling system

Case study with urban district
Heat demand:

29.2 GWh/a

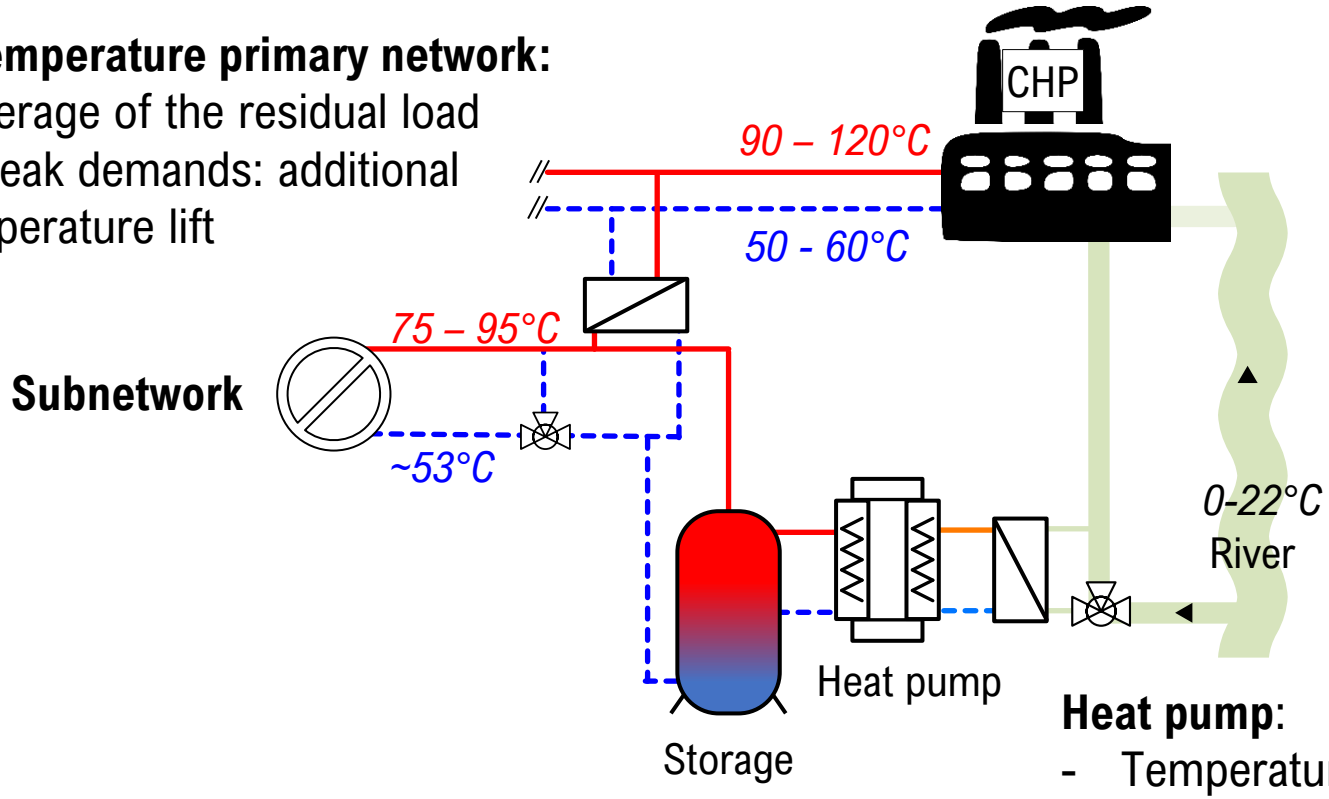
8.6 GWh/a

Linear heat demand density:

2.49 MWh/(m•a)

Integration of a river water heat pump at a CHP plant

High temperature primary network:
- Coverage of the residual load
- At peak demands: additional temperature lift



CHP plant:
Main heat source for urban district heating systems

River water cooling system
Redirection of part of the flow through an additional heat exchanger

Heat pump:
- Temperature lift: 55 K (summer) up to 86 K (winter) → two-stage
- Maximum supply temperature: 90 °C
- Annual COP: ~3

Goal: 50 % share of renewable energies

- ✓ Transferability and scalability of the concept
- ✓ Supporting the energy system transformation process
- ✓ Continued usage of existing plant sites

Techno-economic evaluation of two concepts

- **Simulation** of hourly heat production for the years **2024 to 2038** with the software **energyPRO**
- Long term prognosis for **electricity market prices** → **Sector Coupling**

Minimum dimensioning **vs** **Flexibility**

Concept I

- River water heat pump:

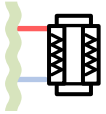
$\dot{Q}$ = 4.7 MW_{th}

- Tank storage:

V = 600 m^3

Concept II

- River water heat pump:



$\dot{Q}$ = 6.2 MW_{th}

- CHP unit:

$\dot{Q}$ = 7.1 MW_{th}
P_{el} = 7.2 MW_{el}

- Power-to-heat (PtH):

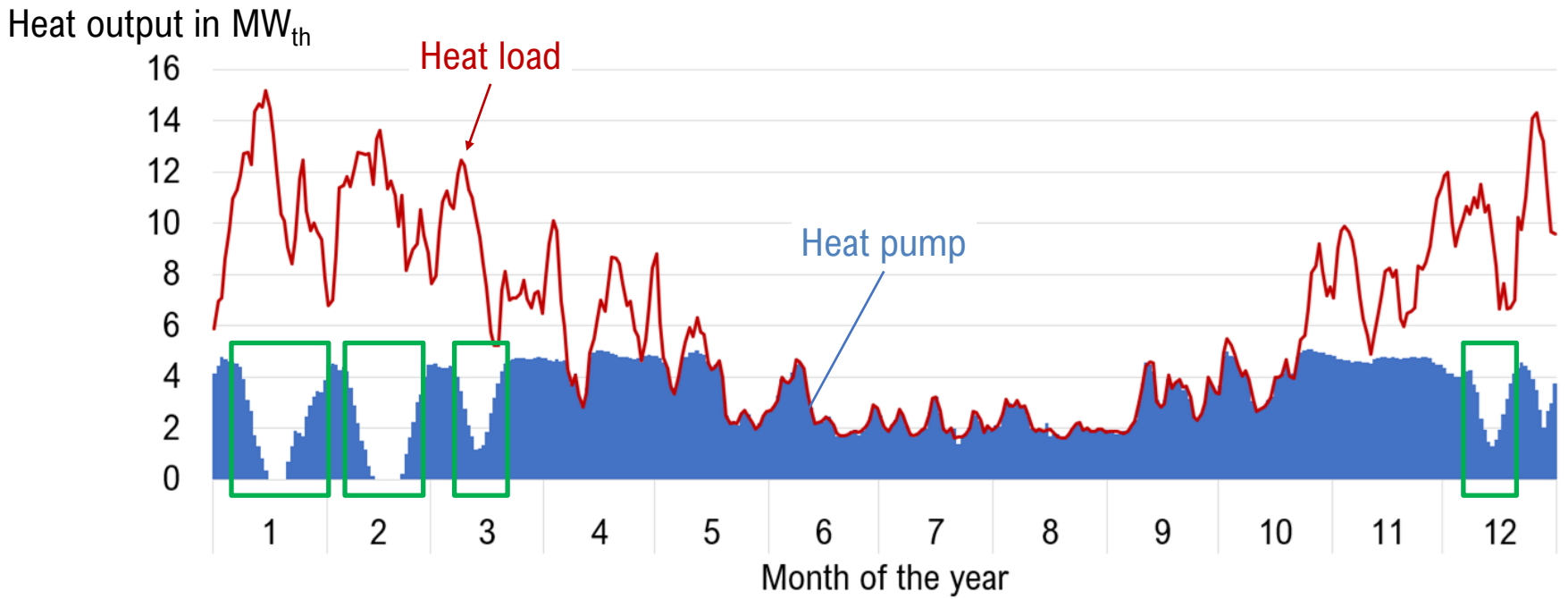
$\dot{Q}$ = 2.2 MW_{th}

- Tank storage:

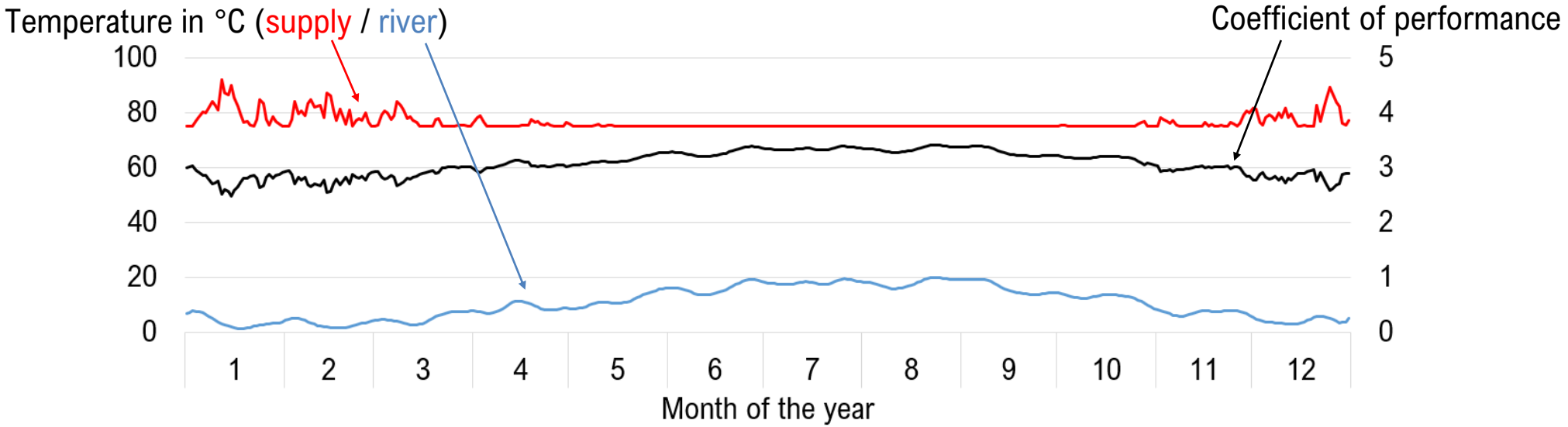
V = 7000 m^3

Backup: Primary district heating network

Mean annual heat pump operation (15-year average)



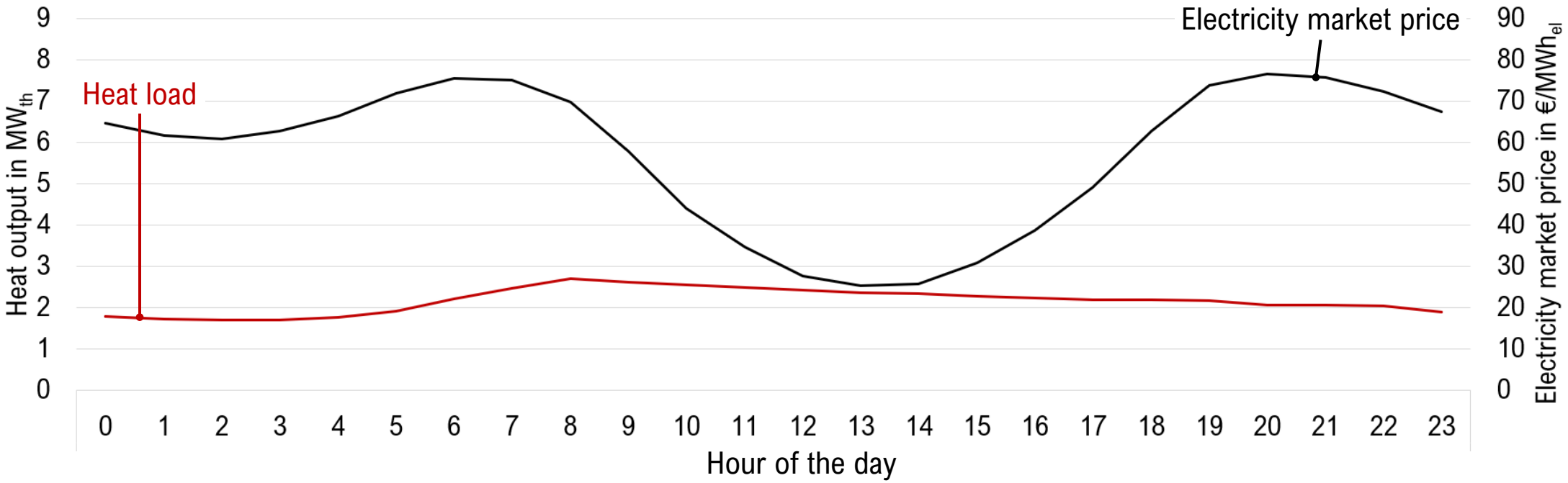
River water too cold!



Sector coupling – electricity market price induced heat production

*Monthly 15-year average (2024 to 2038)

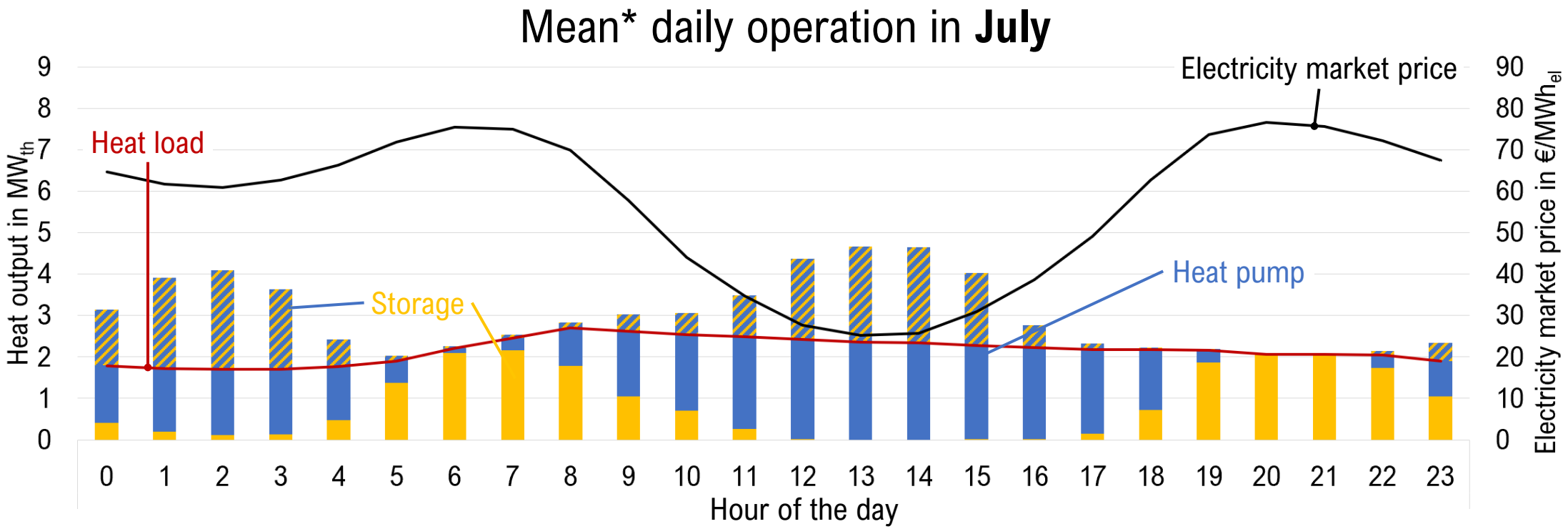
Mean* electricity market price and heat load in **July**



Sector coupling – electricity market price induced heat production

*Monthly 15-year average (2024 to 2038)

Concept I *(Heat Pump)*

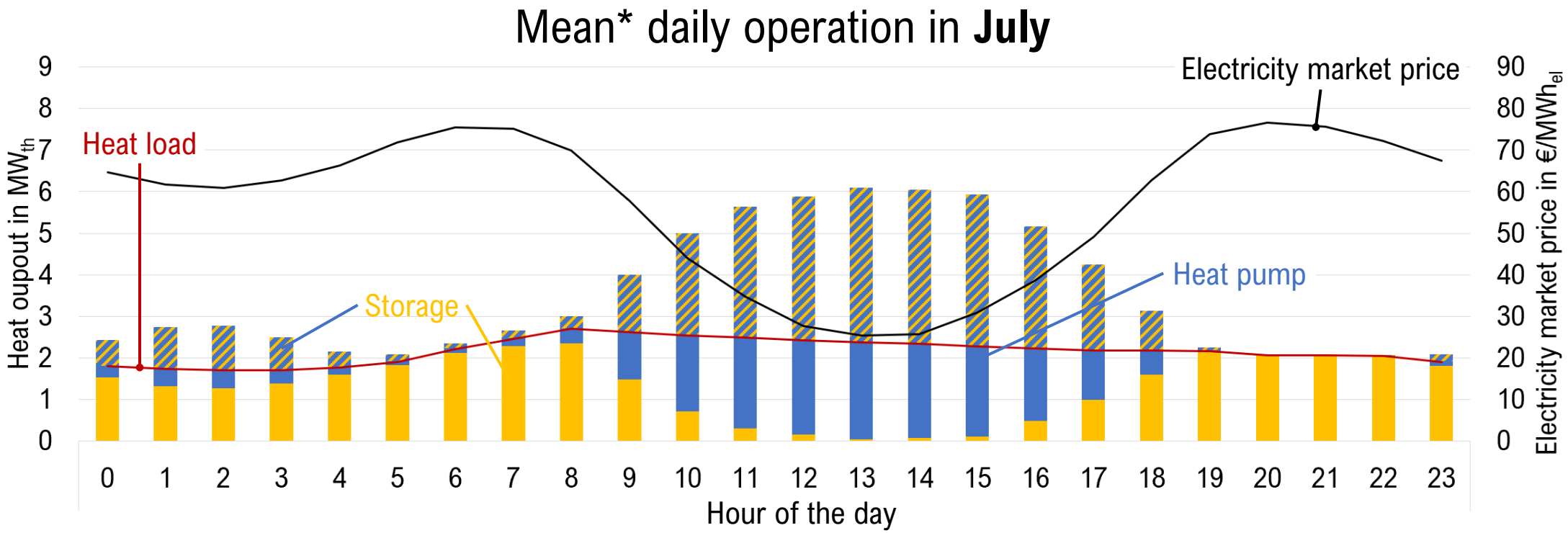


- Heat pump operates during market price dip caused by solar PV electricity feed-in

Sector coupling – electricity market price induced heat production

*Monthly 15-year average (2024 to 2038)

Concept II *(Heat Pump + CHP unit + PtH + large storage)*

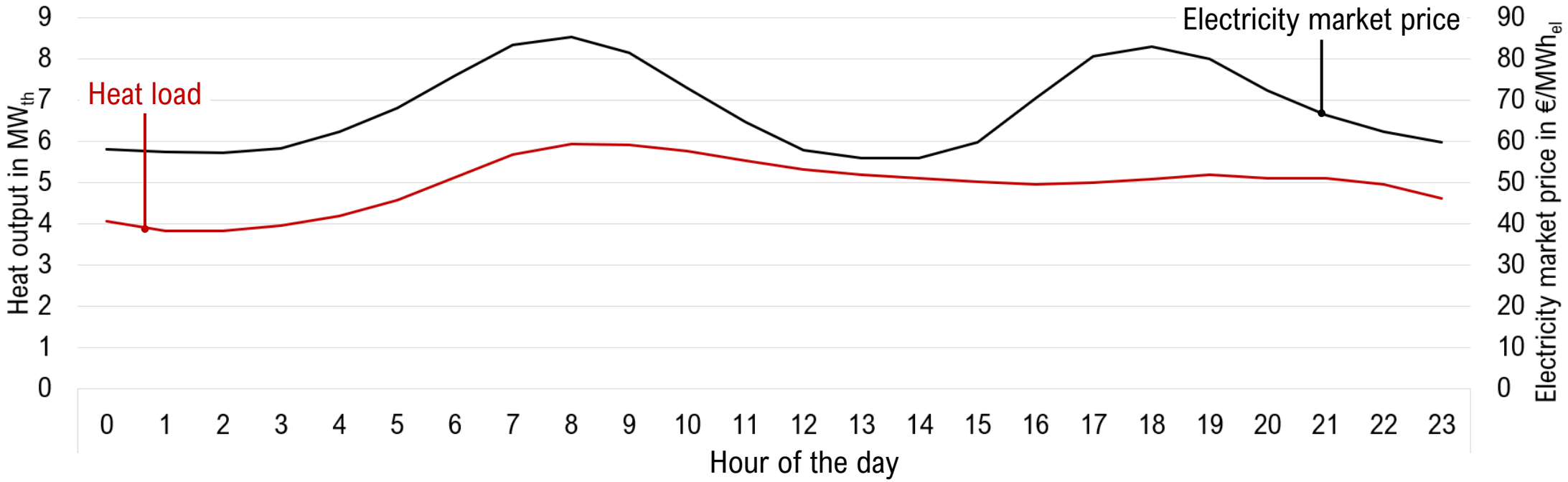


- Heat pump operates during market price dip caused by solar PV electricity feed-in
- More flexibility potential for electricity market with a high thermal output of the heat pump

Sector coupling – electricity market price induced heat production

*Monthly 15-year average (2024 to 2038)

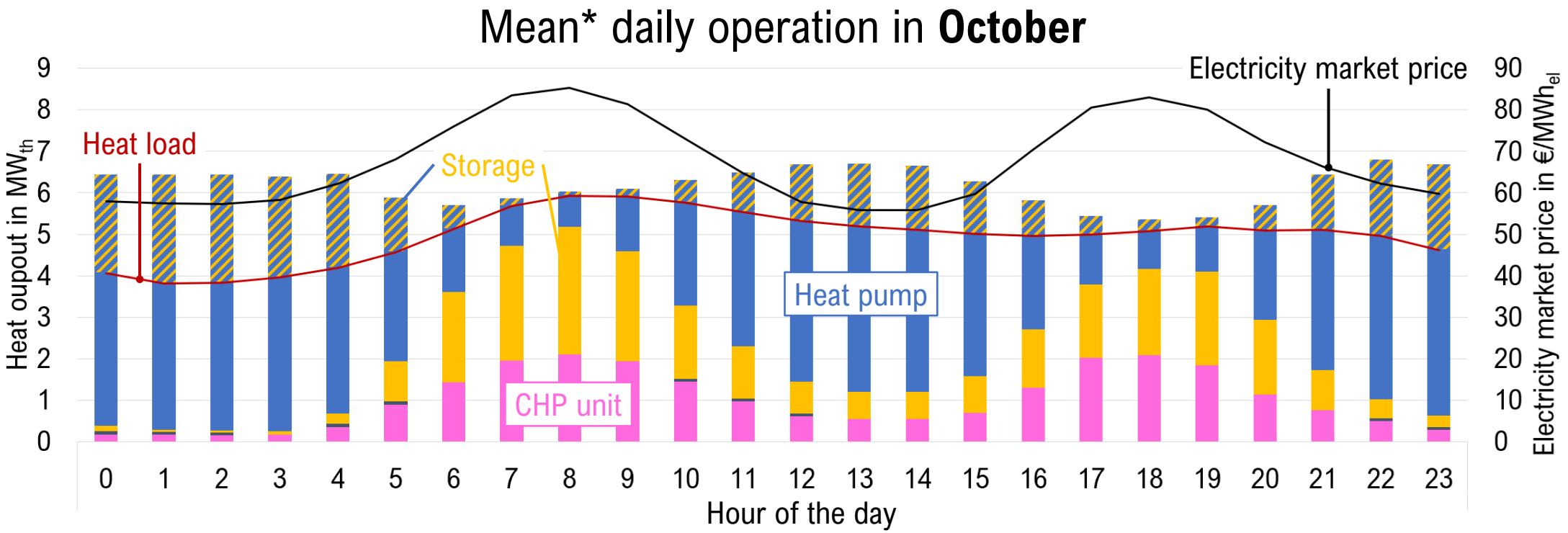
Mean* electricity market price and heat load in **October**



Sector coupling – electricity market price induced heat production

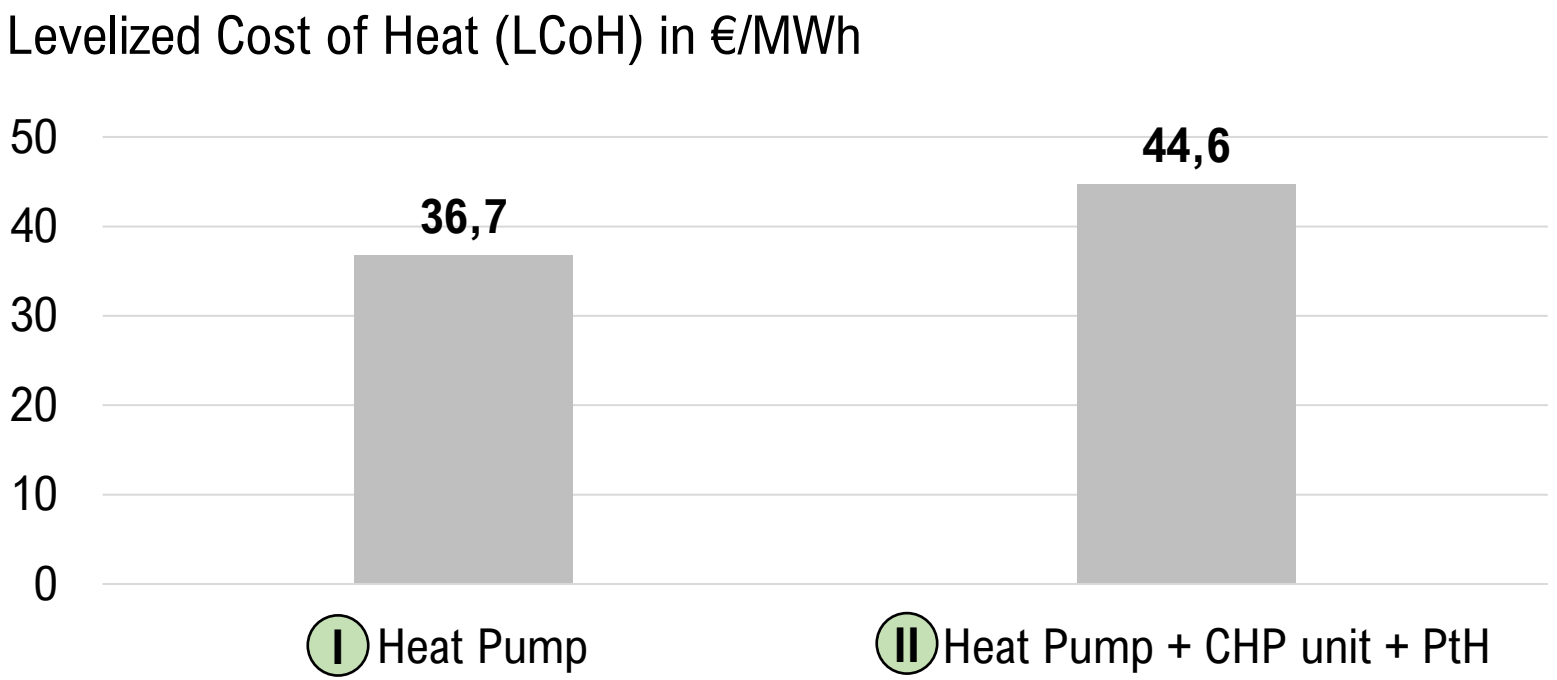
*Monthly 15-year average (2024 to 2038)

Concept II *(Heat Pump + CHP unit + PtH + large storage)*



- Heat production is a good flexibility option for the electricity market from April until October
- More flexible production in winter would require further over-dimensioning of components

Economic comparison



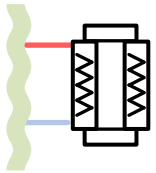
$$LCoH = \frac{I + \sum_{t=1}^{T} \frac{C_t - S_t - RV}{(1+r)^t}}{\sum_{t=1}^{T} \frac{E_t}{(1+r)^t}}$$

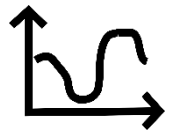
with:
I = Invest (incl. 30% subsidy)
T = Assessment period (15a)
C_t = Operating costs
S_t = Revenue from operation
RV = Residual value
E_t = Heat produced
r = Discount rate (8%)

- Low LCoH possible with self-generated electricity from CHP plant.
- Flexible heat production in Concept II not cost-efficient yet.

Summary

- Excellent and transferable opportunity for **river water heat pumps** at **existing CHP plants.**
- Heat production is a **good flexibility option** for the electricity sector during summer and transitional periods.
- River water heat pumps can achieve **competitive LCoH** to conventional heat supply by CHP plants when using self-generated electricity.
- Very **flexible electricity tariffs** (i.e. flexible grid charges) required for economic efficiency of flexible systems.





Thank you for your kind attention! **solar@uni-kassel.de**