

Co-Simulation of a District Heating and Cooling System in Combination with Mine Thermal Energy Storage:

A Case Study in Germany

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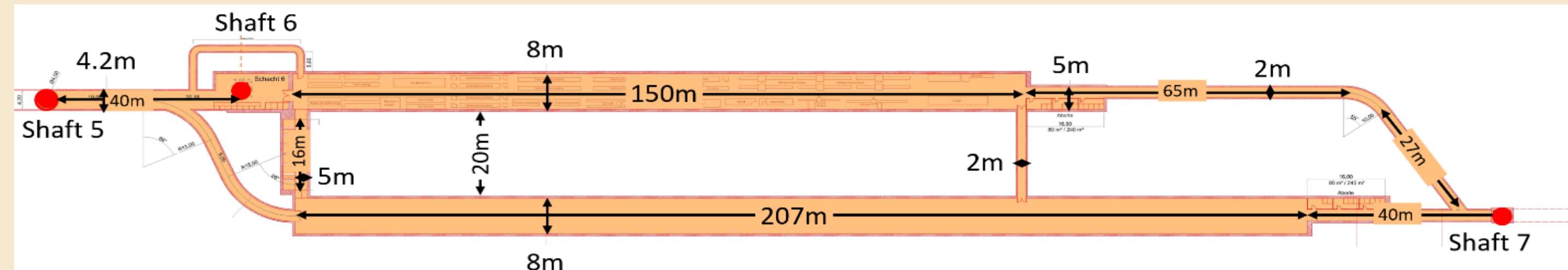
Project Description

Pilot Site

This project is part of the EU-funded PUSH-IT initiative, which develops and demonstrates underground thermal energy storage concepts across Europe. At the Ruhr University Bochum, a mine thermal energy storage (MTES) system is being developed in the former **Mansfeld colliery** beneath the Technical Centre. Some key facts about the mine (Fig. 1):

- The mine is located at a depth of roughly **120 meters**
- The volume of the mine is approximately **10,000 m³**
- Mine water and rock act as a “**geobattery**” for heat storage
- During WWII the mine was used for steel rope production

Fig.1 Top view on parallel, horizontal sections at a depth of 120 m.



Aim of the Project

- **Aim:** Use waste heat from the cooling cycle for the heating cycle to reduce cooling tower and gas boiler usage
- **Problem:** Waste heat is available when heat demand is low, and vice versa (Fig. 2)
- **Approach:** Integrate MTES system to store excess heat and balance seasonal mismatch between demand and supply

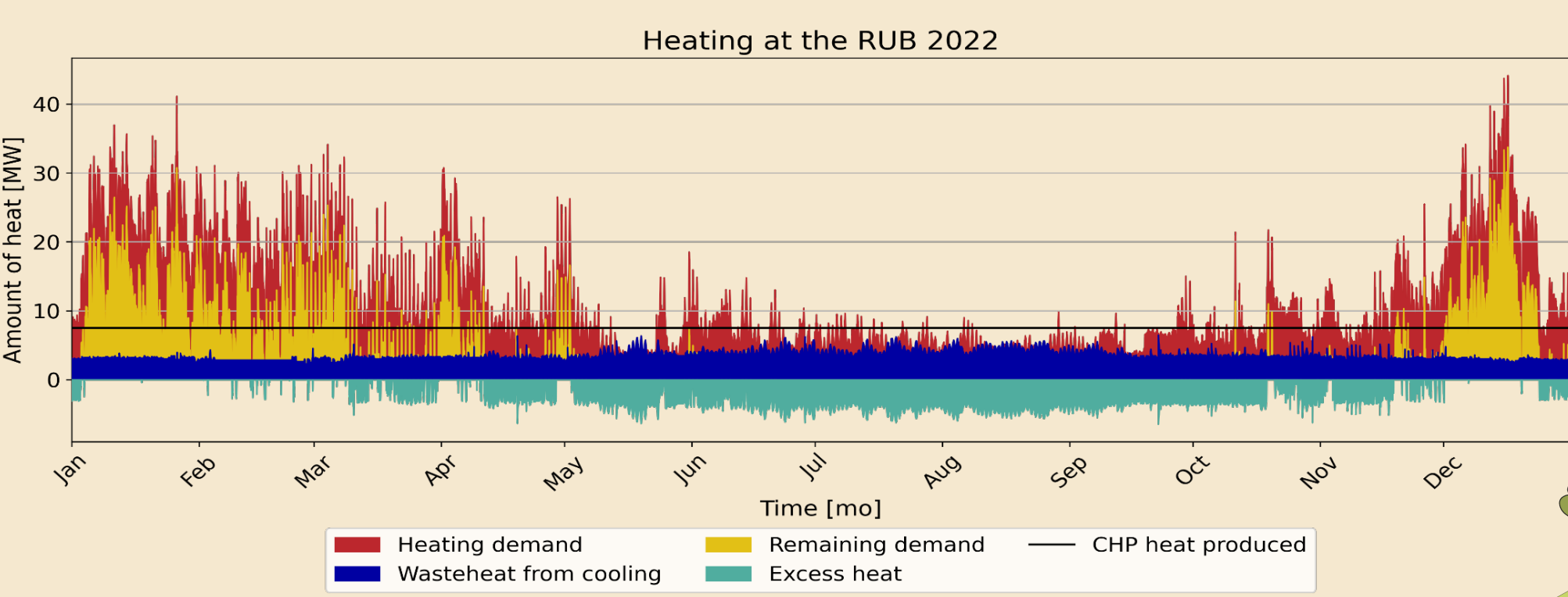


Fig.2 Overview of one year of the RUB's heating cycle data.

Results

Case Study

- MTES volume: **7,000 m³**
- Heat pump size: **2.5 MW**
- Timeframe: **2.5 years**

Tab. 1 The gas boiler and cooling tower output for the case study, compared to the current system.

Variable	Gas boiler output [GWh]	Cooling tower output [GWh]
Old system	86.31	78.01
New system	51.57	53.06
Difference	-34.74	-24.95

Comparison to Other Technologies

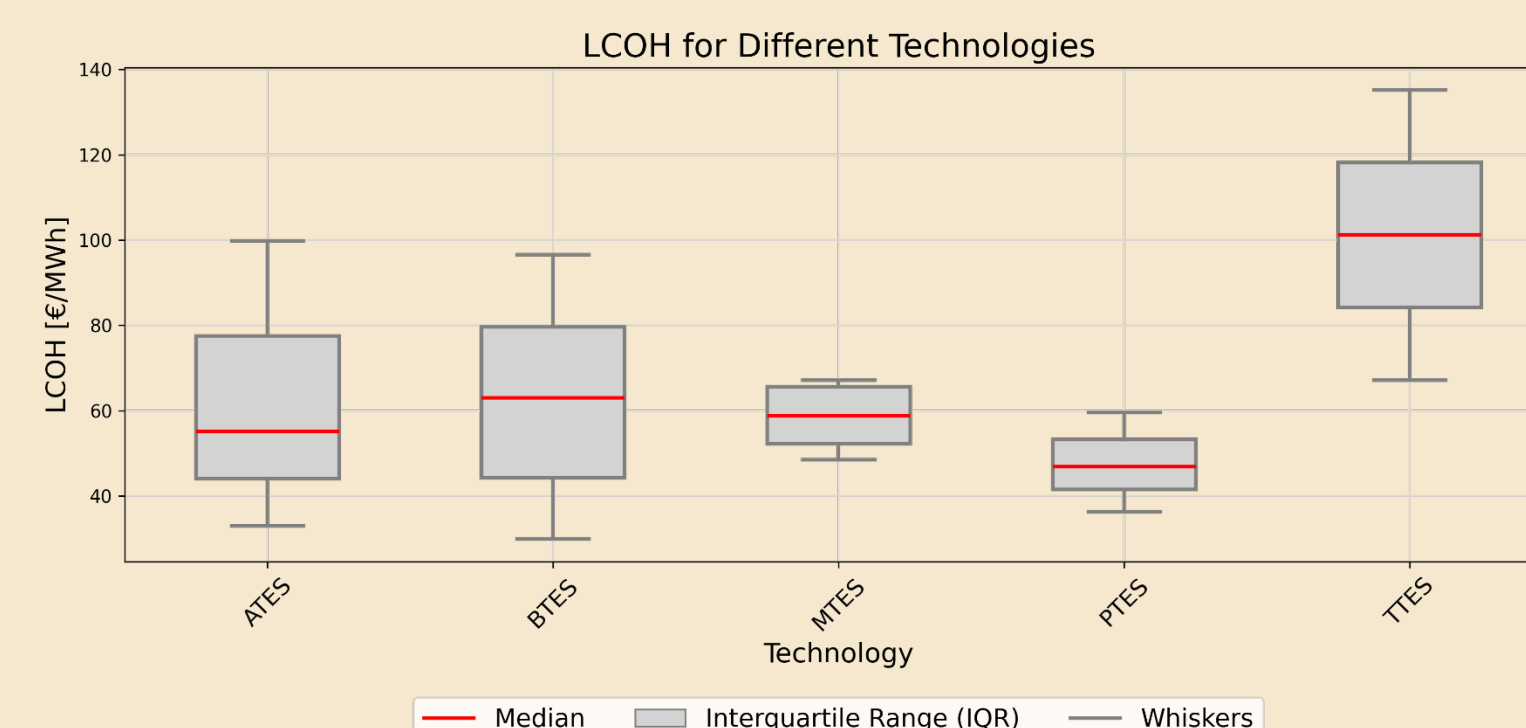


Fig. 5 The LCOH of the MTES compared to other technologies.

- Min. LCOH: **48.47 € MWh⁻¹** (Fig. 5)
- Max. LCOH: **67.16 € MWh⁻¹** (Fig. 5)
- CO₂ reduction: **2.26 kt a⁻¹** (Fig. 6)

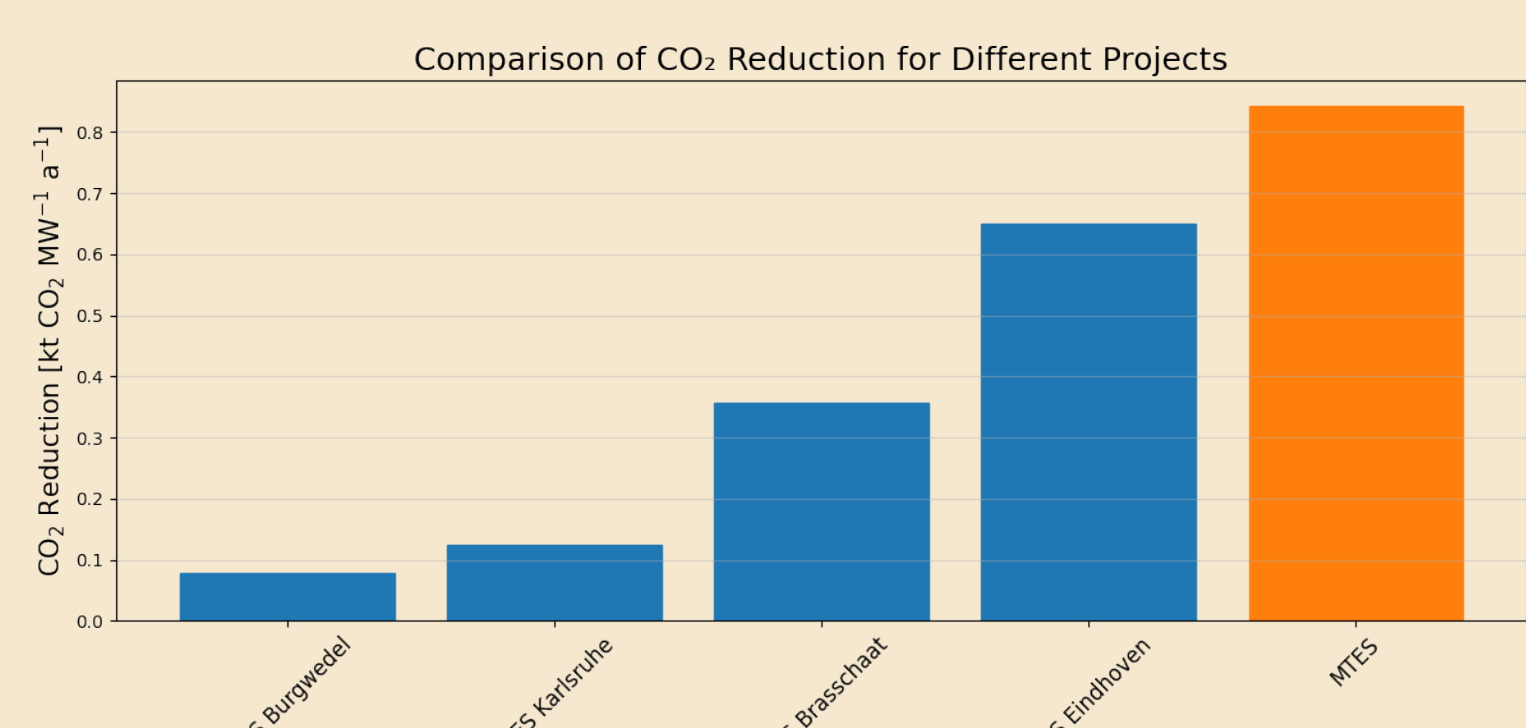
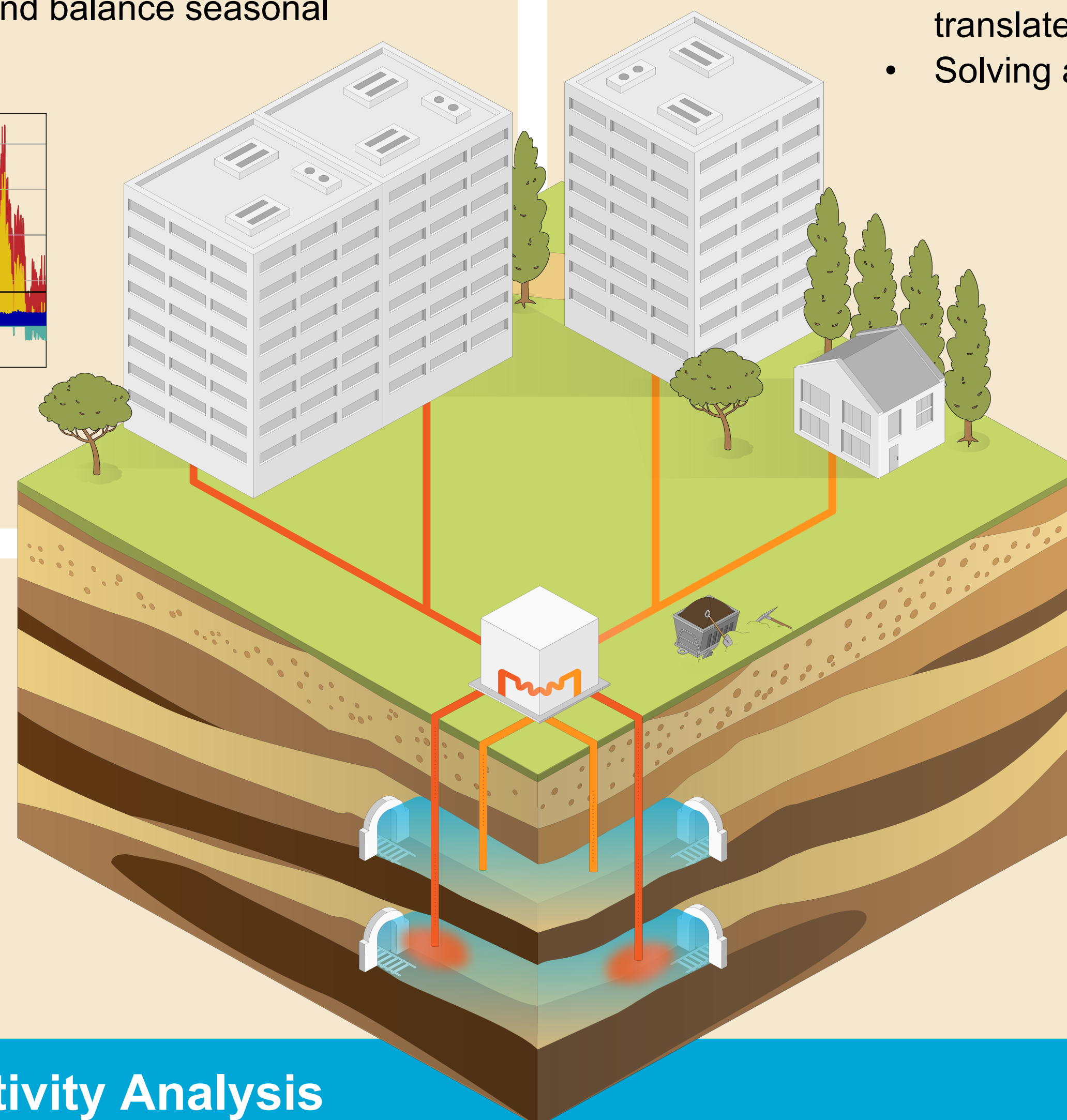


Fig. 6 The yearly CO₂ reduction per capacity.



Sensitivity Analysis

Component Sizing

Tab. 2 Heat pump sizes.

Variables	HP size [MW]	1.0	2.5	4.0	5.5	7.0
Total output [GWh]		13.06	34.74	49.37	51.86	50.94
Total input [GWh]		3.27	10.00	16.78	20.75	20.87
Total COP [-]		3.99	3.47	2.94	2.50	2.44
GB energy saved [GWh]		13.06	34.74	49.37	51.86	50.94
CT energy saved [GWh]		10.98	24.95	34.22	34.88	33.75
Total energy saved [GWh]		24.04	56.69	83.59	86.74	84.69
Tot. energy saved per size [GWh MW ⁻¹]		24.04	22.68	20.90	15.77	12.10
CO ₂ reduction [kt y ⁻¹]		0.84	2.26	3.28	3.49	3.46
LCOH [€/MWh ⁻¹]		81.5	67.2	73.1	93.7	114.8

Operational Parameters

Tab. 4 ΔT values.

Variable	ΔT [K]	0	5	10	15
Total output [GWh]		36.72	36.72	34.74	27.89
Total input [GWh]		10.70	10.70	10.00	7.42
Total COP [-]		3.43	3.43	3.47	3.76
GB energy saved [GWh]		36.72	36.72	34.74	27.89
CT energy saved [GWh]		25.28	25.28	24.84	21.71
Total energy saved [GWh]		62.00	62.00	59.58	49.60
Tot. energy saved per dT [GWh K ⁻¹]		N/A	12.4	5.96	3.31
CO ₂ reduction [kt y ⁻¹]		2.38	2.38	2.26	1.89
LCOH [€/MWh ⁻¹]		65.3	65.3	67.2	75.5

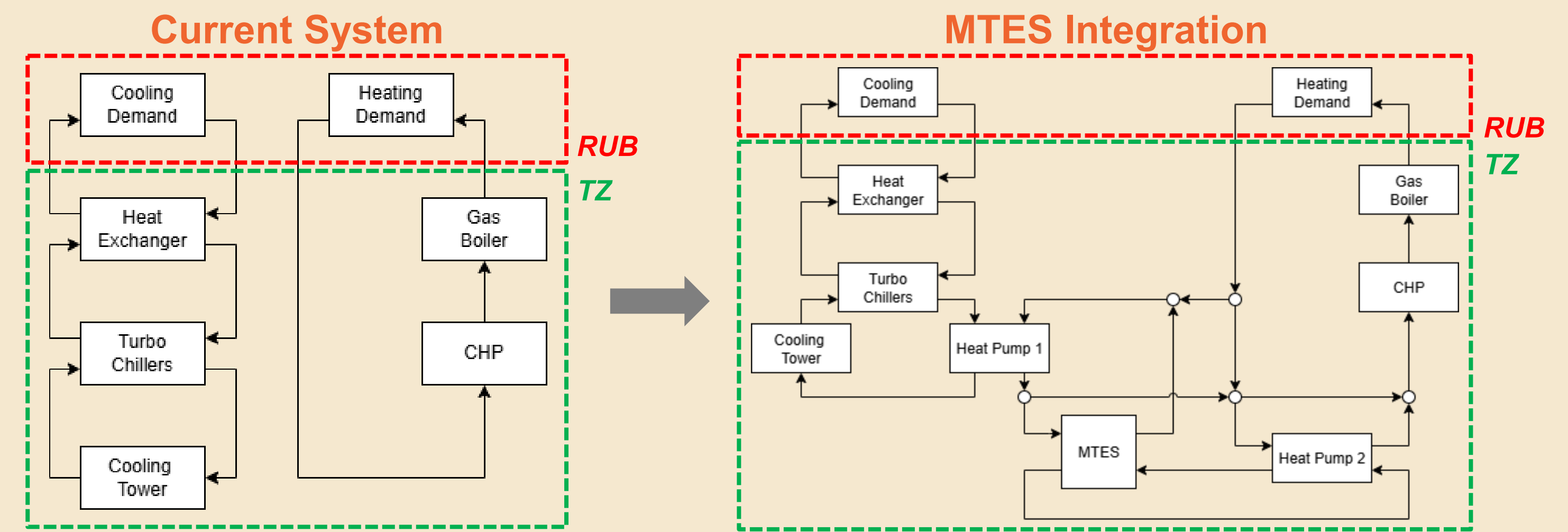
Optimal Setup

For the optimal setup, the energy distribution of the following situations are analysed (Fig. 7):

- Optimal practical setup: HP 5.5 MW, ΔT 5 K; MTES 10,000 m³, 50 °C
- Optimal theoretical setup: HP 5.5 MW, ΔT 5 K; MTES 497,809 m³, 50 °C

Methods

MTES Integration and Co-Simulation



TZ = Technical Centre
RUB = Ruhr Universität Bochum

Fig. 3 Schematic setup of the current system (left) and the system with integrated MTES (right), as developed in this project.

Software:

- Heating and cooling system (surface) modelled with **Modelica**
- MTES (subsurface) modelled with **Python**

Co-simulation:

- Coupling: Orchestrator and MTES model in Python, Modelica is translated with Functional Mockup Unit (FMU) (Fig. 4)
- Solving algorithm: **non-iterative Gauss-Seidel**

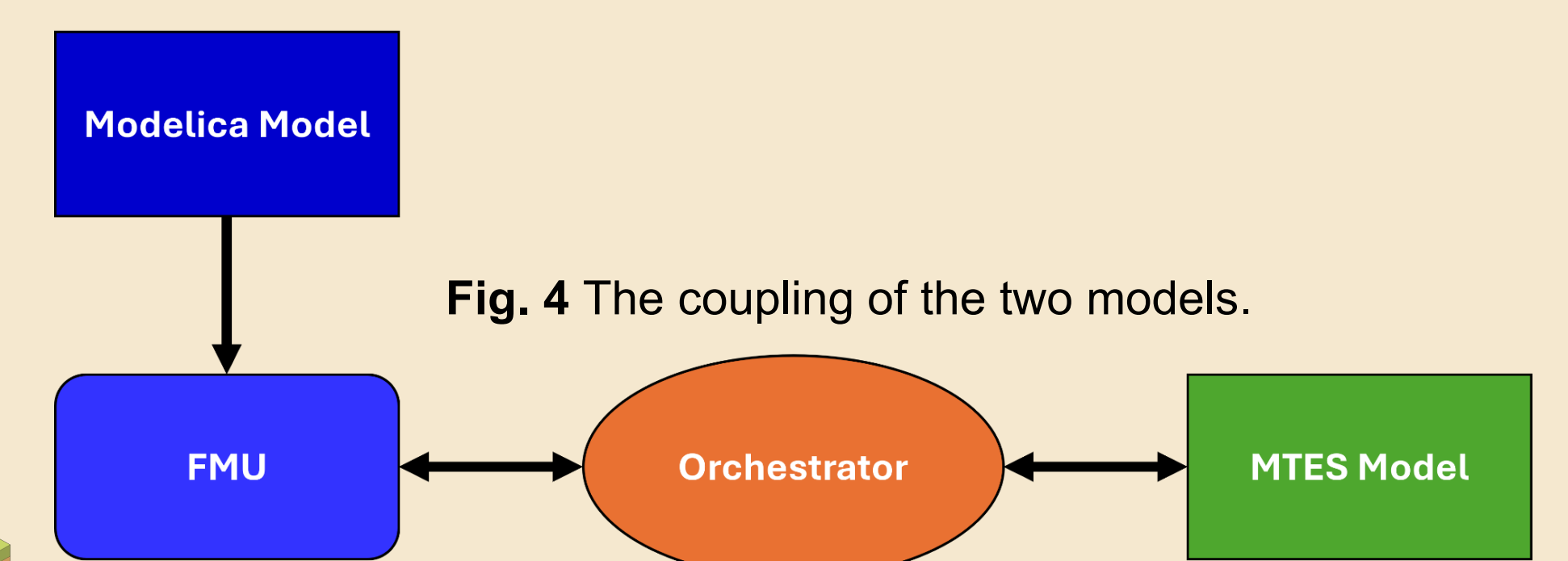
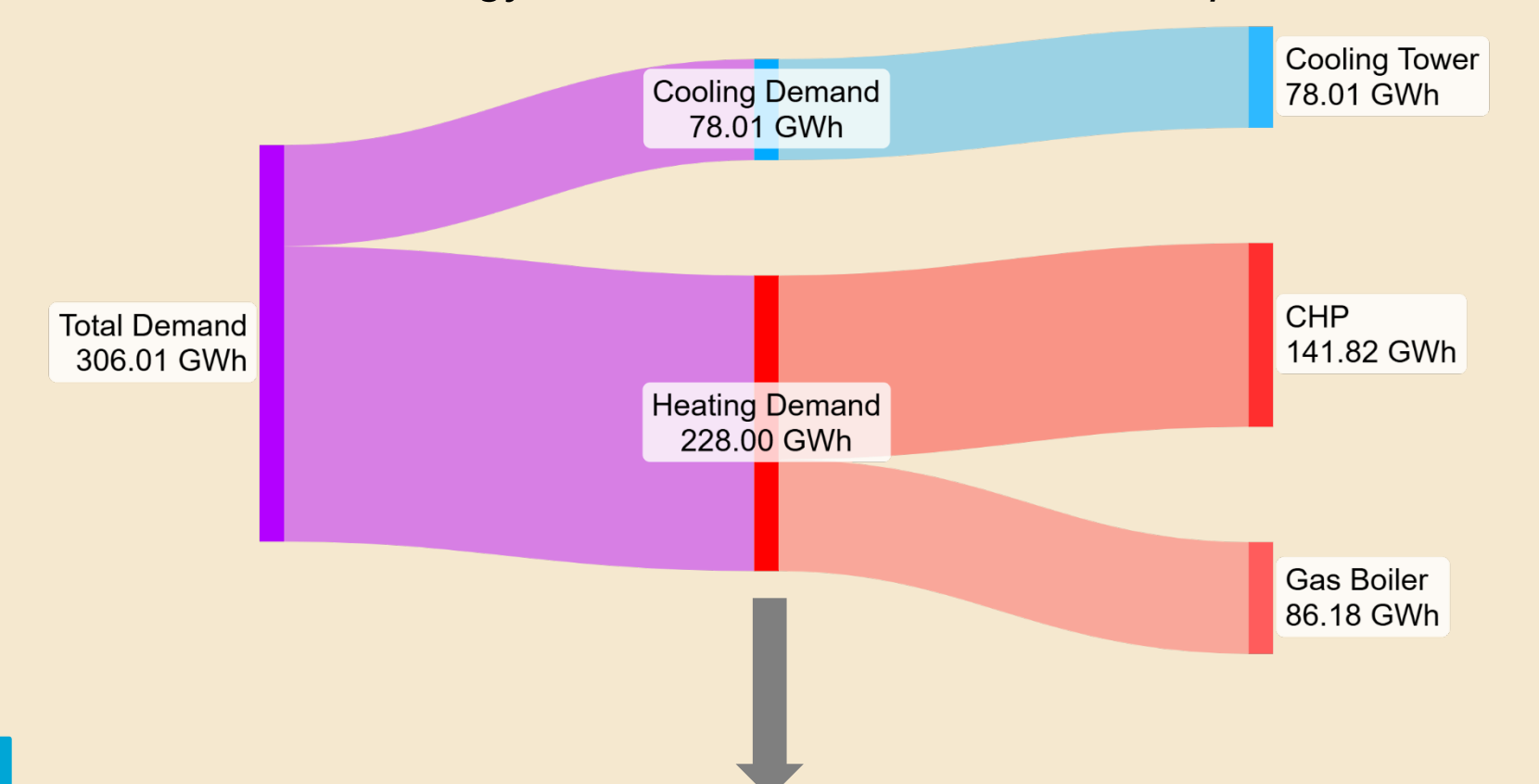
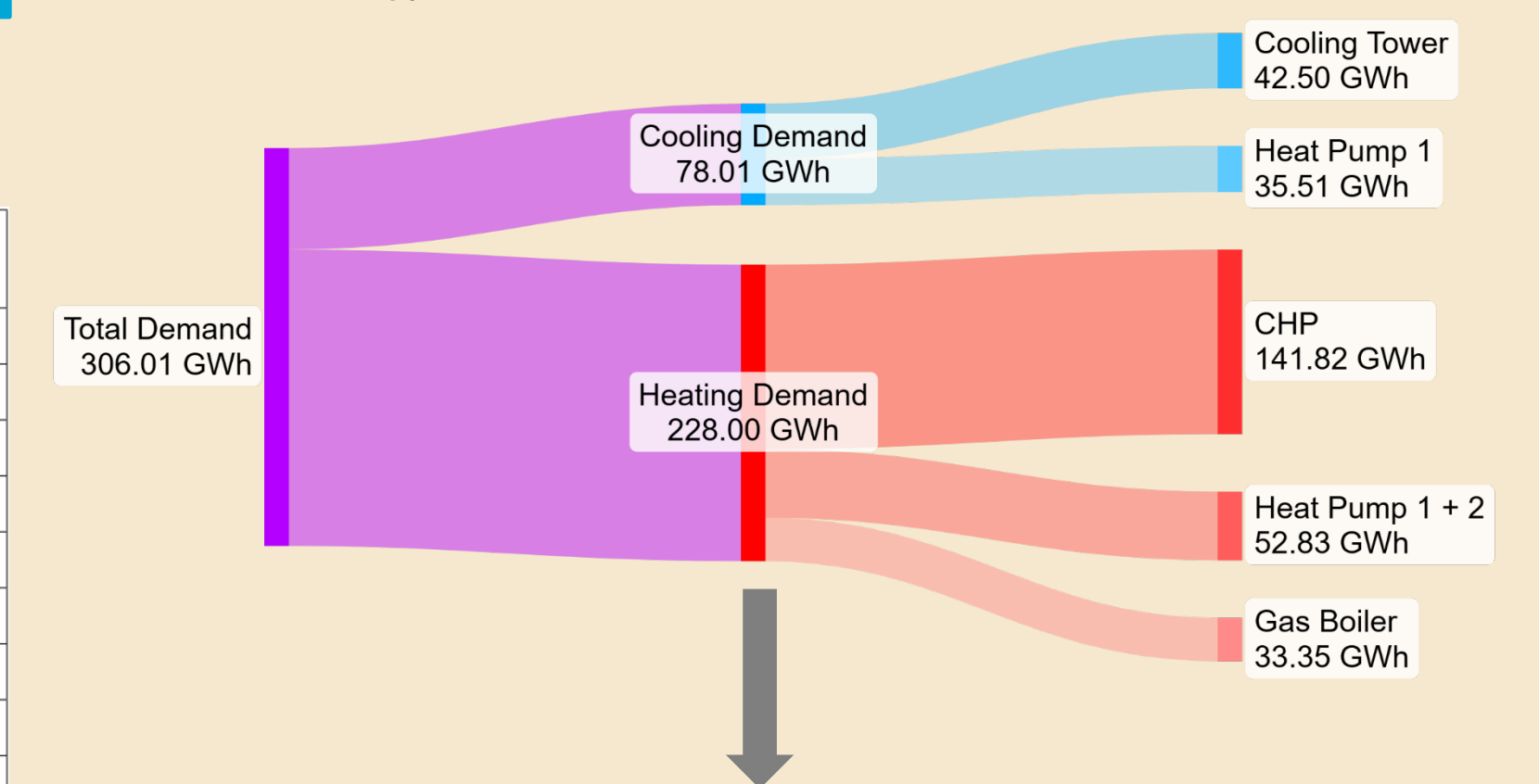


Fig. 4 The coupling of the two models.

The energy distribution for the current setup



The energy distribution for the optimal practical setup



The energy distribution for the optimal theoretical setup

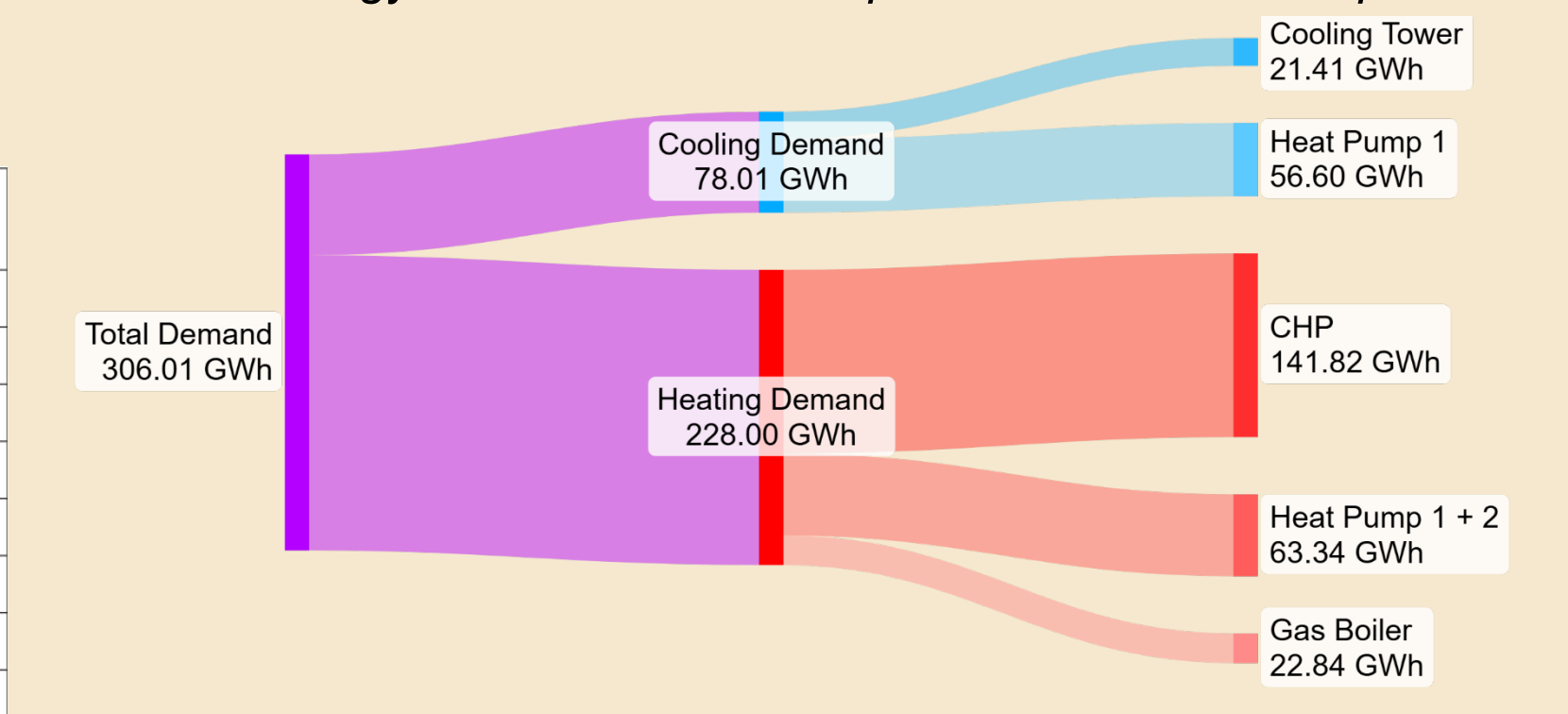


Fig. 7 The energy distribution for different scenarios.

Conclusion

The MTES system is technically, environmentally and economically effective, offering a promising solution for balancing seasonal mismatches between demand and supply.

