Development of a model library to identify energy saving potentials through process coupling in the thermal process industry

5th Aachen Thermoprocess Colloquium

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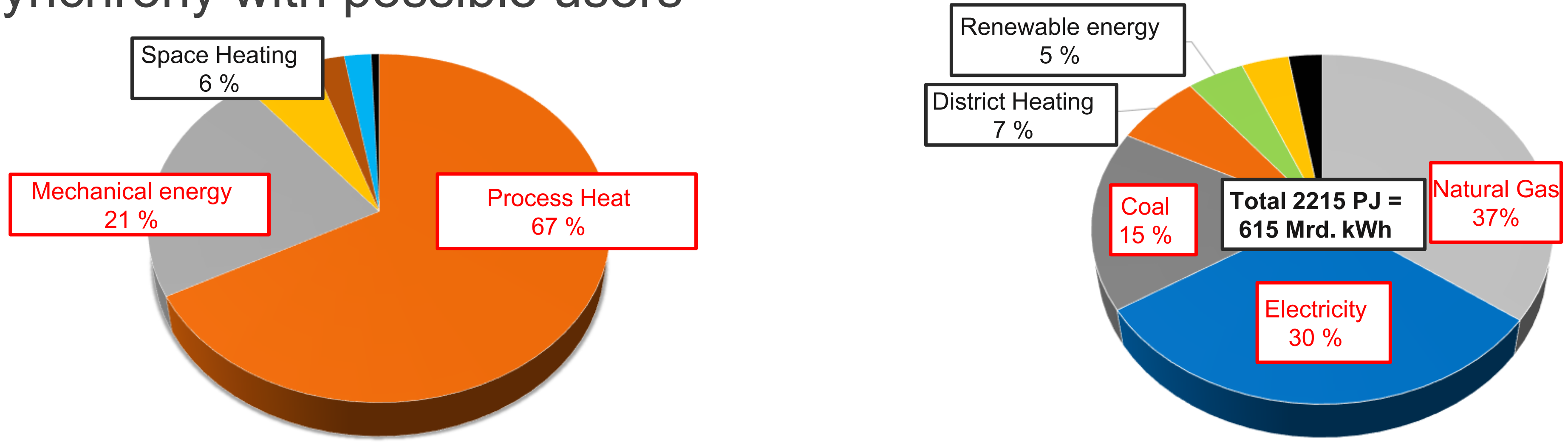
Aachen, 23.09.2025

Motivation

- Final energy use in the industrial sector is primarily process heat
- Large share of the unused energy is lost as waste heat
  - In natural gas-fired industrial furnaces, the share of waste heat amounts about 20 % to 75 % depending on temperature and operating mode
- Waste heat occurrence is characterized by significant temporal fluctuations and lacks synchrony with possible users



Final energy in German industry 2023 by applications (left) and energy sources (right)*

*Source: Erstellung von Anwendungsbilanzen für die Jahre 2021 bis 2023 für die Sektoren Industrie und GHDAG Energiebilanzen

Main driver for CO_2 reduction

1990 2020 2030 2040 2050

Efficiency improvements

Individual processes

Process coupling

Sector coupling

Technological change

Fuel change

Use of electrical energy

Other

CCS

CCU

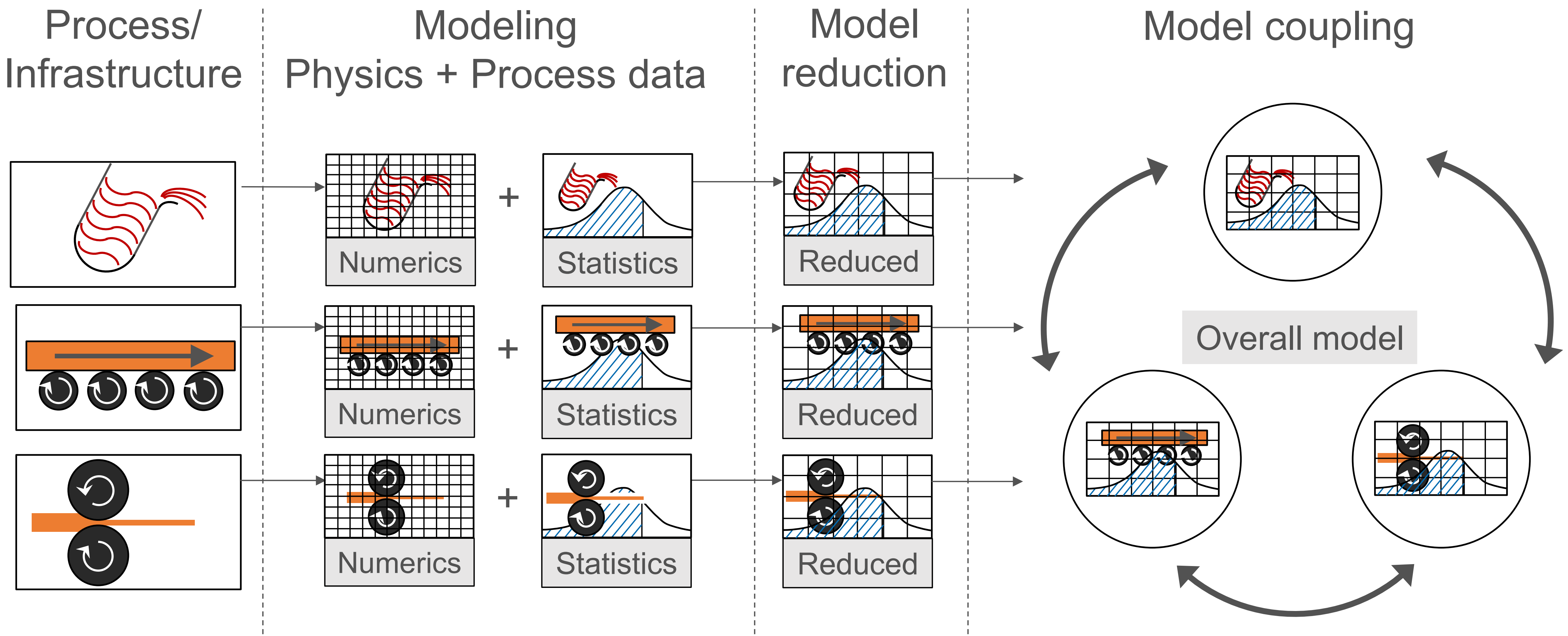
Primary

Secondary

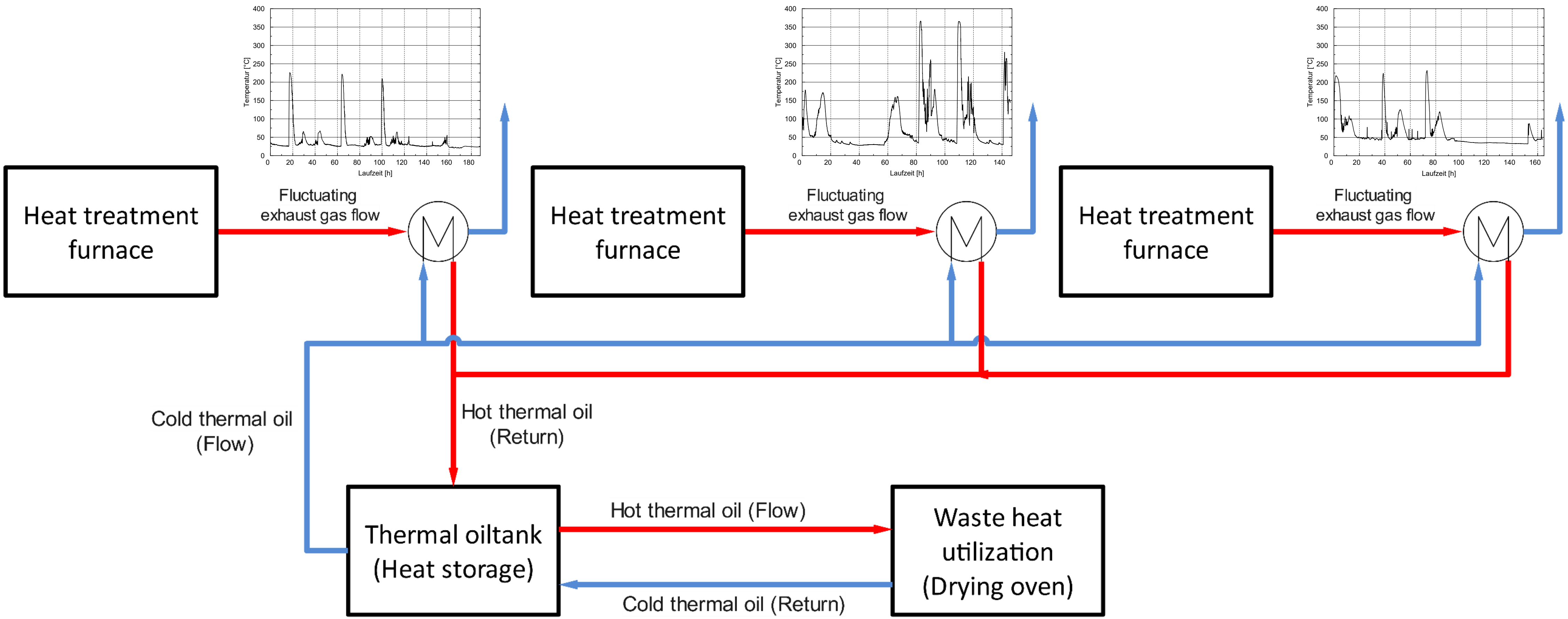
Tertiary

Development of a model library as a tool for utilizing process- and sector coupling

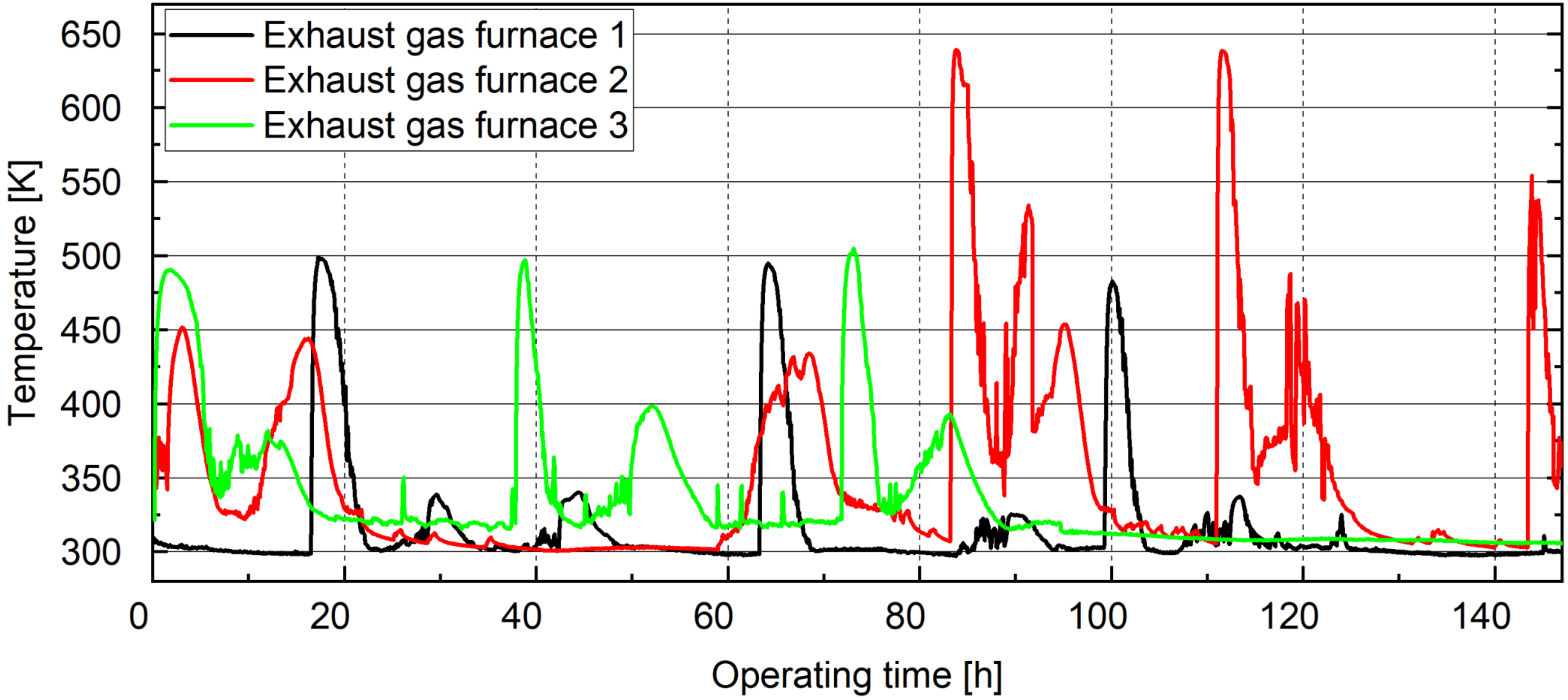
Methodological Approach: Model Development



Application example

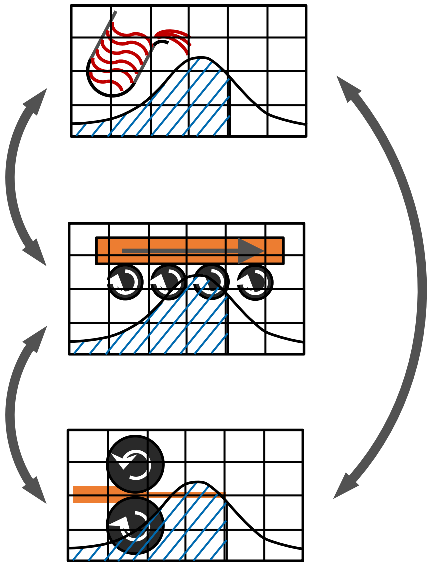


Application example

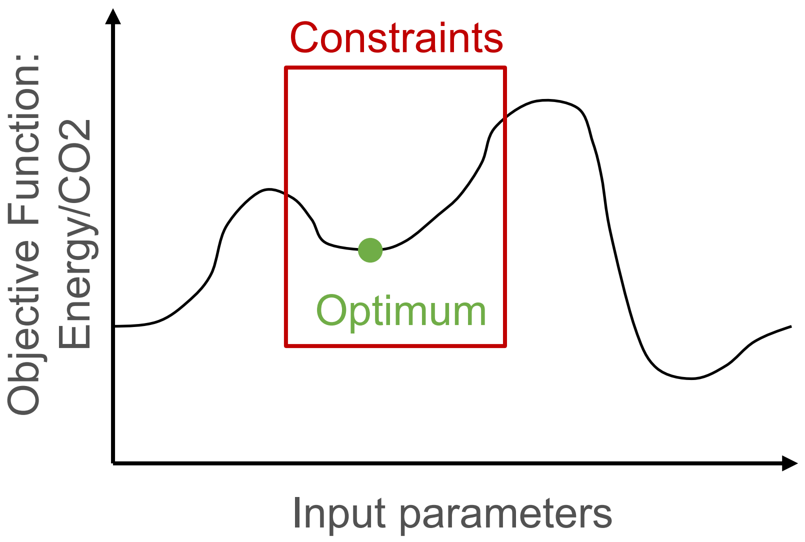


Methodological Approach: Structural optimizer

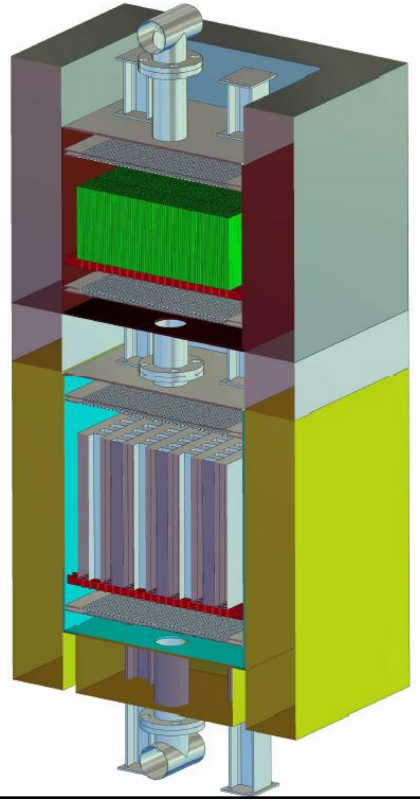
Overall model



Optimization



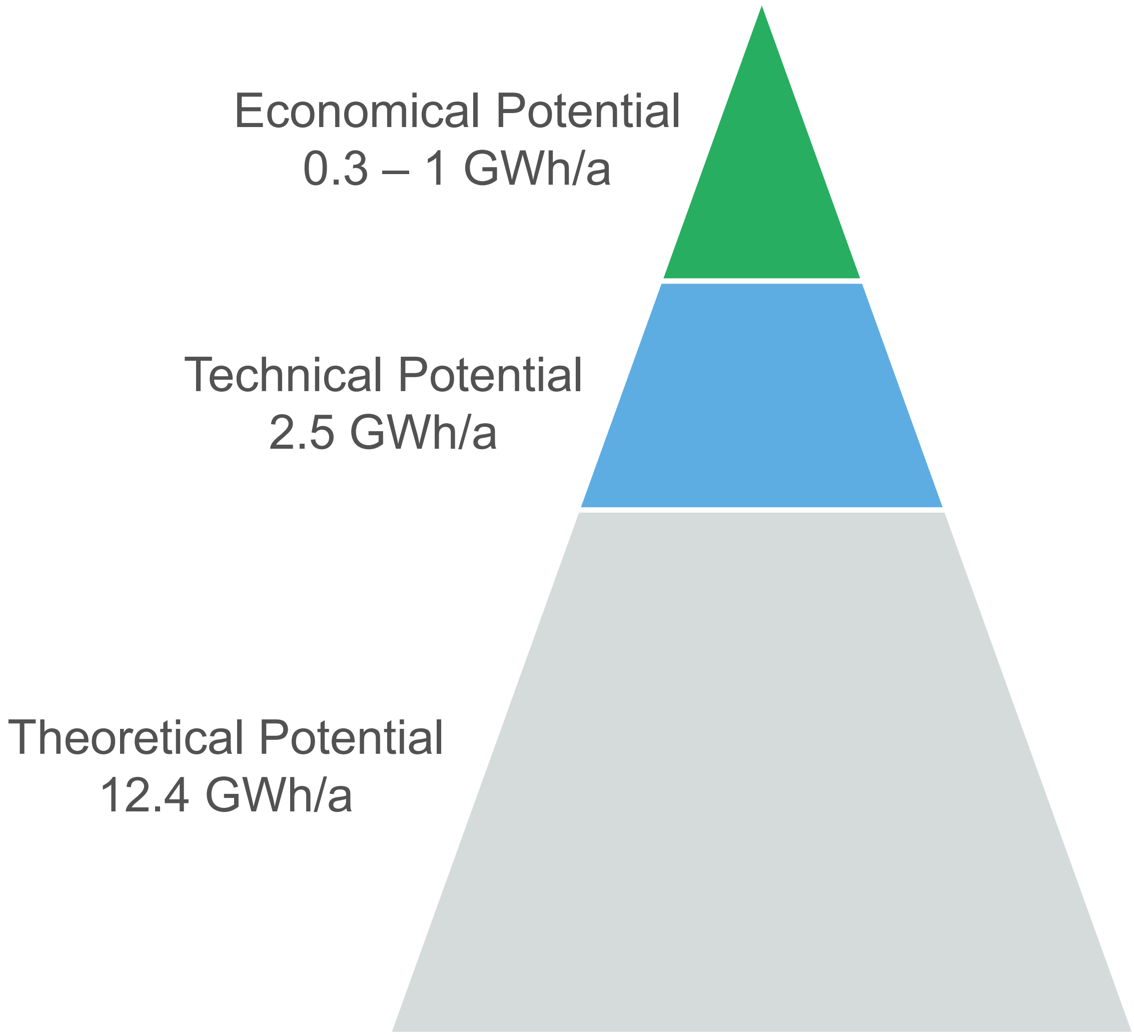
Sample application: Thermal storage



Potential amount of usable waste heat

- Constraints:
  - Temperature of heat utilization 130 °C
  - Temperature difference for heat exchangers
  - Spatial allowance for additional components
  - Different chimney structures for each furnace

- Economical
  - Investment costs such as heat exchangers, thermal heat storage, thermal oil etc.
  - operating costs
  - saving potentials

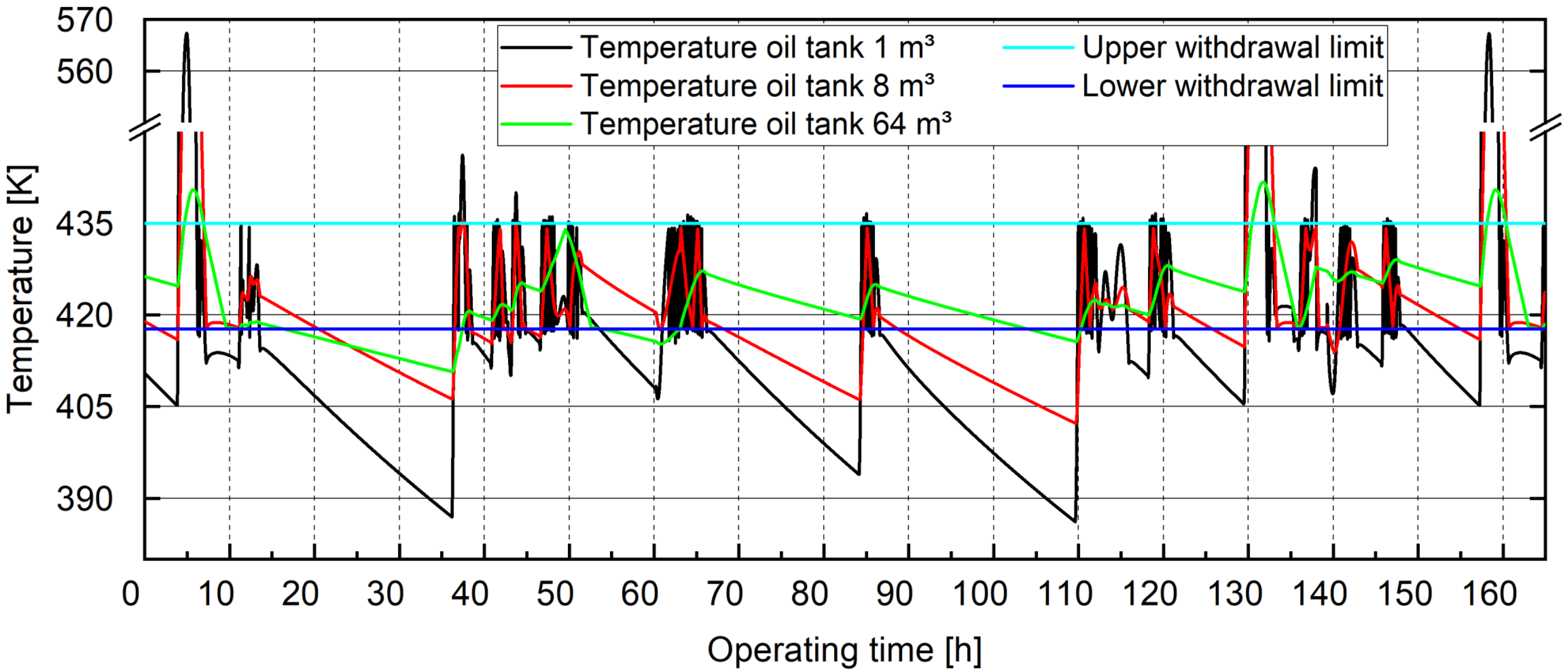


Results structural optimization

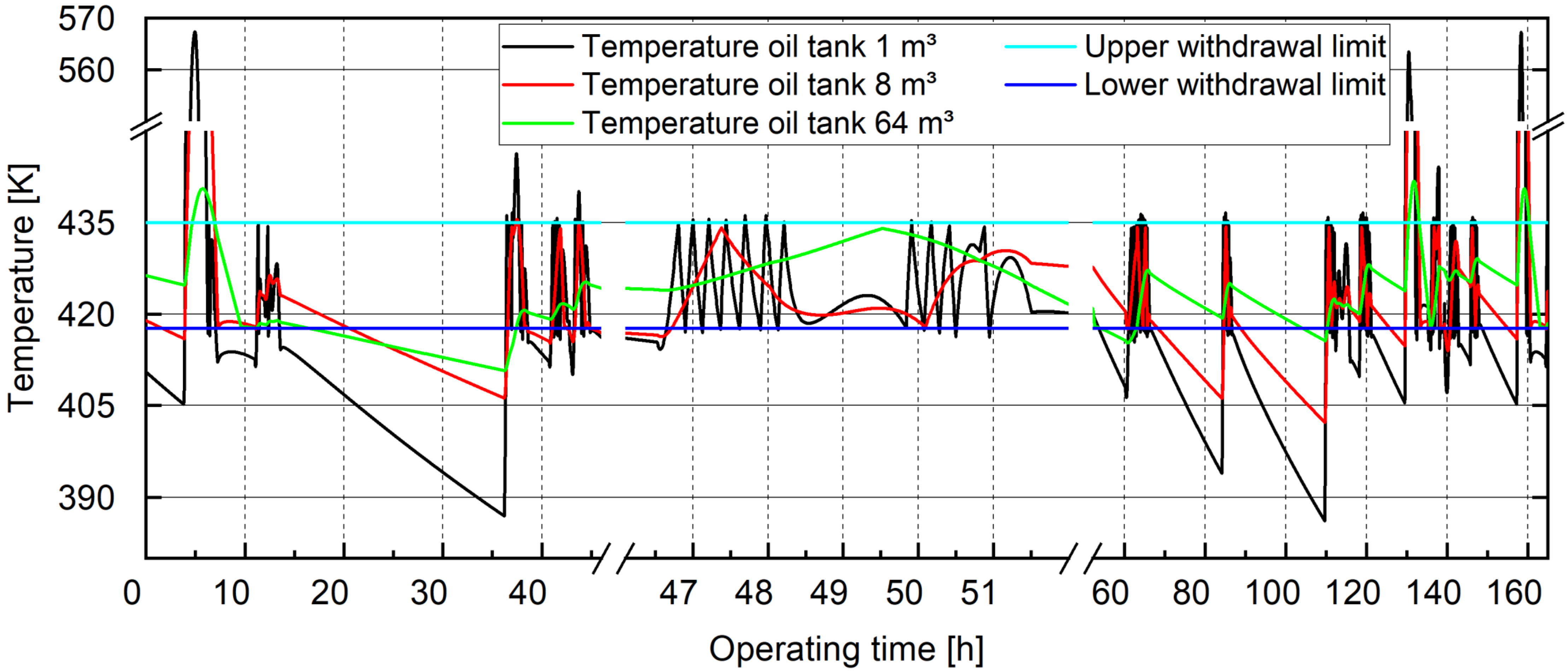
- Use of the optimizer to identify the optimal oil tank size for maximizing waste heat utilization (10 cycles run)

	Design Variable	Results		Cost function	
	Edge length $[m]$	Heat Losses $[MWh]$	Surface area $[m^2]$	$Q_{Usefuel\ Heat}$ $[MWh]$	Volume $[m^3]$
Initial value	4	22.6	96	31.4	64
Intermediate	2	6.5	24	44.4	8
Best Case	1	1.8	6	44.5	1

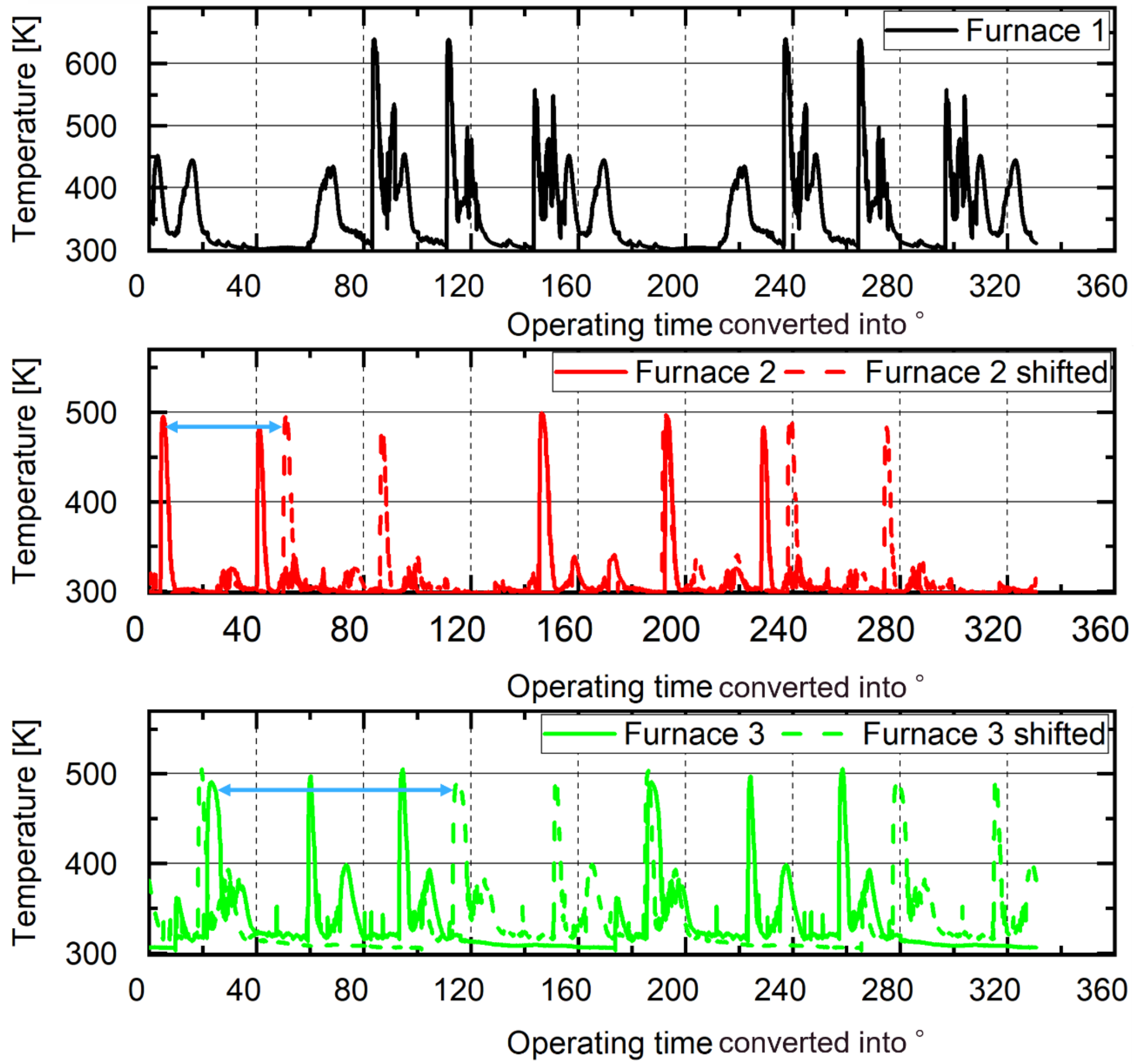
Results structural optimizer



Results structural optimizer



Operation optimizer



Current situation:

- The reheating furnaces produce unused heat at different times.
- In some cases, several furnaces simultaneously generate excess heat that exceeds the storage capacity.
- Long periods without unused heat force us to resort to fossil fuels.

Example use of the operation optimizer

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- Use of the optimizer to identify the optimal operating shift to maximize waste heat utilization (10 cycles run)
- Thermal oil tank size 1 m³

Case	Design variables		Results	
	Shift of Furnace 2 [°]	Shift of Furnace 3 [°]	Heat Losses $[MWh]$	$Q_{Useful\ Heat}$ $[MWh]$
1	0	0	1.76	44.5
2	158	93	1.75	36.8
3	72	35	1.75	45.2

Operation optimizer

Ideal scenario:

- Avoiding oversupply at any given time
- Avoiding periods during which there is no supply at all
- Maximizing continuous charging of the heat storage unit
- Reducing energy waste and fossil fuel consumption

Conclusion

- The use of system modeling facilitates an evaluation of the energy saving potential in complex systems
- Using structural and operational optimization provides the magnitude of potential energy savings and a rough estimate of their economic feasibility
- The approach can be readily adapted and applied to various processes in order to identify potential energy savings

Thank you very much!

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Supported by:

Federal Ministry for Economic Affairs and Energy

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG

on the basis of a decision by the German Bundestag

- Funding: This work was supported through funding from the German Ministry of Economical Affairs and Energy (BMWE) through the IGF Program (Nr. 22494 N).