FME HighEFF

Centre for an Energy Efficient and Competitive Industry for the Future

Deliverable D5.2_2020.05

Cost-efficient thermal energy storage for increased utilization of renewable energy in industrial steam production – CETES

Delivery date: 2020-10-22

Organisation name of lead beneficiary for this deliverable:

AIT

HighEFF- Centre for an Energy Efficient and Competitive Industry for the Future is one of Norway's Centre for Environment-friendly Energy Research (FME). Project co-funded by the Research Council of Norway and Industry partners. Host institution is SINTEF Energi AS.		
Dissemination Level		
PU	Public	X
RE	Restricted to a group specified by the consortium	
INT	Internal (restricted to consortium partners only)	

Deliverable number:	D5.2_2020.05
ISBN number:	
Deliverable title:	Cost-efficient thermal energy storage for increased utilization of renewable energy in industrial steam production – CETES
Work package:	WP 5.2 Novel emerging concepts
Deliverable type:	Presentation
Lead participant:	AIT

Quality Assurance, status of deliverable		
Action	Performed by	Date
Verified (WP leader)	Arne Petter Ratvik	15.12.2020
Reviewed (RA leader)	Ingrid Camilla Claussen	15.12.2020
Approved (dependent on nature of deliverable)*)		

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Abstract

This deliverable is a presentation of results from the NEC project CETES - Cost-efficient thermal energy storage (TES) for increased utilization of renewable energy in industrial steam production – presented at the HighEFF Annual Workshop. The presented approach allows for detailed cost analysis of the individual TES technologies, yielding important decision-support for cost-efficient TES. The case studies show that case-specific cost estimations are necessary to identify the most cost-efficient TES solution.

Cost-efficient thermal energy storage for increased utilization of renewable energy in industrial steam production – CETES

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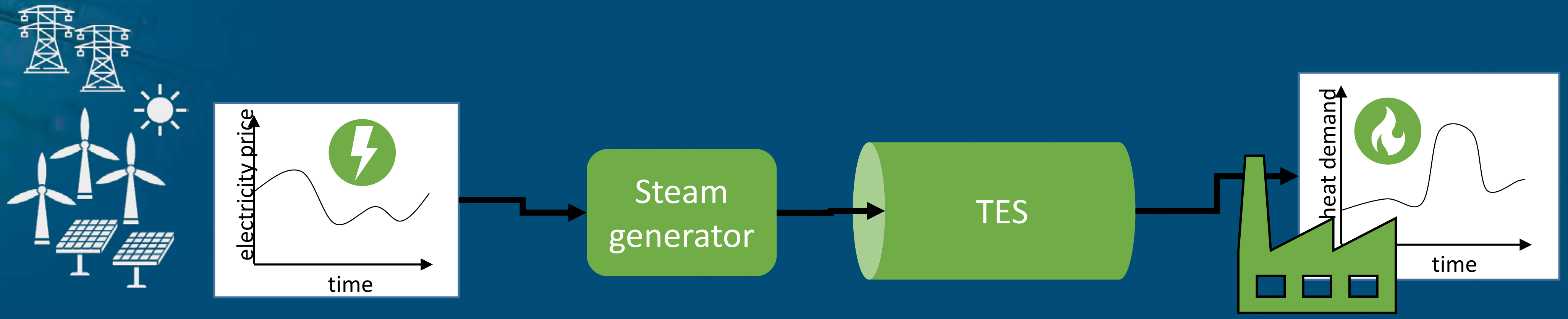
CETES – Why?

- Share of **fluctuating energy sources** increases in future decarbonized, electricity driven energy systems
- **Active market participation** from industry required for stable and flexible electricity supply.
- TES + P2H can **decrease energy costs** by shifting the electricity consumption to low-cost periods.
- **Short payback time** and profitability are key criteria for investment decisions

➔ **Problem:** How can we identify the most cost-efficient TES system?



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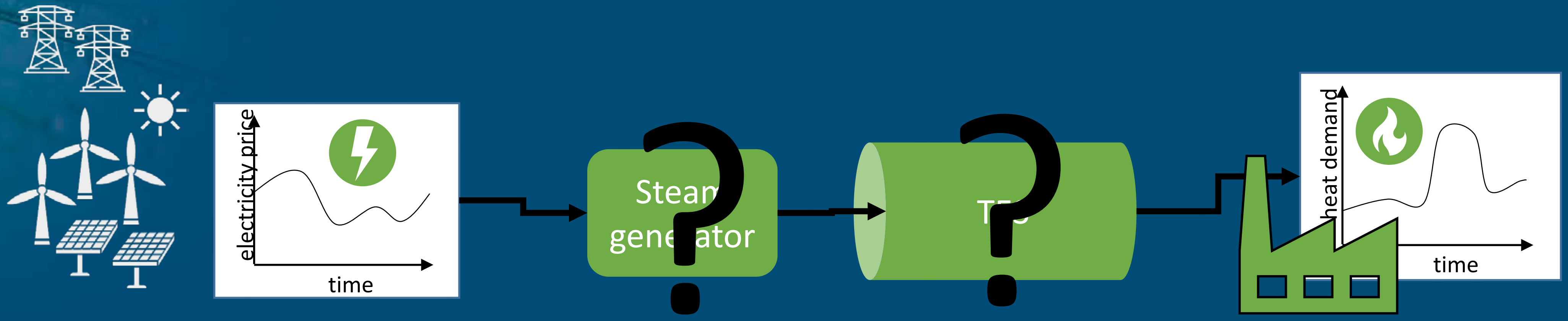
CETES – Why?

- **Most approaches** for cost-optimal storage integration consider **only storage capacity as a cost driver**
- Especially for industries, **heat load requirements are** a **crucial** factor for storage costs
- Also available **storage temperature range** and **thermal requirements** have a significant impact on storage costs

→ Cost functions including all these requirements are necessary!



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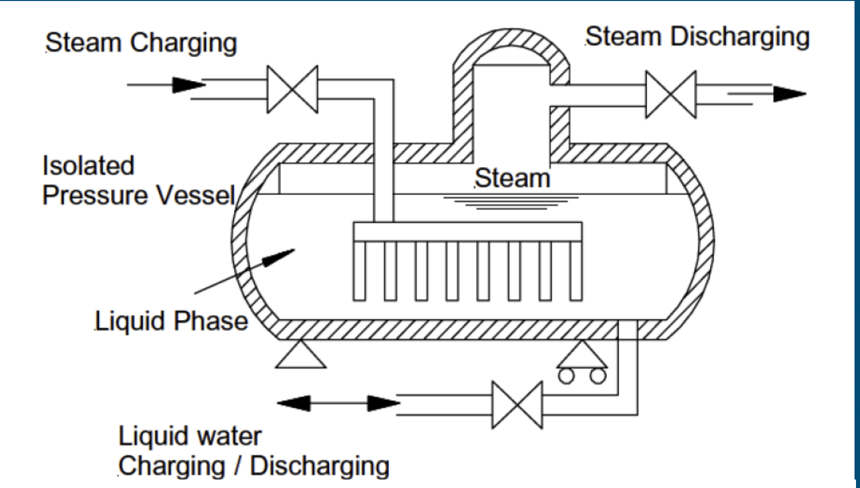
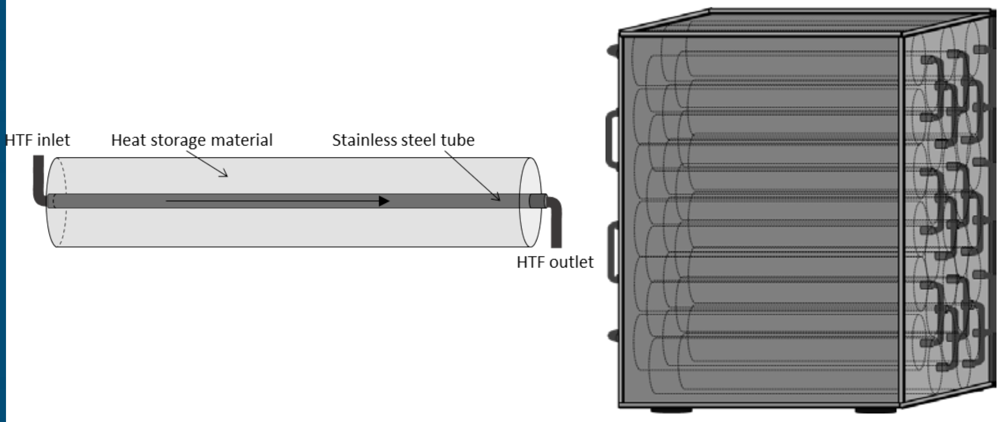
CETES – Storage Technologies

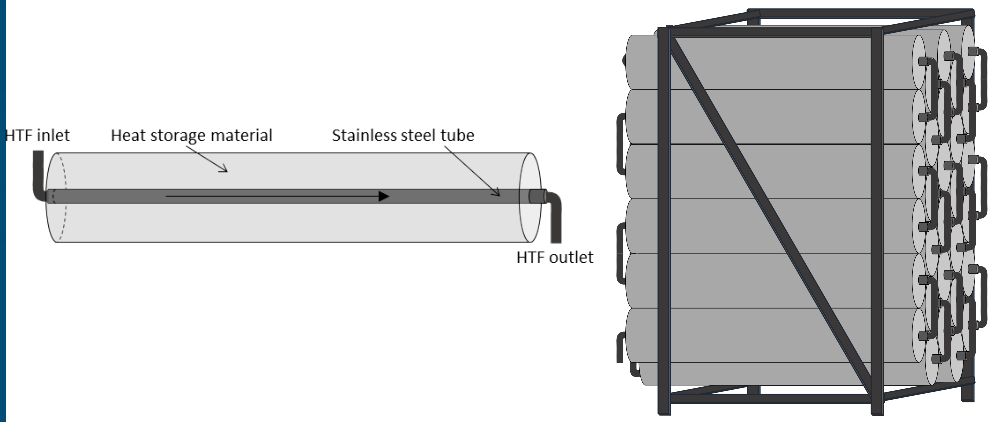


Ruths steam accumulators



Latent Heat Thermal Storages (LHTS)

Molten salt storages



Concrete storages

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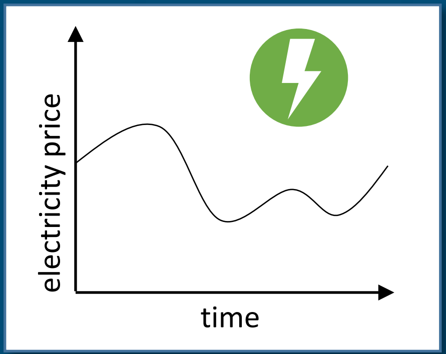
CETES – How?

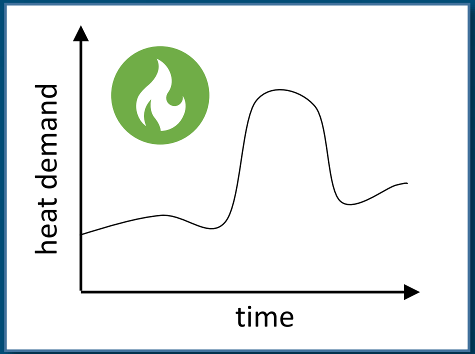
Equipment costs from Database:

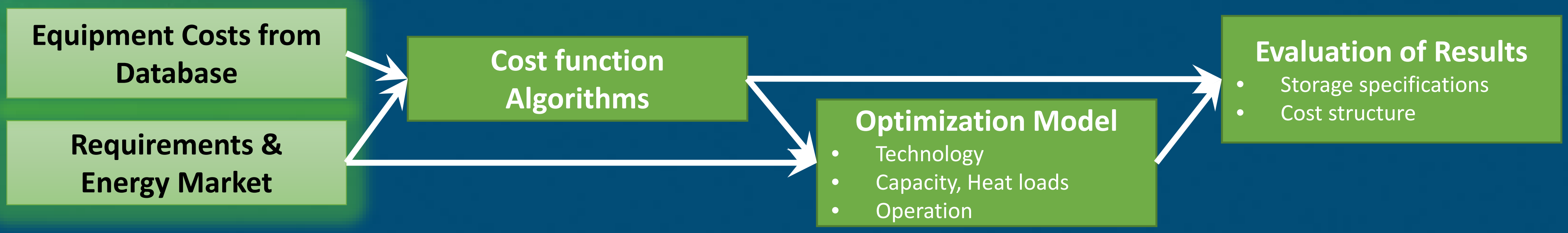
- Piping,
- Vessels, Tanks,
- Valves,
- Instrumentation,
- Insulation,
- Pumps, Motors,
- Storage Material,
- …

Requirements & Energy Market:

- Steam demand (temperature, heat flow)
- Energy markets (fluctuating energy prices)





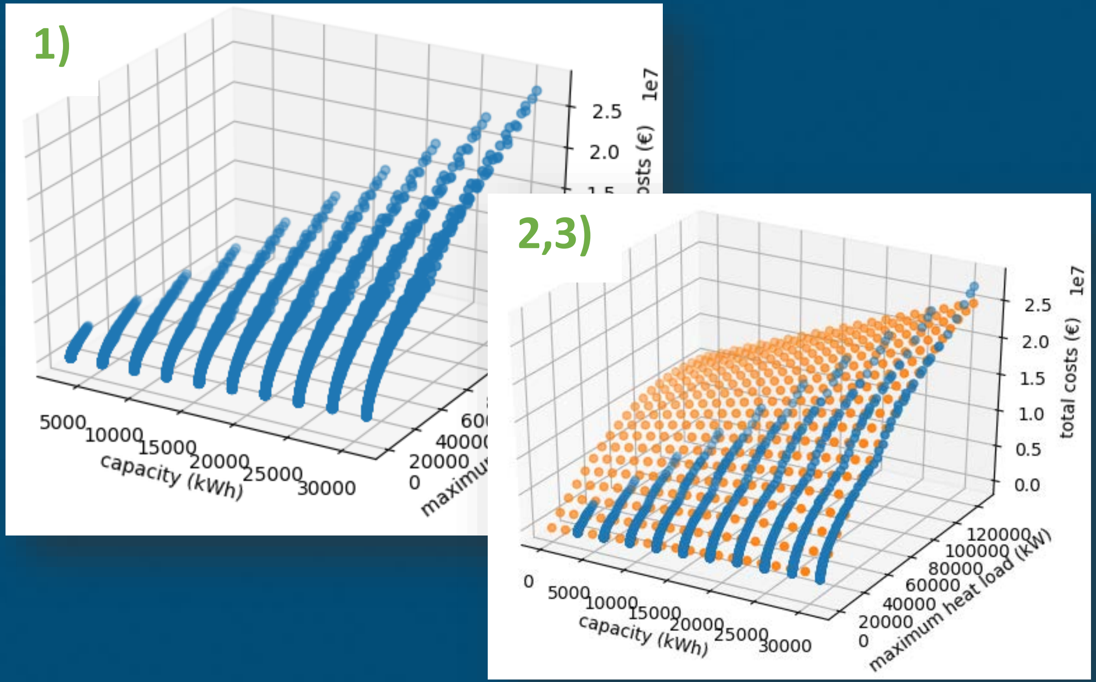


CETES – How?

Cost function algorithms:

1. Calculate costs for lots of different storage configurations → Datapoints
2. Eliminate suboptimal datapoints (if necessary)
3. Linear / Polynomial fit for optimal datapoints

$$costs = f(capacity, heat\ load)$$



Equipment Costs from Database

Requirements & Energy Market

Cost function Algorithms

Optimization Model
- Technology
- Capacity, Heat loads
- Operation

Evaluation of Results
- Storage specifications
- Cost structure

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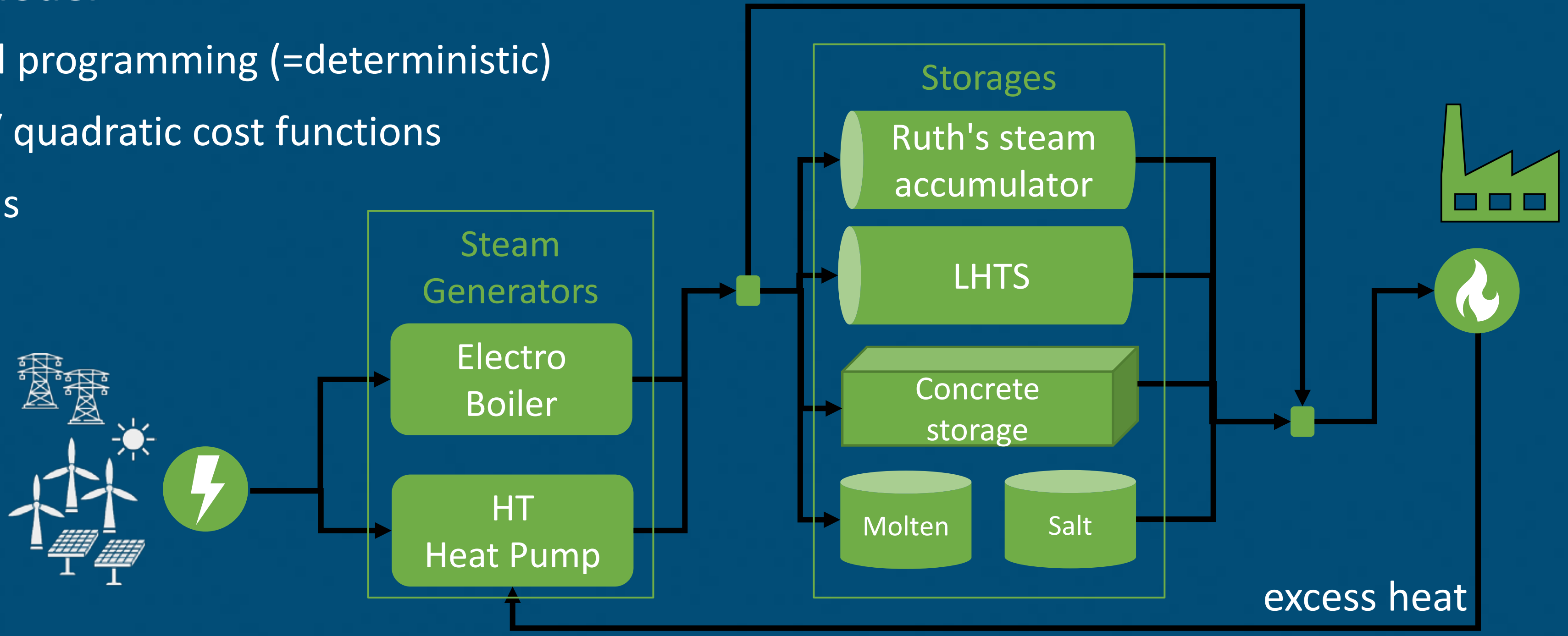
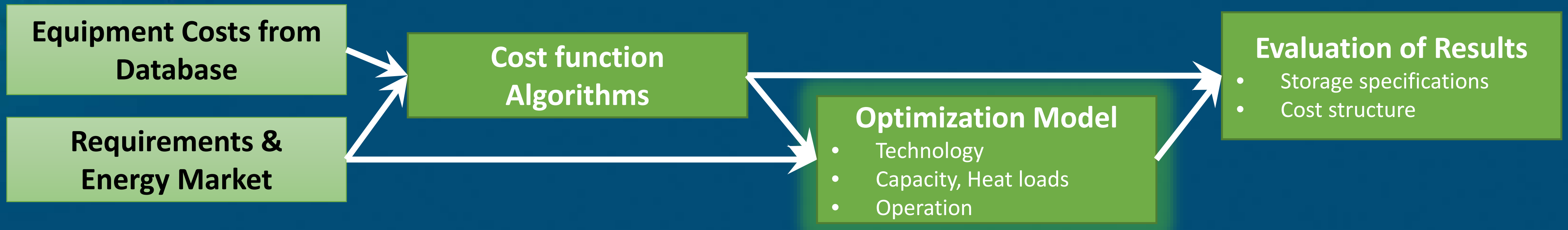
CETES – How?

Optimization Model

- Mathematical programming (=deterministic)
- (Non-)linear / quadratic cost functions
- Simple models
- Fast to solve





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CETES – How?

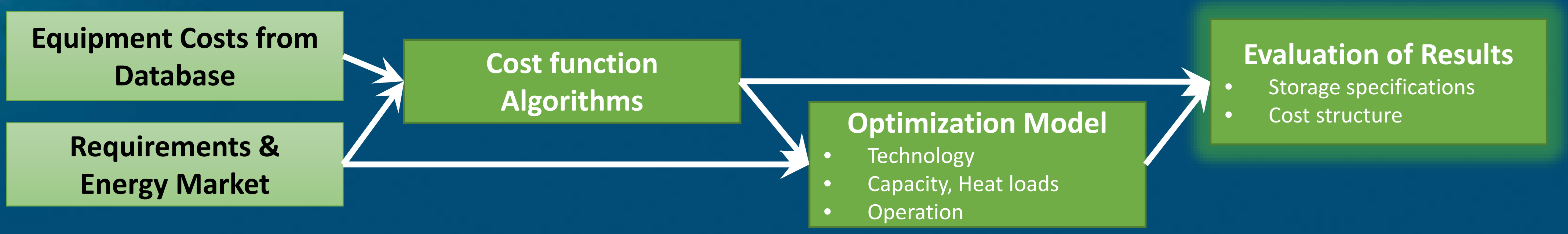
Evaluation of Results

The outputs of the optimization model are

- Storage capacities,
- Maximum heat loads and
- Optimal operation (Load profiles)

No details for the individual equipment such as piping, vessel geometry etc.

→ **Details** are calculated using **cost function algorithms**



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CETES – Example 1

Bayer process for producing alumina from Bauxite

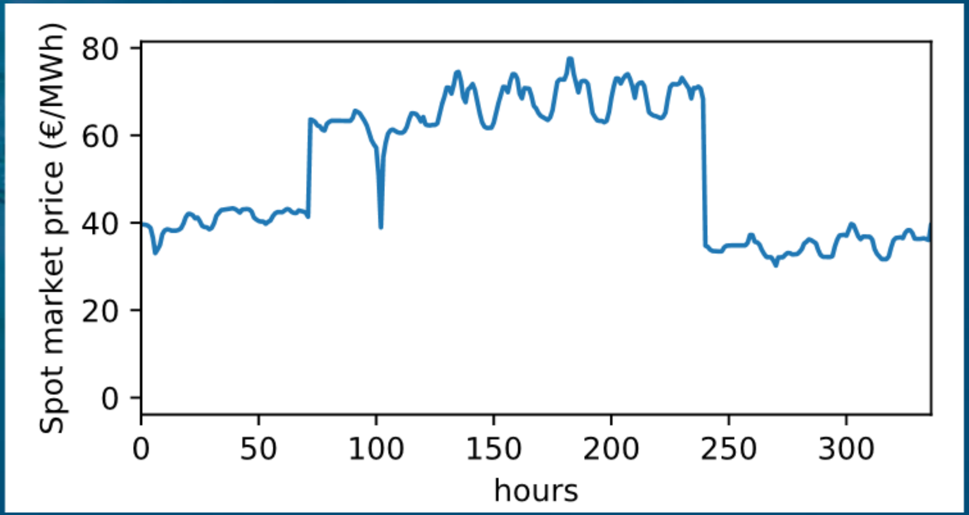
Constant steam demand: 900 MW – 200°C saturated steam

Steam generation temperature: 300°C

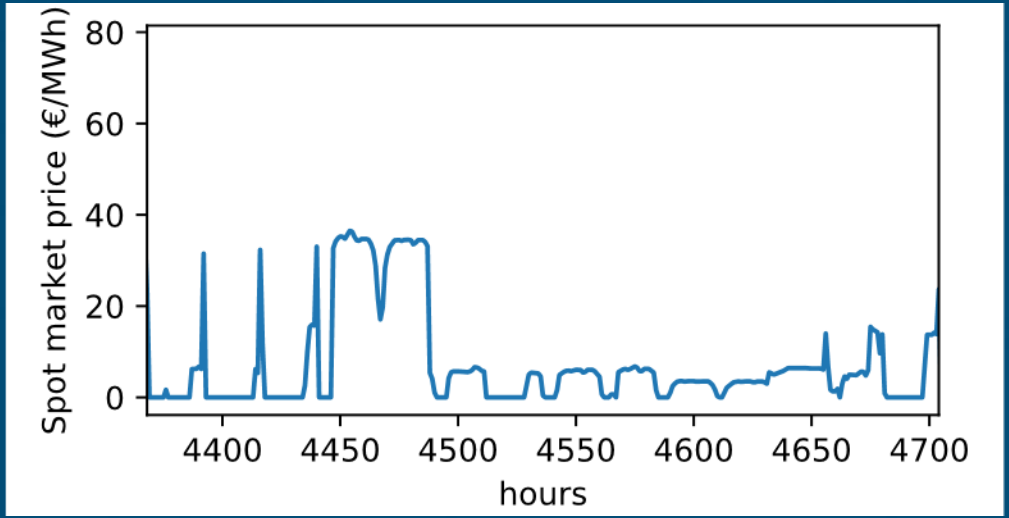
Temperature range for storage integration: 200-300°C

Spot-market prices (Brazil – selected weeks from January (dry season) and March (wet season) 2020)

Dry Season



Wet Season



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CETES – Example 2

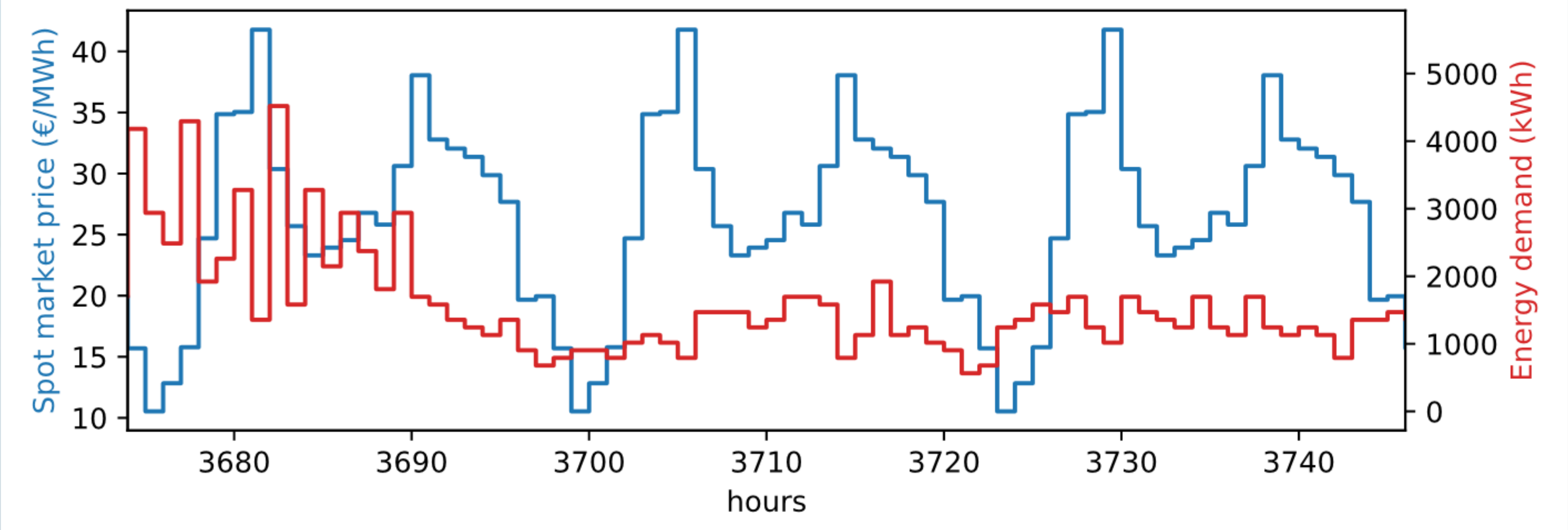
Brewery

Varying steam demand: 105 °C saturated steam

Steam generation temperature: 155 °C

Temperature range for storage integration: 105-155°C

Spot-market prices (Belgium, 22.01.2020, repeated for each day)



CETES – Example 1

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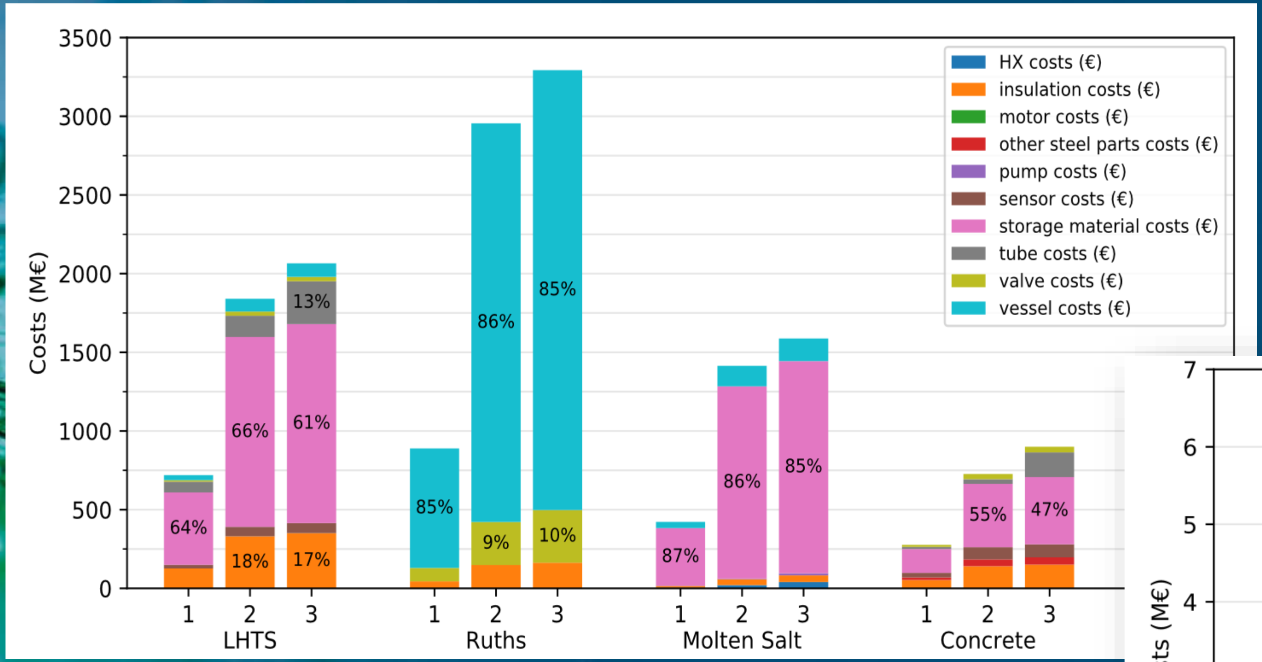
Bayer process for producing alumina from Bauxite



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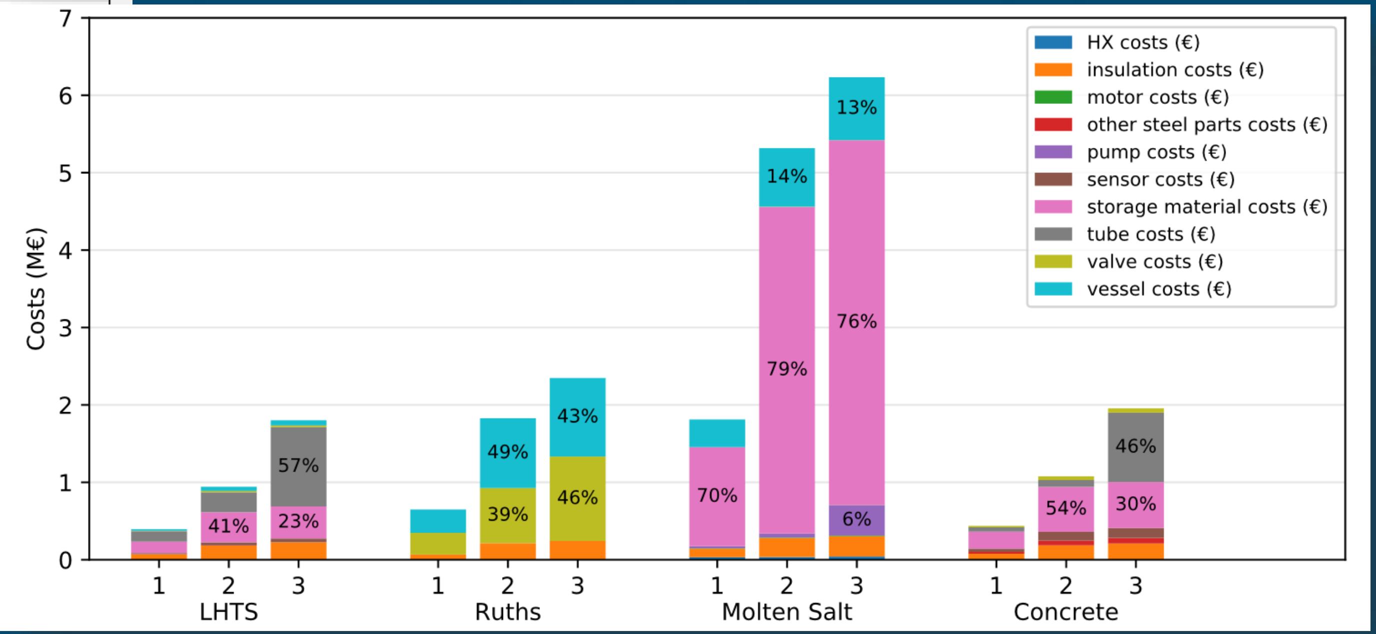

1: low C / low HL
2: high C / low HL
3: high C / high HL

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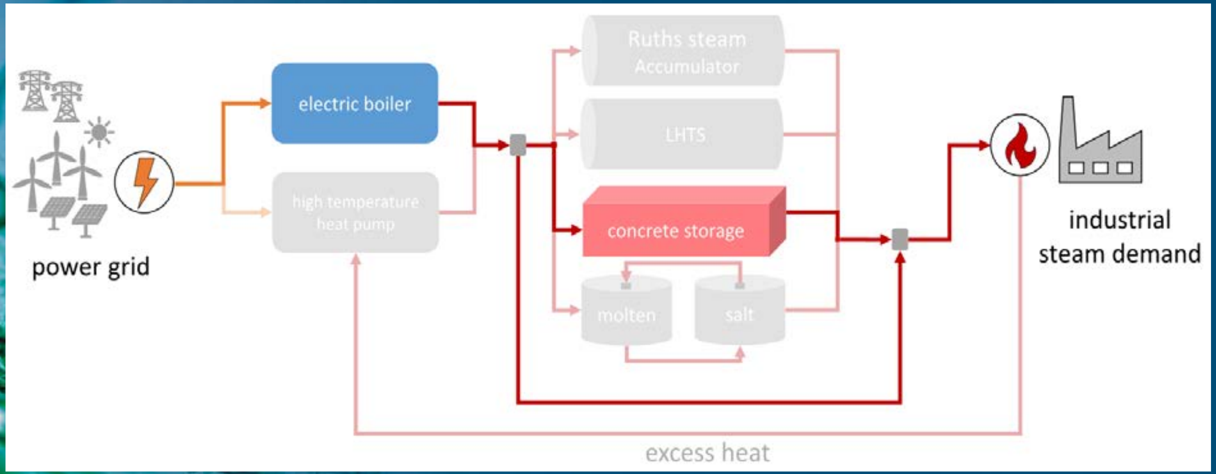
CETES – Example 1

Bayer process for producing alumina from Bauxite



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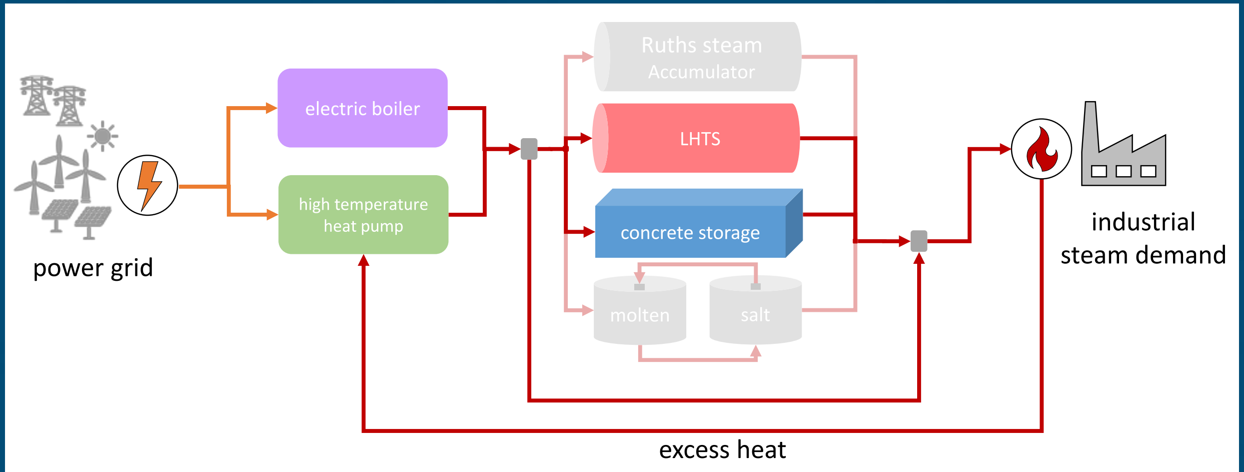

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CETES – Example 1

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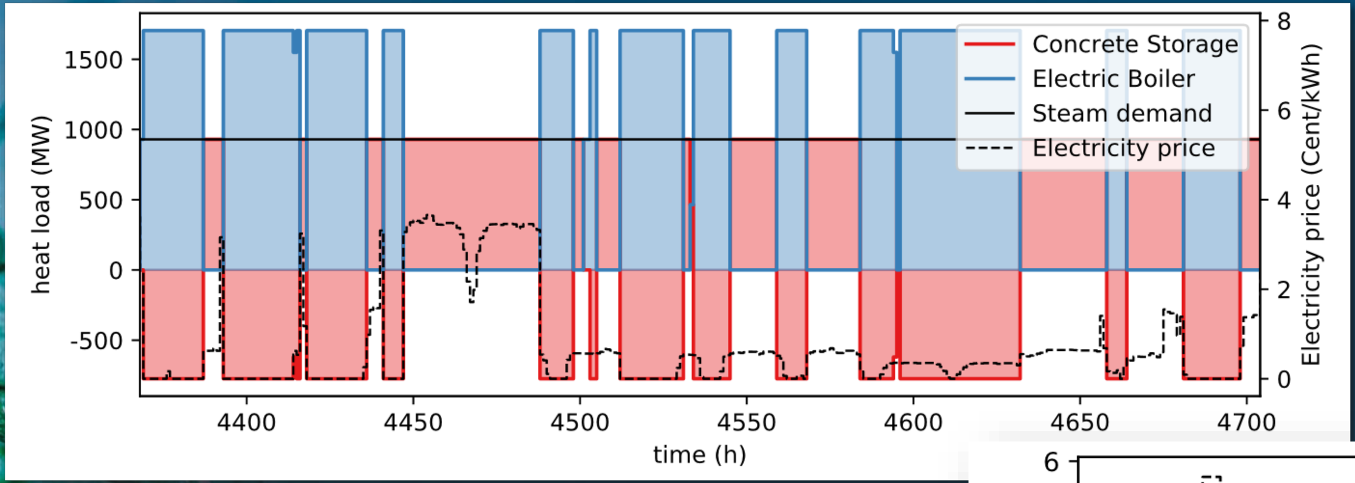

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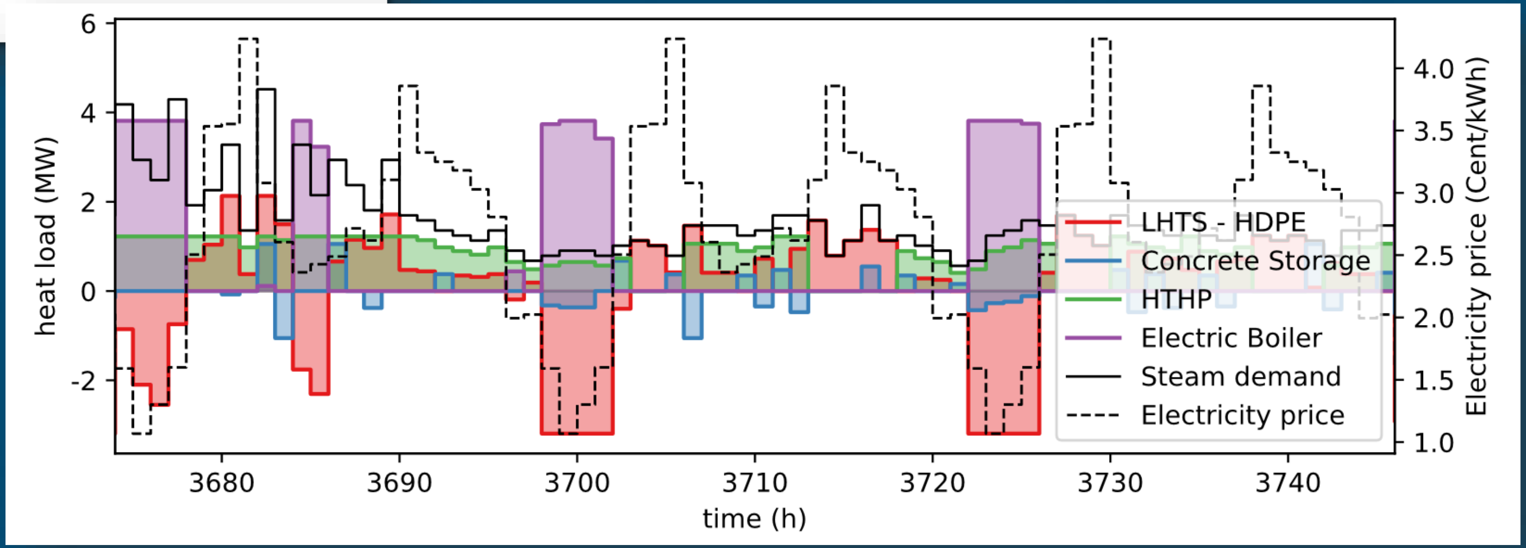

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CETES Conclusion

- The new approach allows for detailed cost analysis of the individual TES technologies
- It yields important decision-support for cost-efficient TES
- The case studies show that case-specific cost estimations are necessary to identify the most cost-efficient TES solution
- The available temperature range for TES is especially crucial:
  - Ruths: vessel wall thickness rapidly increase with higher storage temperatures
  - LHTS: the availability of appropriate PCMs with both low costs and high volumetric energy density is a decisive factor regarding cost-effectivity.
- Case 2 shows that heat load requirements can be a major cost driver for LHTS and concrete storages due to large amounts of steel tubes

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CETES Outlook

- Optimization model can easily be extended for PV or wind turbines for local power generation
- Cost functions can be used in other storage integration problems

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Thank you very much!
Questions?

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