

# Cost-effective and Emission-Free Energy Supply of Chemical Sites Using Thermal Energy Storage

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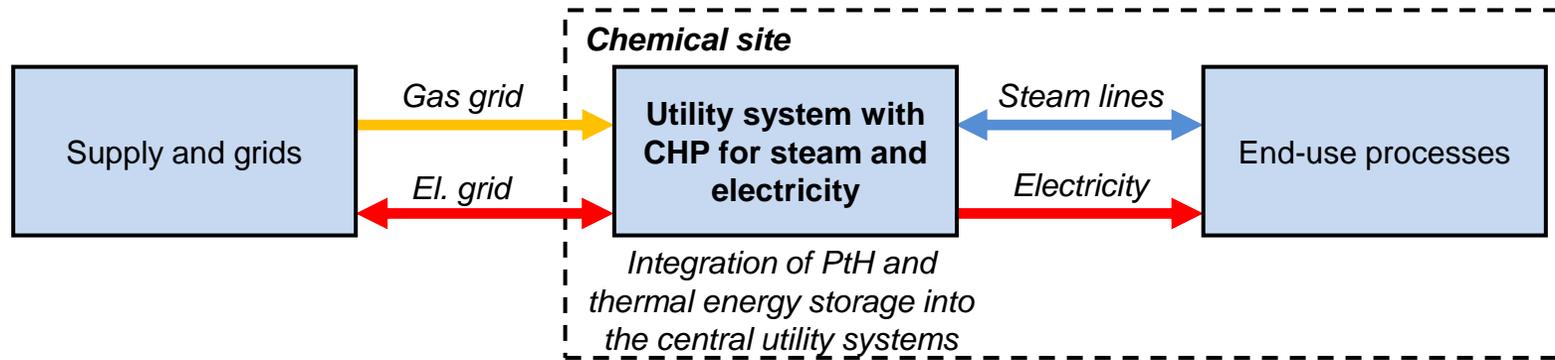


# Project TransTES-Chem



**Project goal:** Identification and evaluation of Power-to-Heat and Thermal Energy Storage solutions to facilitate the integration of renewable energy into chemical sites

## Today's typical chemical site:



Adapted from: [1]



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# Concept: Zero-emission chemical site

- **Energy supply**

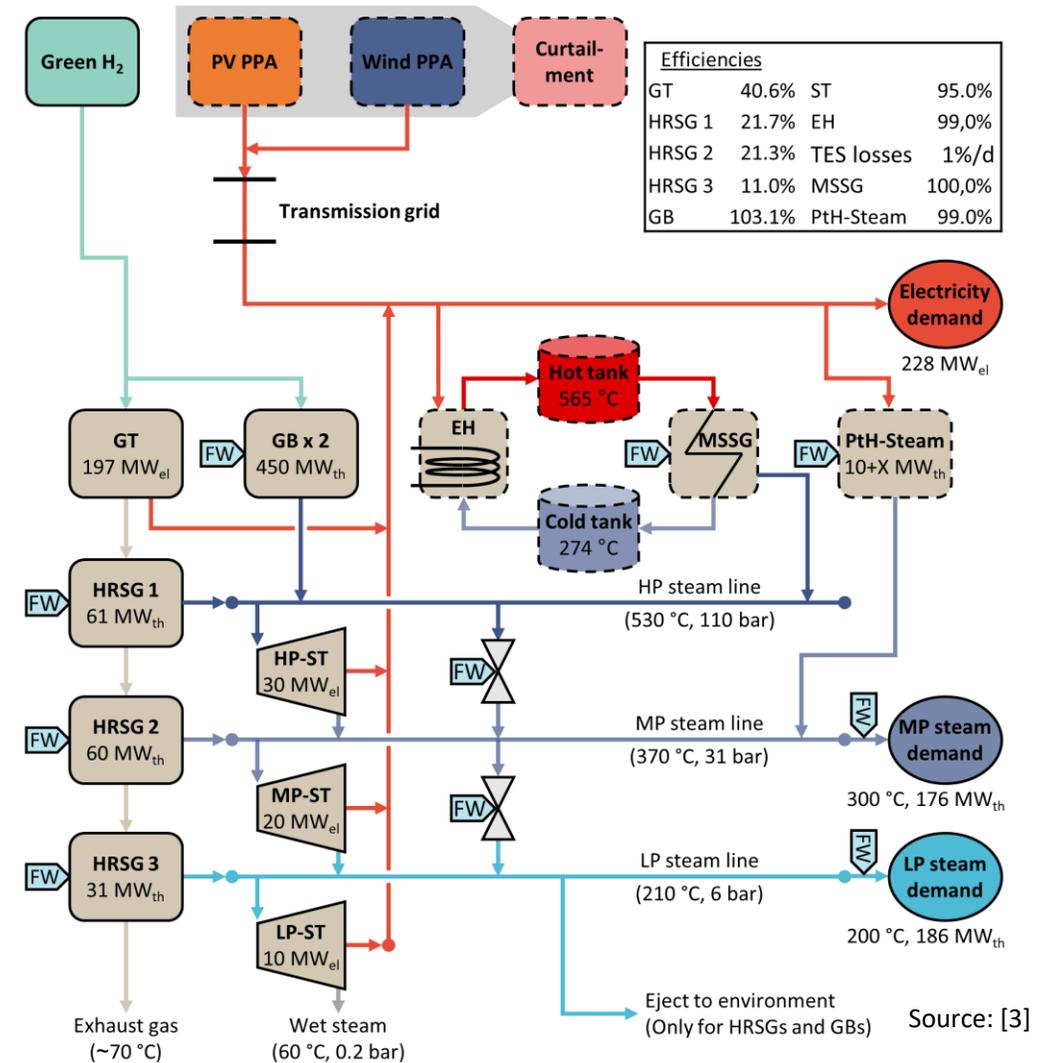
- Green hydrogen
- Pay-as-produced PV und Wind PPAs
- Curtailment as flexibility options

- **Energy demand**

- Electricity demand: 2 TWh
- Steam demand: 3.2 TWh

- **Utility system**

- Hydrogen gas turbine, boilers, and steam turbines for security of supply
- **Power-to-Heat or Thermal Energy Storage**

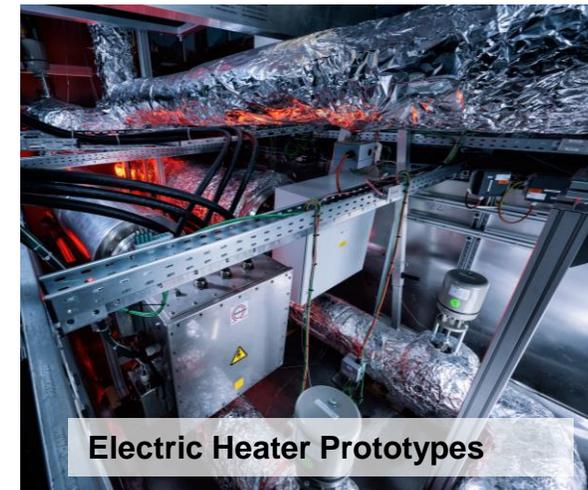


Source: [3]

# Thermal energy storage: Technology and integration

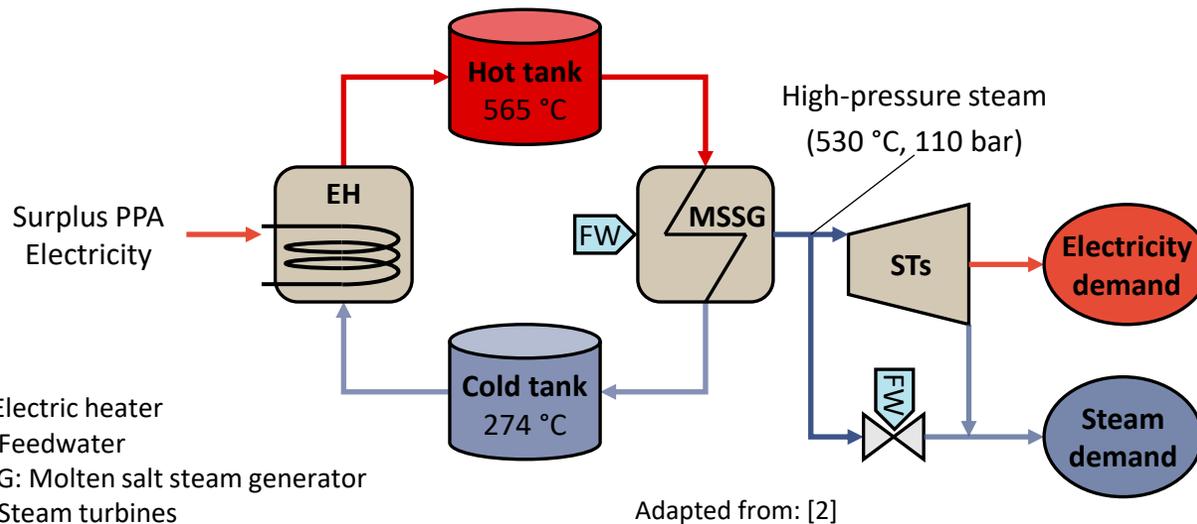
## Molten salt energy storage system

- Proven technology
- Charging via electric heater
- CHP discharge
- Enables simultaneous charging and discharging



Electric Heater Prototypes

© DLR



Molten Salt Storage Andasol 3

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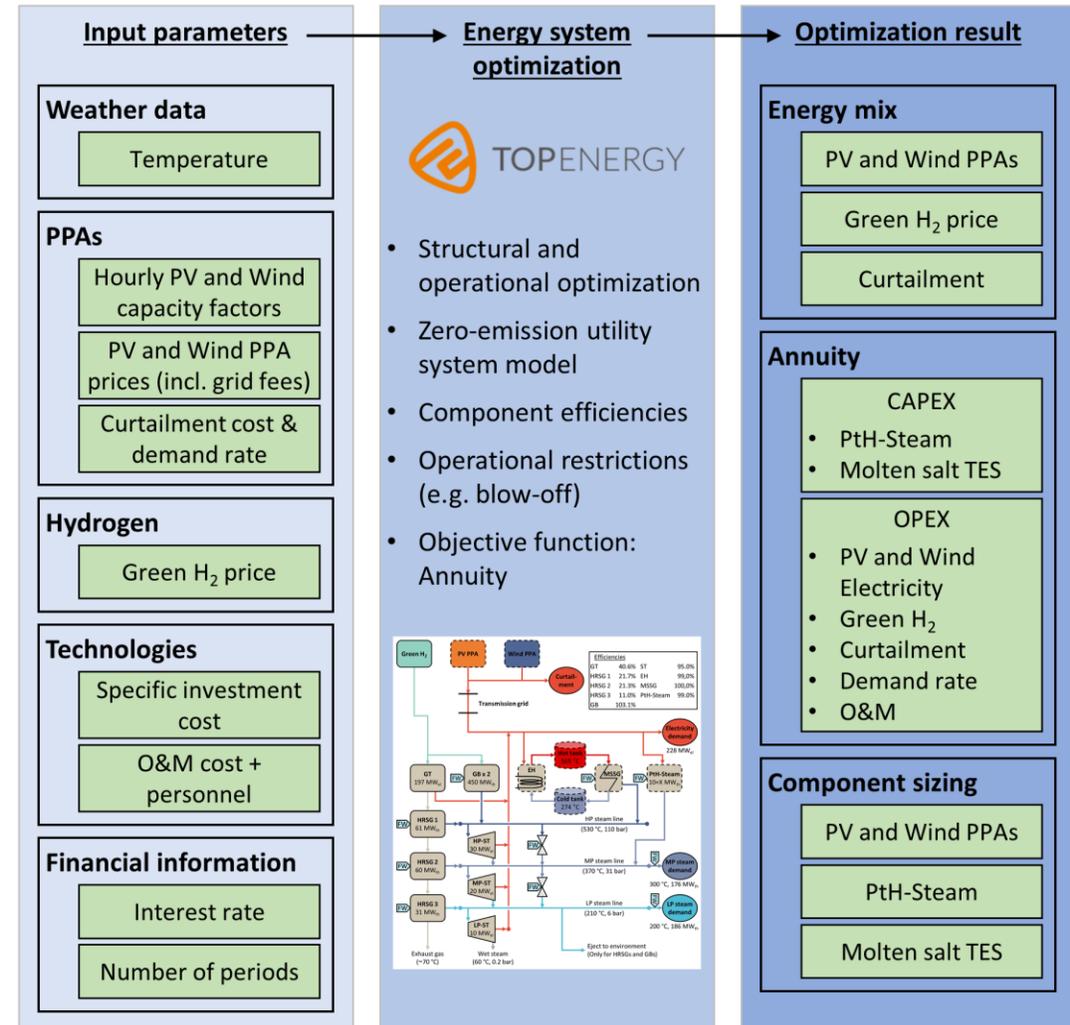
# Energy system design

## Fixed components (security of supply)

- Gas turbine + heat recovery steam generator
- Steam boiler
- Steam turbines

## Optimizable components

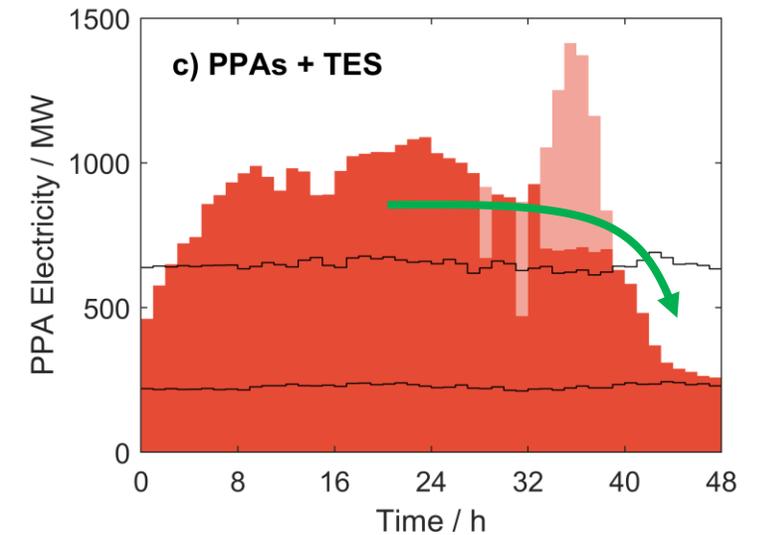
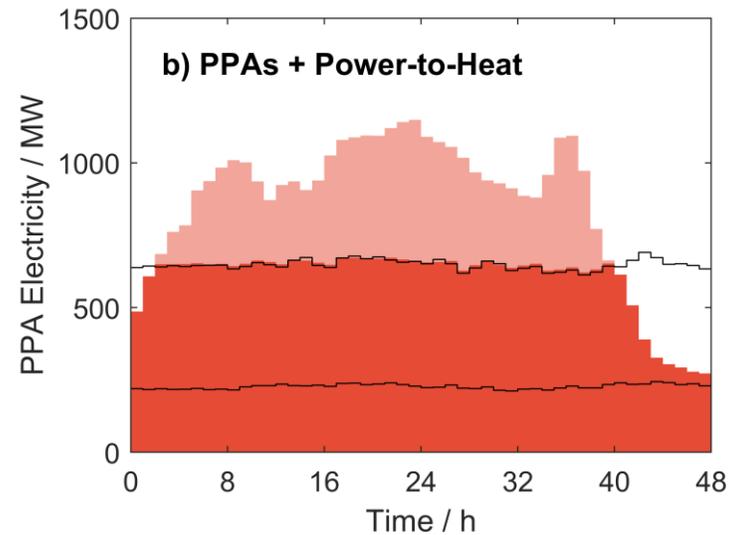
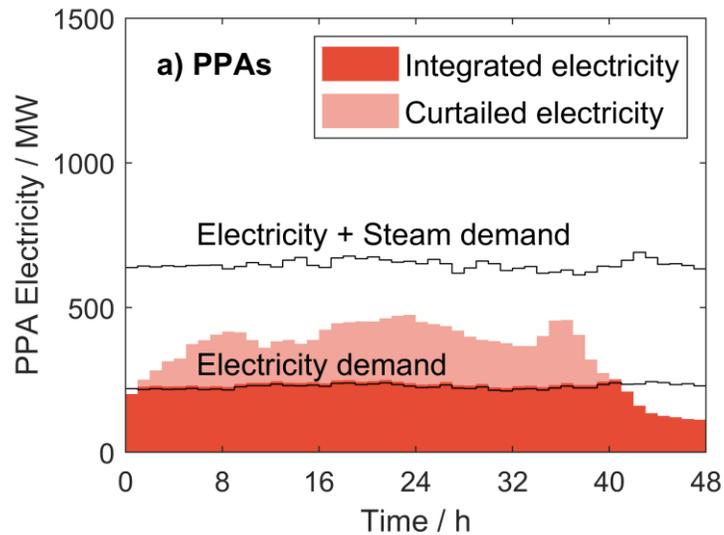
- PV and wind PPAs (installed capacity)
- Power-to-Heat
- Molten salt TES
  - Electric heater
  - Molten salt tanks (storage capacity)
  - Steam generator



Source: [3]

# Integration of renewable electricity

## Comparison of flexibility options



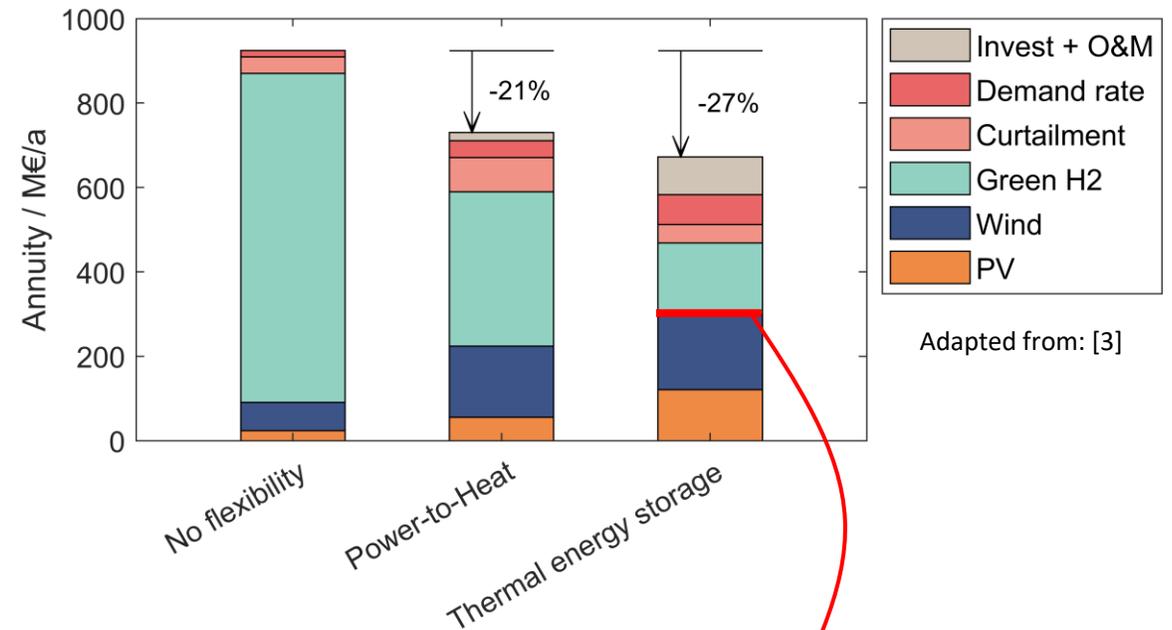
Adapted from: [3]

- **No Flexibility:** PPA intake is capped by electricity demand
- **Power-to-Heat:** Expands intake to total energy demand
- **Thermal Energy Storage:** Maximizes PPA utilization with minimal curtailment

# Total cost of the chemical site

## Thermal Energy Storage – Benefits and tradeoffs

- ✓ Lowest total cost
- ✓ Max. integration of renewable energy (85% of total energy demand)
- ✓ Minimal curtailment (6% of PPA electricity)
- ✓ Efficient use of renewable resources and land area
- High upfront capital investment
- Space requirements on site
- Emission-free = Higher energy cost



Energy cost (~300 M€) of a comparable study with grid electricity and gas in 2035 (with CO<sub>2</sub>-emissions): [https://doi.org/10.2991/978-94-6463-156-2\\_25](https://doi.org/10.2991/978-94-6463-156-2_25)

# Conclusions

## Thermal Energy Storage as a key technology

- Enables cost-optimal, 100% defossilization of chemical and process industries
- Facilitates efficient integration of renewable energy
- Offers flexibility and potential grid services

## Key challenges to overcome

- High upfront investment for Thermal Energy Storage with PtH
- Need for expanded power grid connections
- High grid-fees pose a threat for decarbonization efforts

# Thank you!

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Links to research (open access):

- <https://doi.org/10.1002/cite.202100164> [1]
- [https://doi.org/10.2991/978-94-6463-156-2\\_25](https://doi.org/10.2991/978-94-6463-156-2_25) [2]
- <https://doi.org/10.1016/j.est.2025.115667> [3]



# Assumptions: Cost data



Variable	Value	Comment
PPA electricity price (PV)	62.57 €/MWh	Incl. grid fees per MWh (High-voltage grid)
PPA electricity price (Wind onshore)	66.66 €/MWh	Incl. grid fees per MWh (High-voltage grid)
Demand rate electricity grid	57.87 €/kW <sub>year</sub>	Based on maximum power demand within one year
Curtailement fees	138.71 €/MWh	Total costs for curtailed MWh
Green hydrogen price	205.58 €/MWh <sub>LHV</sub> (6.85 €/kg)	Derived based on the Renewable Energy Directive, production in Germany
PtH for steam generation	300 €/kW <sub>th</sub>	Incl. transformer, switchgear, cabling
Charging unit (electric heater)	300 €/kW <sub>th</sub>	Incl. transformer, switchgear, cabling
Storage unit (Molten salt)	35 €/kWh <sub>th</sub>	Foundation, thermal insulation, pumps, system peripherals, auxiliary equipment
Discharging unit (Steam generator)	150 €/MW <sub>th</sub>	Piping, thermal insulation, steel structure, instrumentation
Investment period	10 Jahre	Used for annuity calculation of the investment
Interest rate	8%	Used for annuity calculation of the investment

Detailed explanations and original references in: [3]