CTU

CZECH TECHNICAL UNIVERSITY IN PRAGUE

TECHNOECONOMIC ANALYSIS OF HIGH TEMPERATURE CARNOT BATTERY RETROFIT INTO SEVERAL DISTRICT HEATING CHP PLANTS

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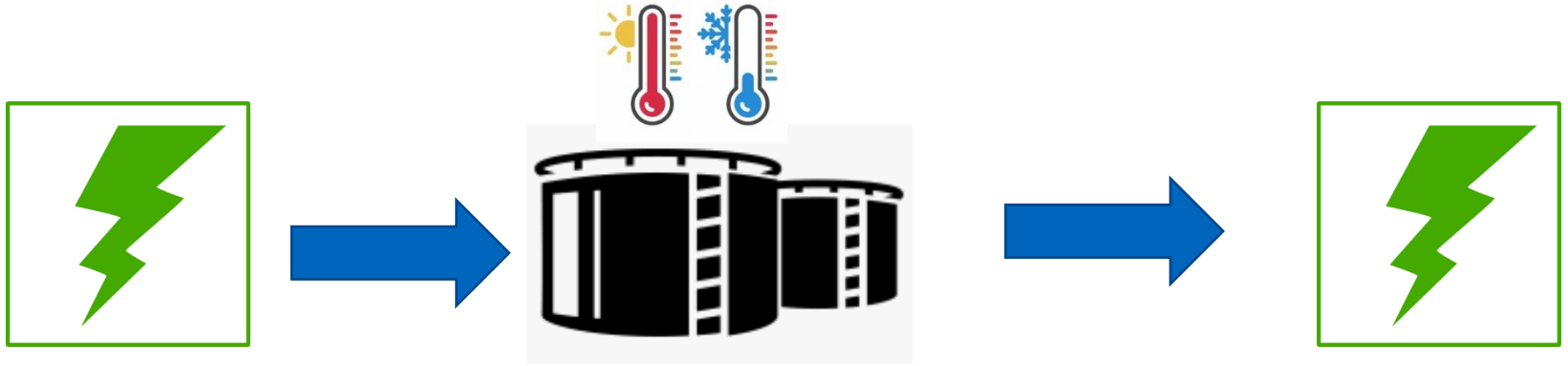
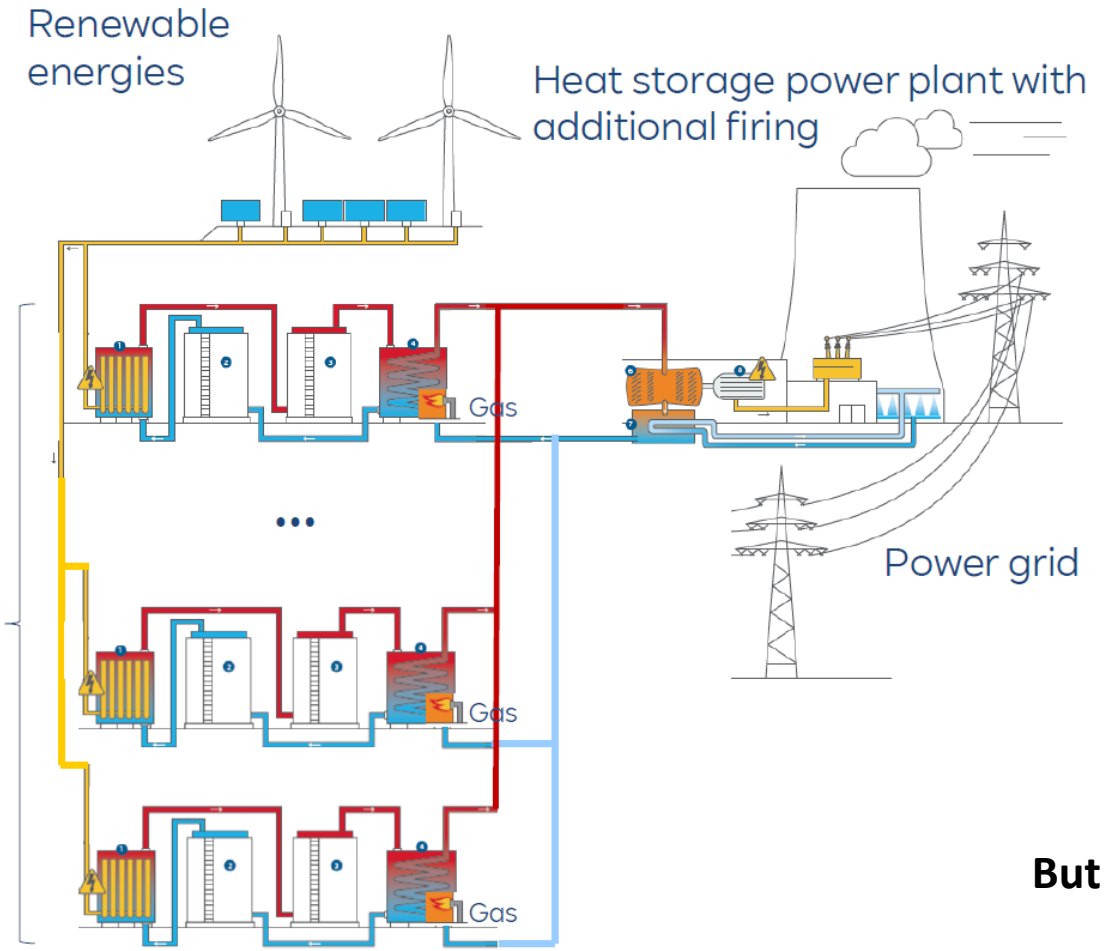
MOTIVATION & BACKGROUND

- Carnot battery via coal plant conversion
  - simple and cheap P2H2P solution



SECOND LIFE FOR COAL PLANTS

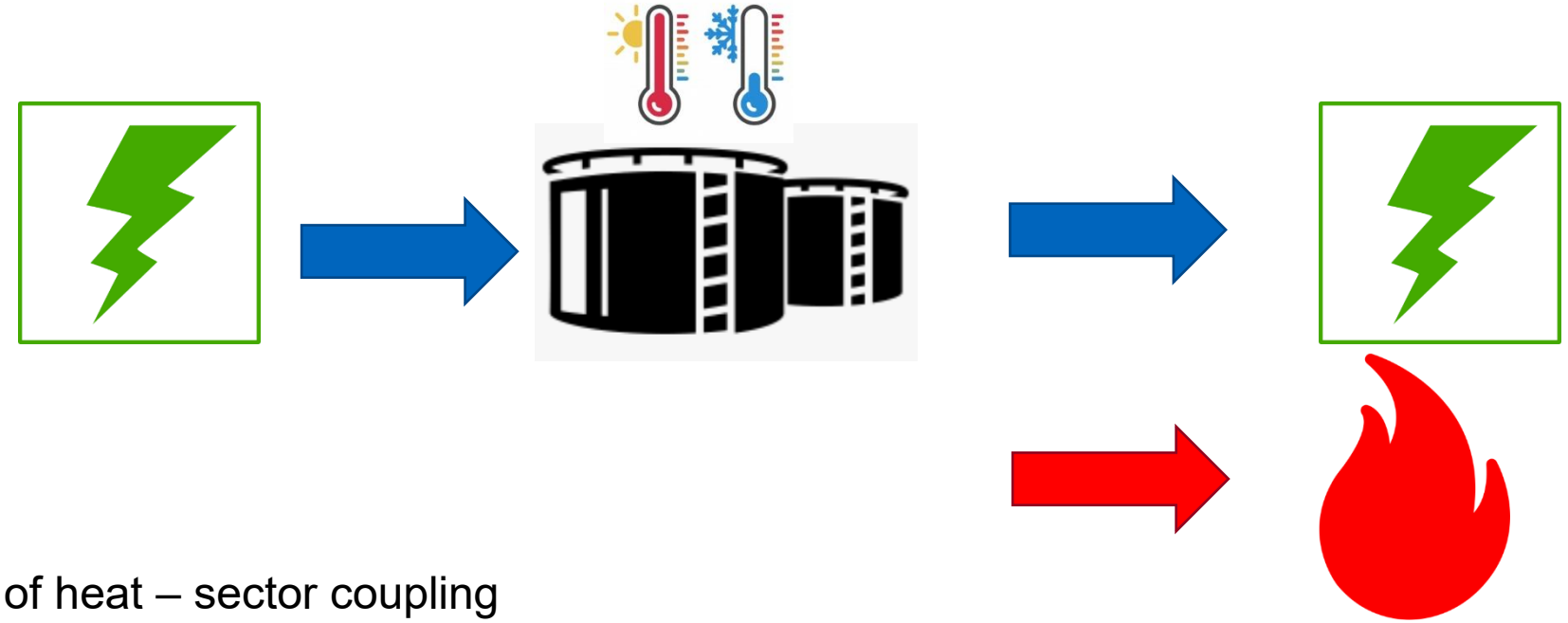


But offers still very low efficiency

(Arnold W., StoreToPower - Pilot plant for the development of a heat storage power plant, 15.09.2020, RWE)

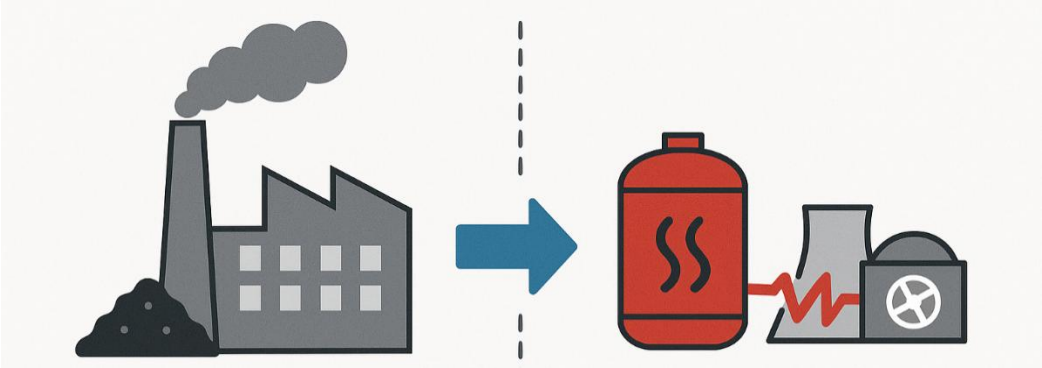
MOTIVATION & BACKGROUND

- Coal plant conversion – simple P2H2P offers very low efficiency



- Addition of heat – sector coupling
  - Can improve economic viability
  - Improves overal efficiency, possibly towards >90%

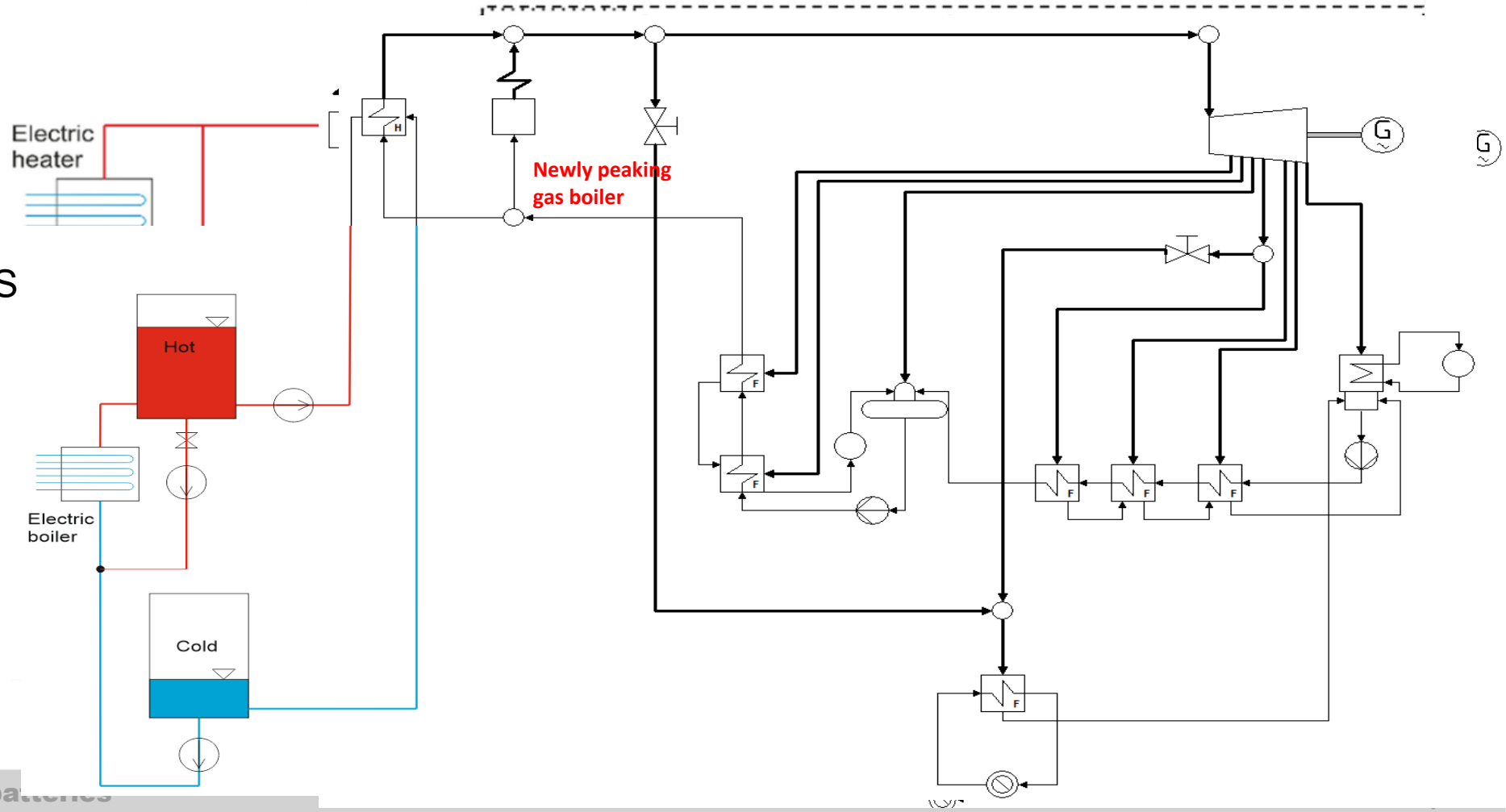
BACKGROUND & MOTIVATION FOR CB CHP PLANTS



- 40% of the CZ population uses district heating
- **Repurposing** of **fossil** power **plants**
  - Heat & power station **suitable for CB early adopter**
    - Demand for heat
    - Most of the technology already in place (for free)
      - Flexible steam system, existing connections to heat and power grid
      - Additions of heater and storage relatively small investment
      - Less costly materials than for modern coal plants
    - Available space on-site (especially since oversized in past)
    - Geographically distributed, smaller capacities (dozens MW)

SYSTEM 1 – COAL CHP PLANT CONVERSION

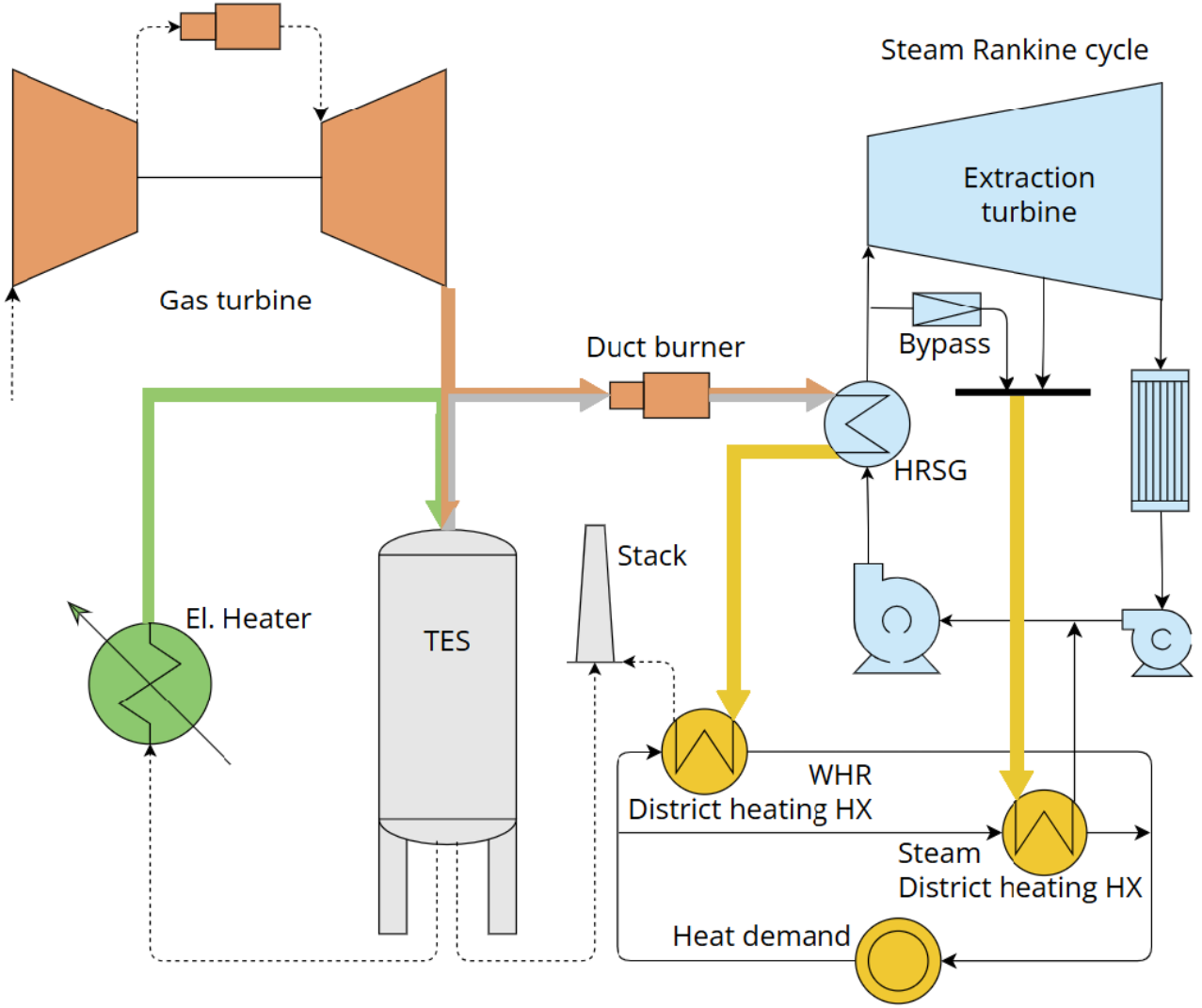
- Conversion of CHP plant with one condensing and backpressure turbine
  - Simplified model
  - Addition of storage and el. heating
  - Rock packed bed TES or
  - Molten salt



SYSTEM 2 – CCGT CHP PLANT

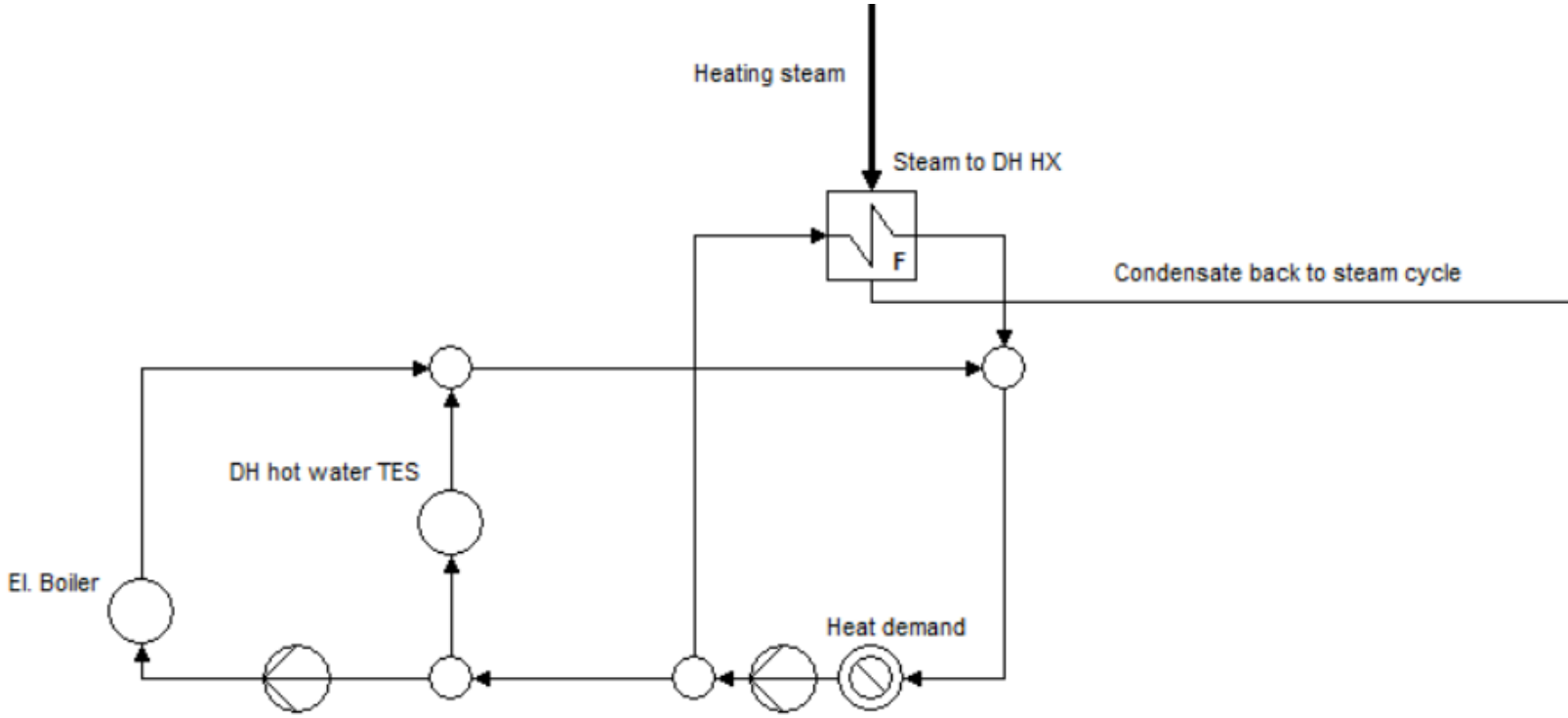
- Conversion of CCGT CHP plant
  - TES decoupling GT and bottoming RC

    addition of el. heating loop
  - Only rock packed bed TES



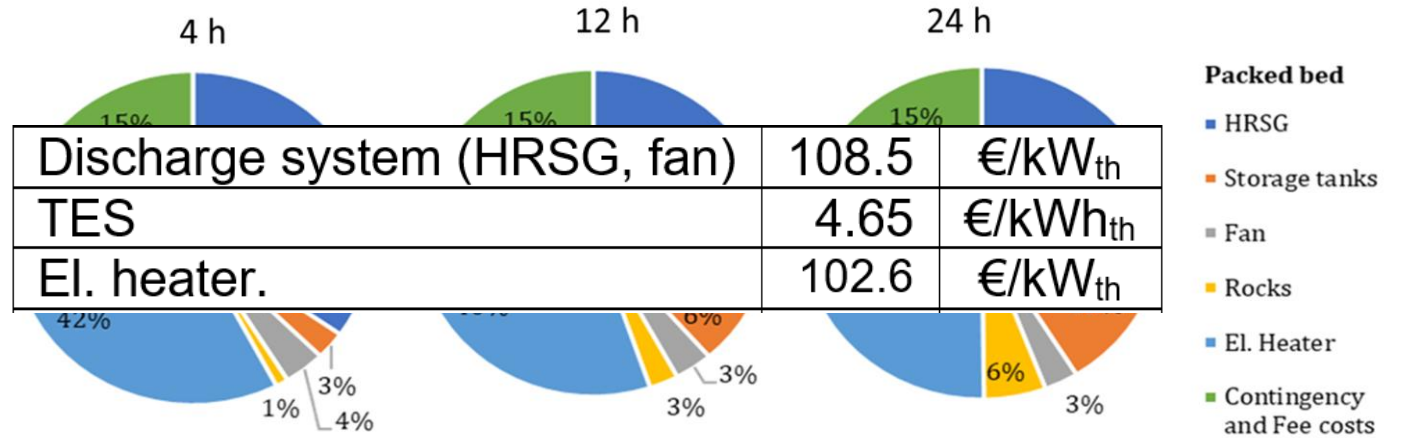
SYSTEM 3,4 – ELECTRIC WATER HEATER + WATER TES

- Simple and state of the art
- Used as a benchmark system



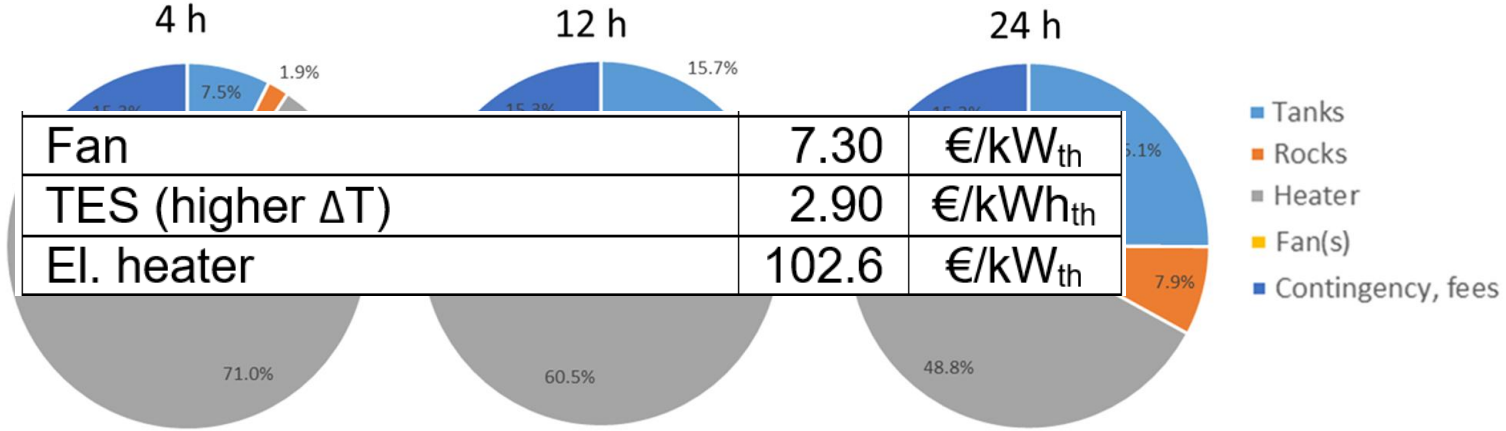
PRIOR WORK - SIZING & COSTING

- Coal CHP plant conversion
  - Here only PB TES



Discharge system (HRSG, fan)	108.5	€/kW$_{th}$
TES	4.65	€/kWh$_{th}$
El. heater.	102.6	€/kW$_{th}$

- CCGT plant conversion



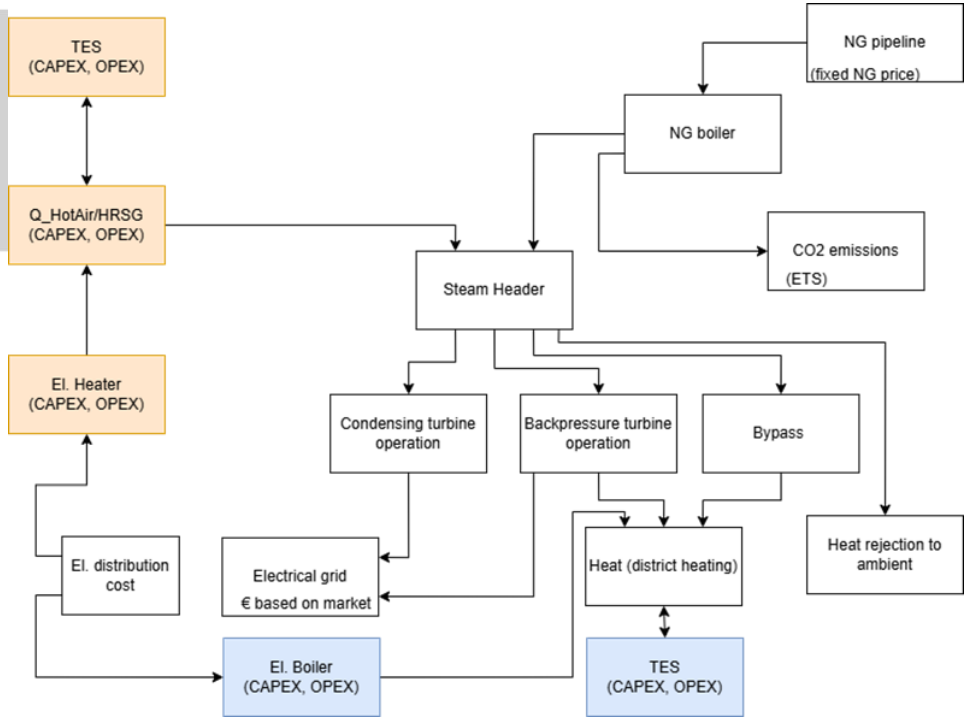
Fan	7.30	€/kW$_{th}$
TES (higher ΔT)	2.90	€/kWh$_{th}$
El. heater	102.6	€/kW$_{th}$

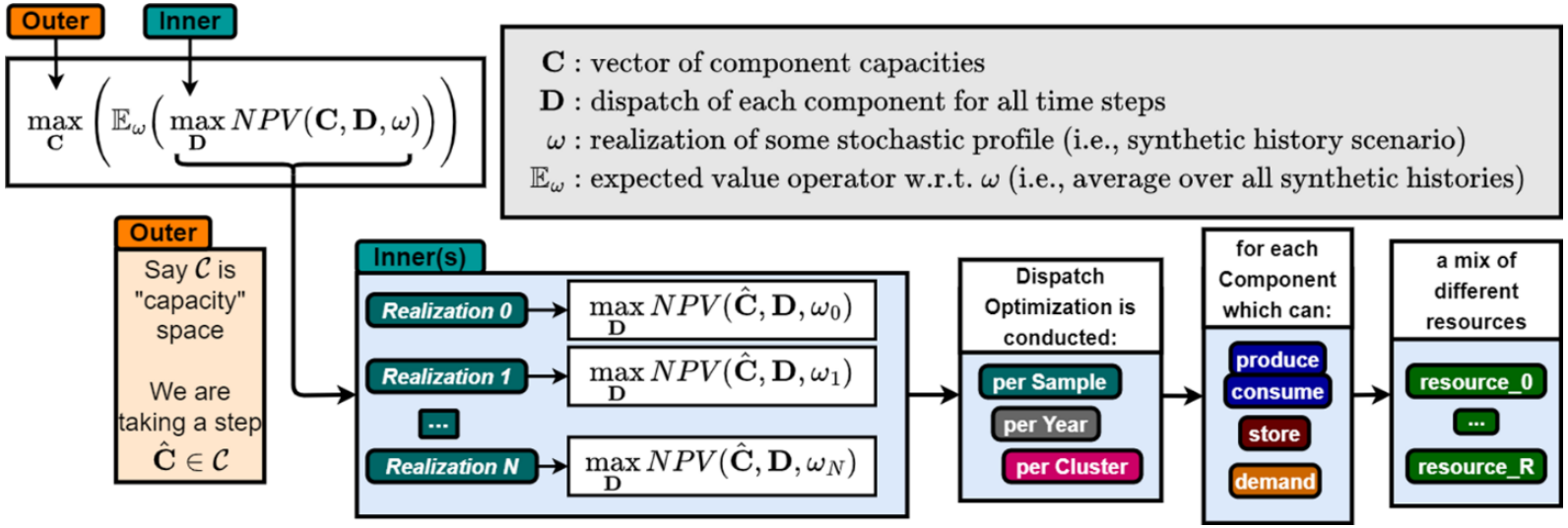
- Electric boiler + water TES

TES (guess)	2.90	€/kWh$_{th}$
Electric water boiler	51.3	€/kW$_{th}$

ECONOMIC ANALYSIS

- Model represented by “comodity“ transfer functions between components and adjusted monetary values
- Dispatch optimization as a driver for capacity optimization

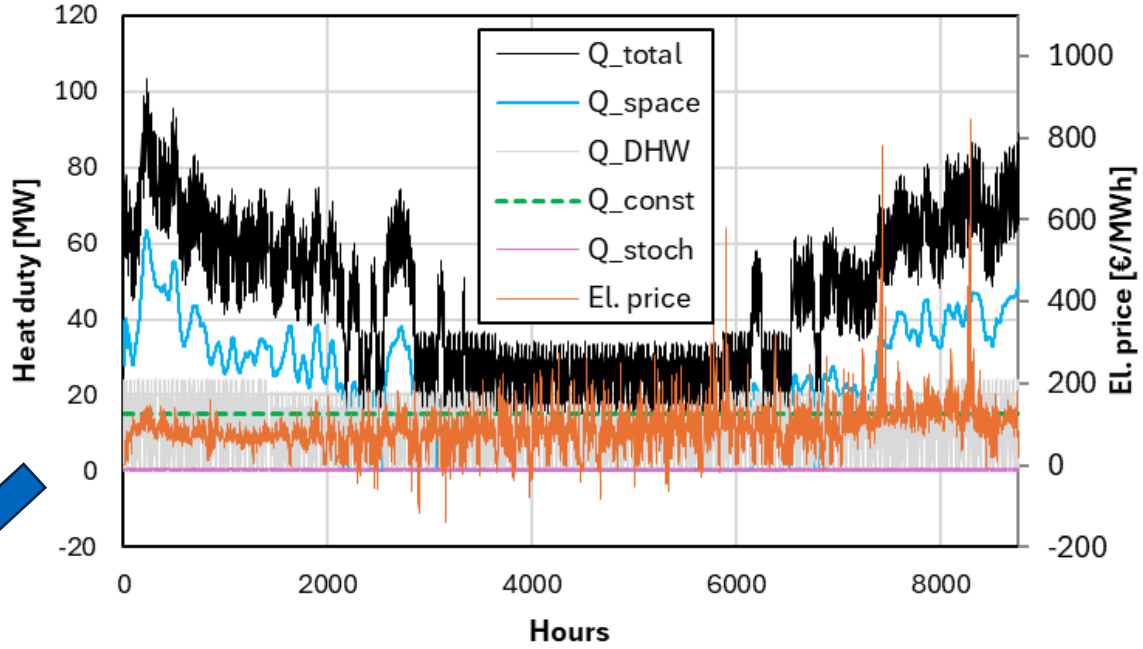


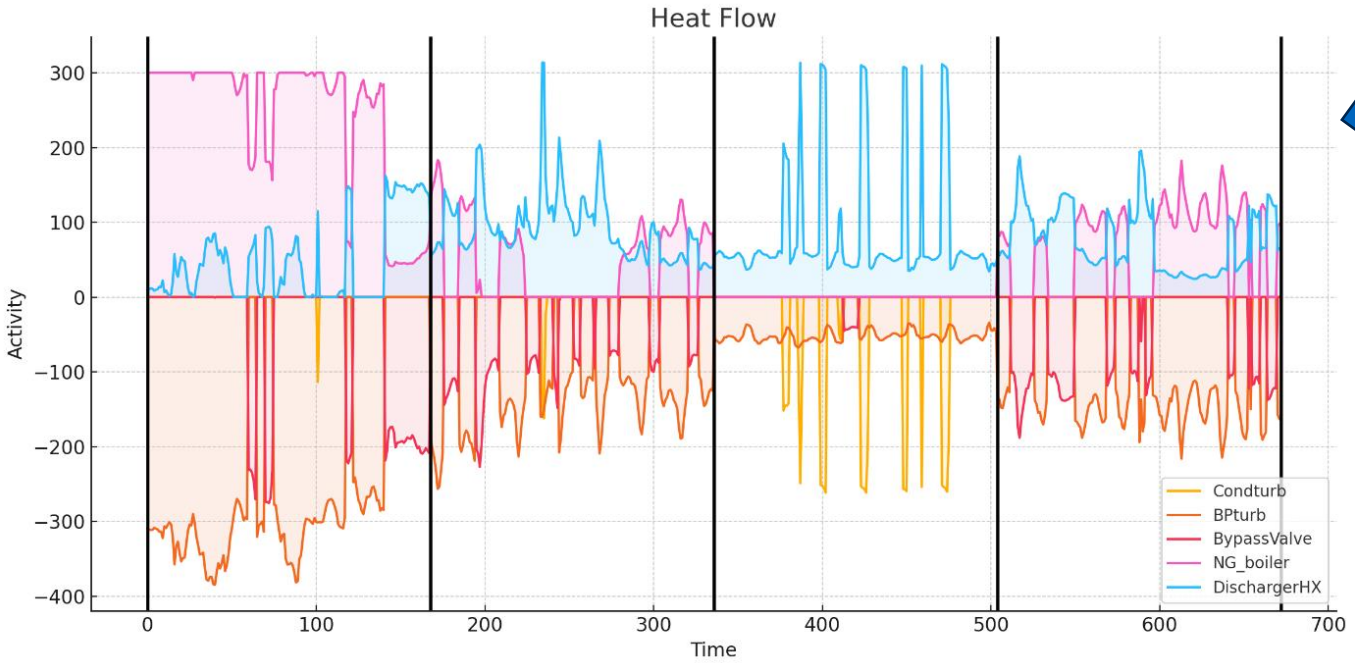


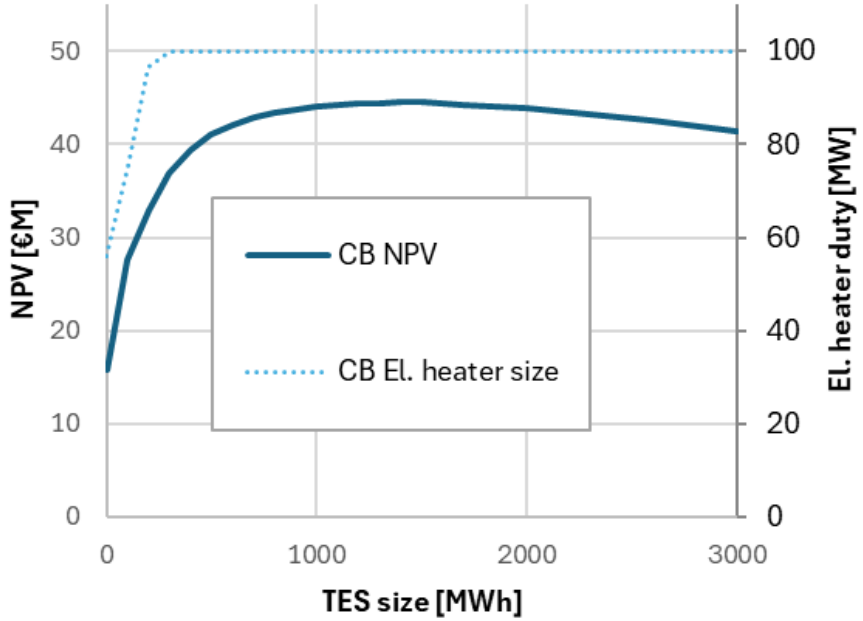
- Tool HERON, developed at INL
- Stochastic resource capacity optimization
- Dispatch optimization
  ➔ Sizing optimization
- Automated stepping parameter sweep, where the code systematically explores different combinations of installed unit capacities or "portfolios„
- Open source

ECONOMIC ANALYSIS

- Hourly resolution of dispatch optimization
- Benchmark system – LT water heating + TES

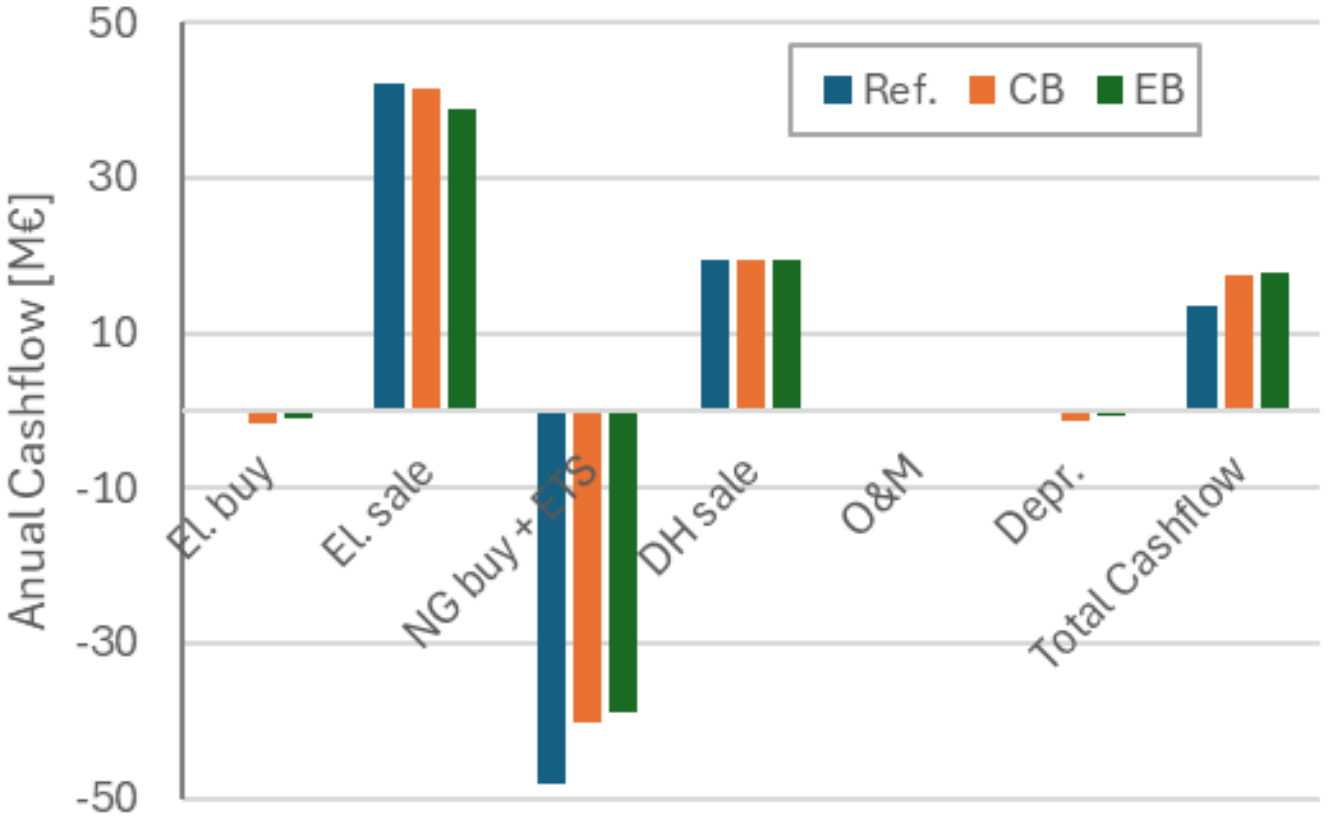






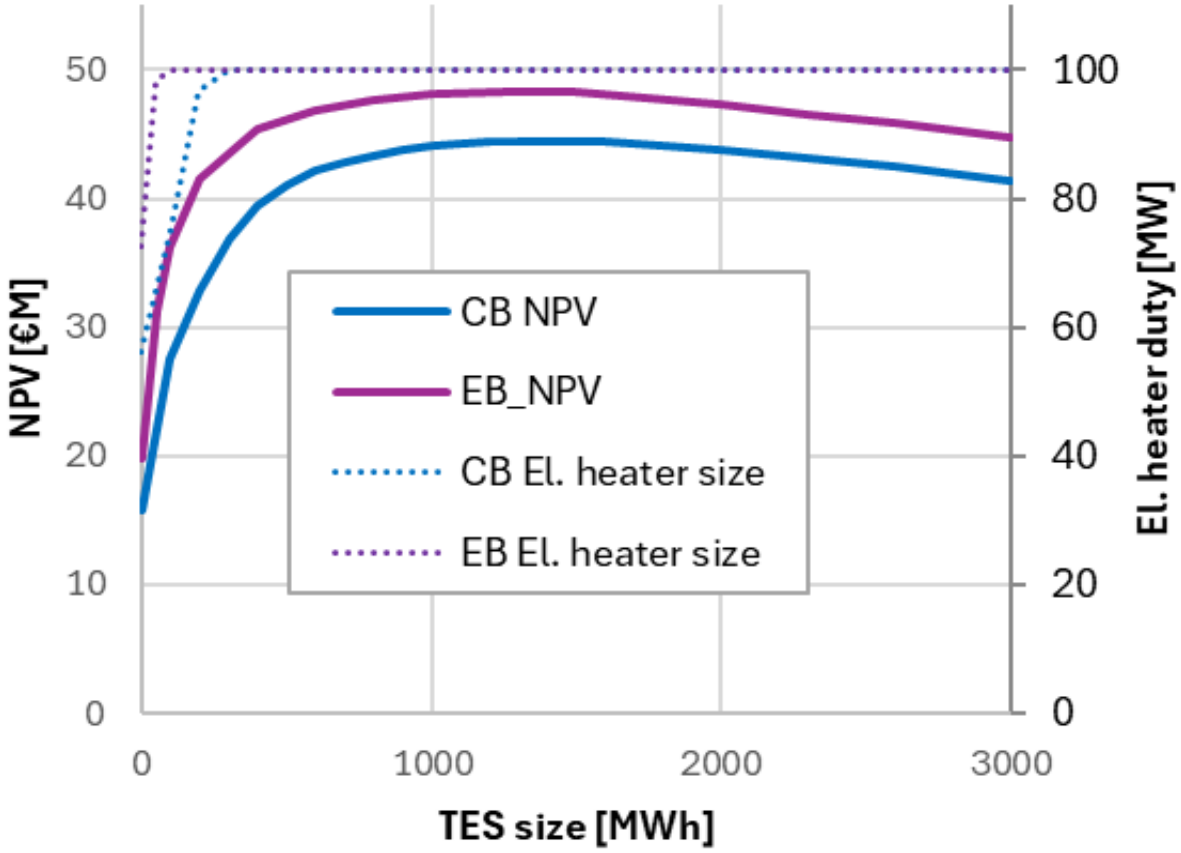
ECONOMIC ANALYSIS

- Case of 50 + 30 MW CCGT
- Annual cash-flow, revenue sources



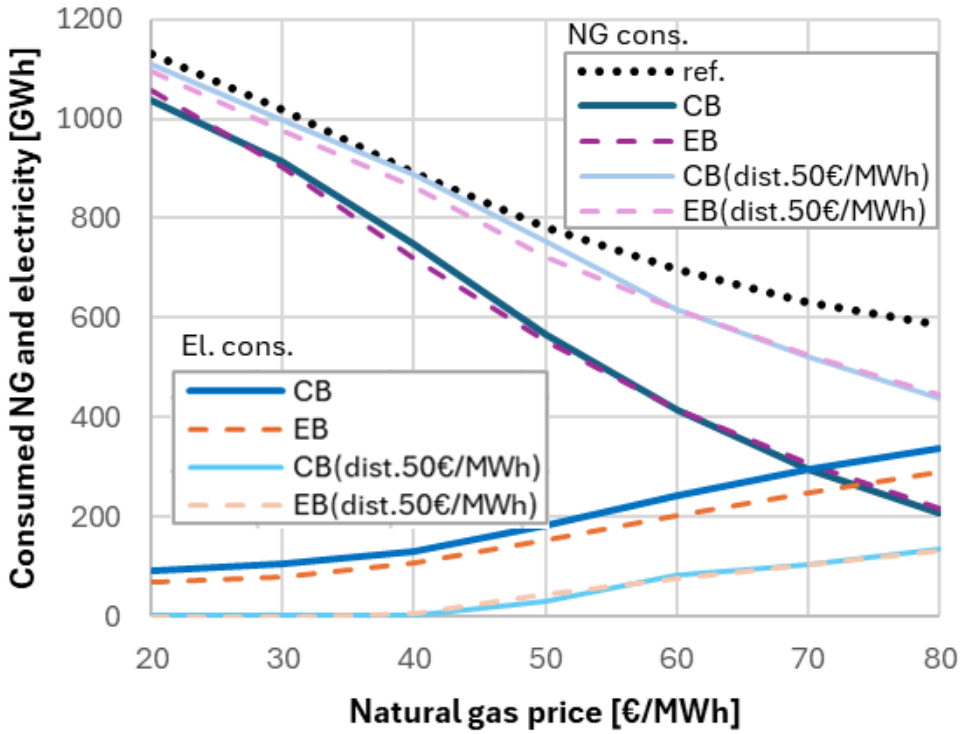
RESULTS

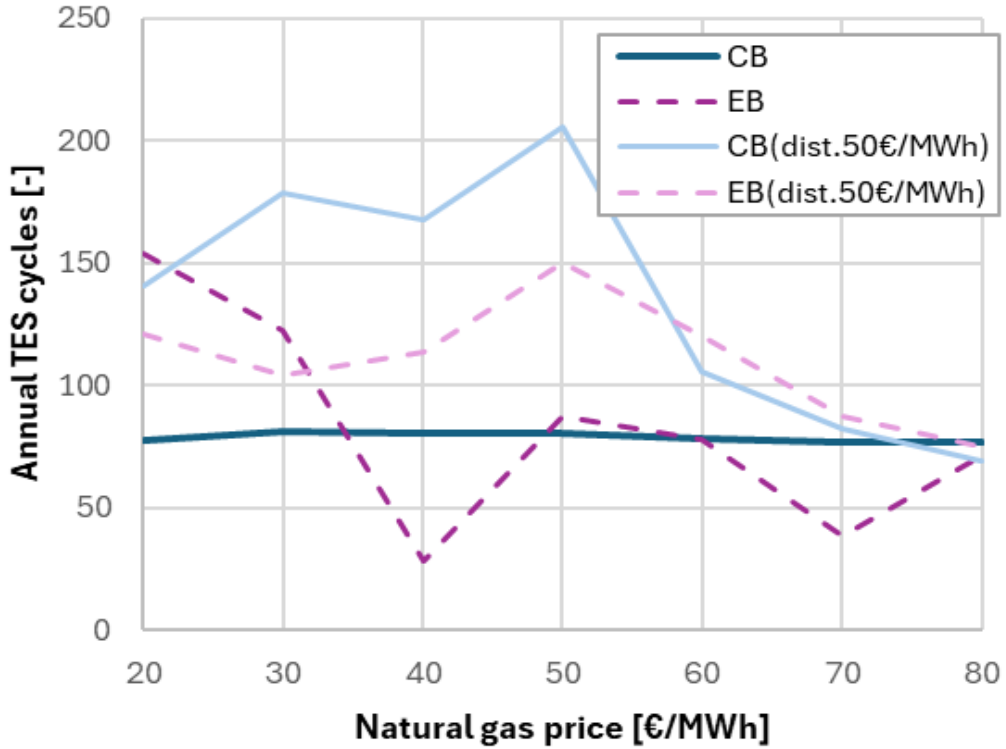
- Implementing P2H & generally CB returns positive effect across a range of boundary conditions
- Simple P2H without TES already beneficial
- Results similar between NGCC and steam CHP plant
- EB generally somewhat better (lower CAPEX, OPEX)



RESULTS

- Benefit rises with NG prices
- Grid distribution fees reduces benefit of CB more than of EB
- TES w/o P2H also provides positive effect
- Optimal sizing 1-3 cycles / week
- Relatively low sensitivity of NPV to size





SUMMARY

- CB by converting CHP plants is feasible (and much cheaper than lithium batteries (€/kWh))
- In CHP operation good overall efficiency
- Integration to CHP plants brings positive NPV from energy arbitrage
- Operation mainly heat demand - driven
  - Simple electric boilers and hot water TES can be a serious competition
  - Question of auxiliary services, future value of medium duration electricity vs. heat price