University of Vaasa

Decoupling of heat and power production in engine-driven CHP plants

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Introduction

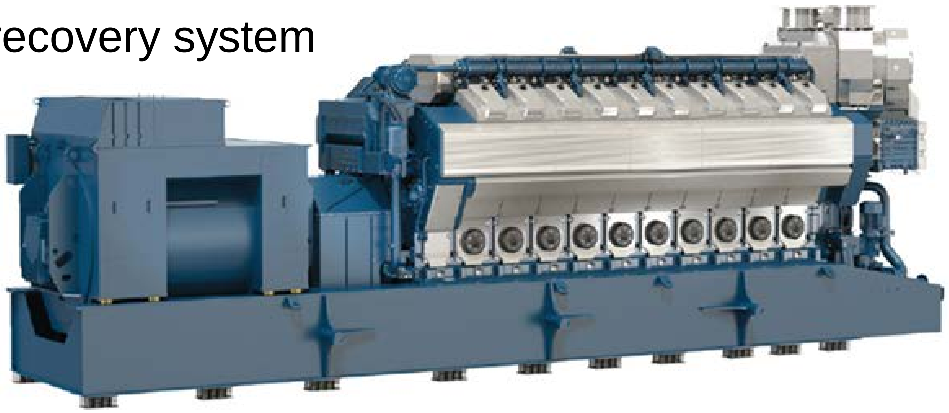
- Part of research program Flexible Energy Systems in collaboration with universities and companies

- Aim to study possibilities for decoupling of heat and electricity production in engine-driven CHP plant by means of energy storage solutions

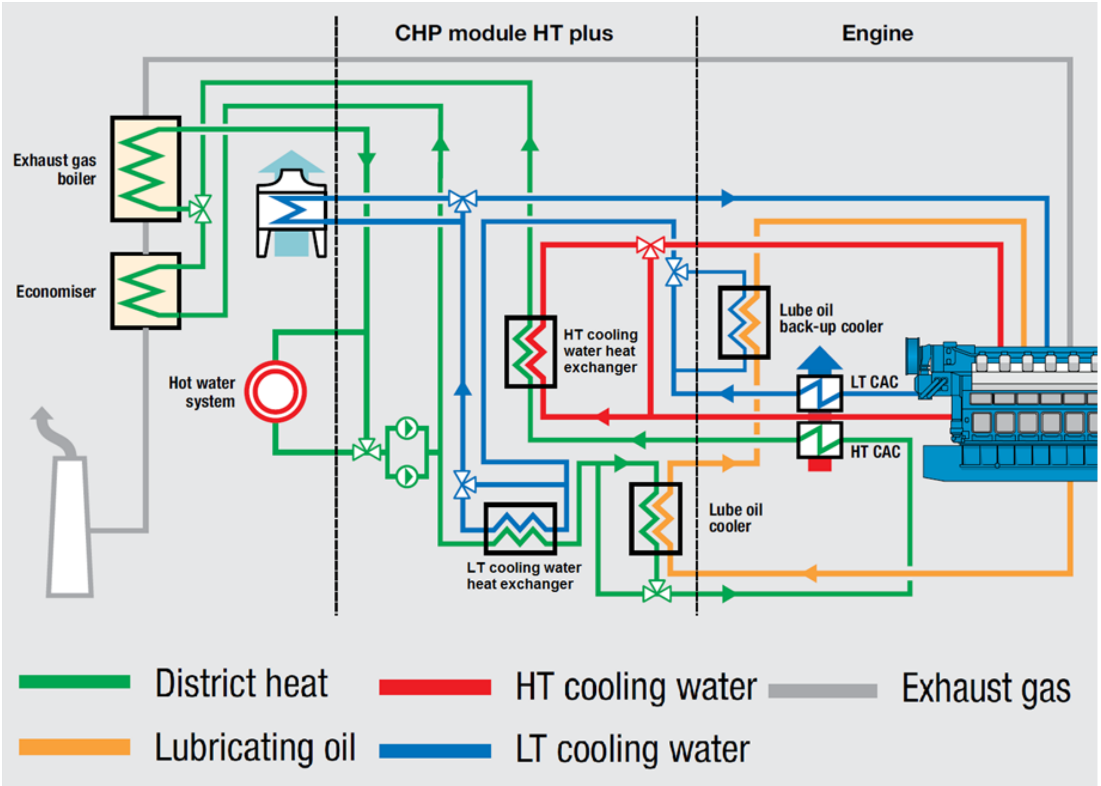
- Decoupling
  - Plant is run during high electricity prices when the income is the highest and excess heat energy can be stored. When electricity prices are low, heat energy can be released from storages.

Engine-driven CHP plant

- Wärtsilä 20V34SG
  - 10 MW_e & 10,6 MW_{th}
  - In CHP use in Denmark, Hungary and Italy
- One generating set includes
  - Combustion engine
  - Generator
  - Heat recovery system



Engine-driven CHP plant



Energy storage solutions

- Heat accumulator
  - Energy stored in water
  - Solution to decouple
  - Need for peak-load boilers reduced
  - Buffer during maintenance

- Water stratifies in the tank

- Energy stored in the tank

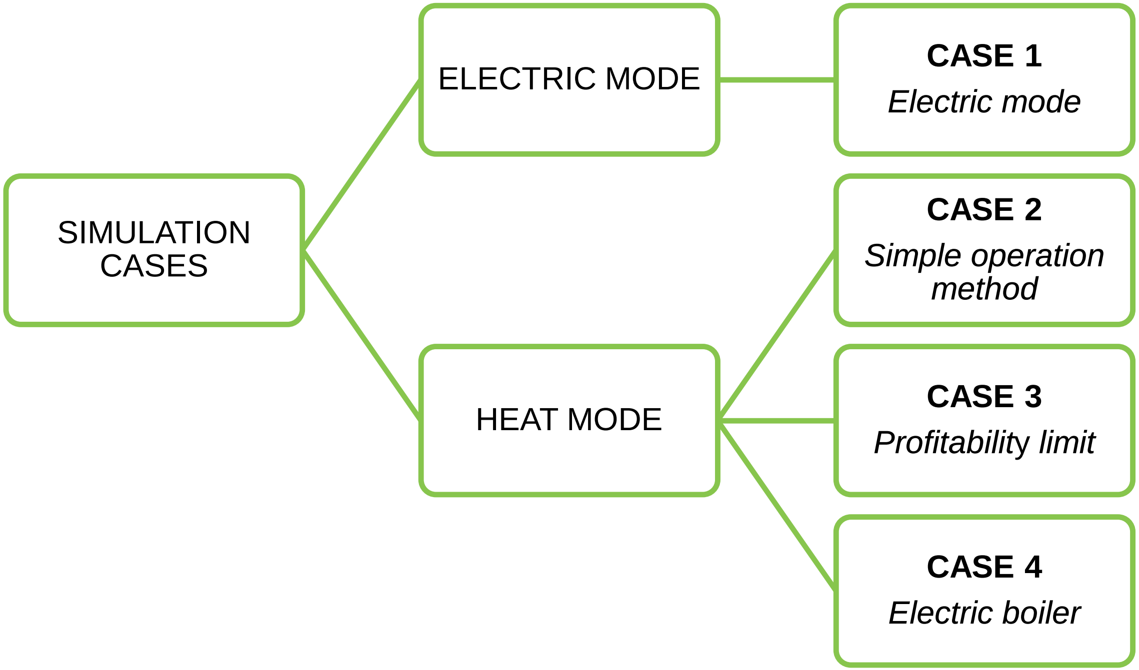
$$E = cm\Delta T$$

Energy storage solutions

- Lithium-ion batteries
  - High power and energy densities
  - Ideal choice for applications requiring short discharge and high power performance

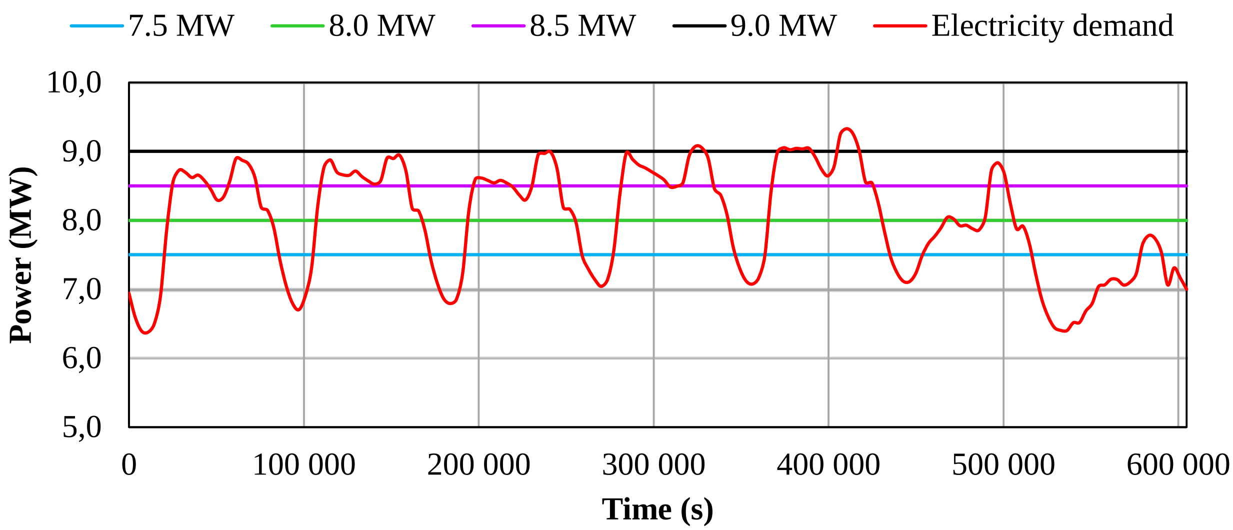
- Saft IM+ 20M battery
  - Energy 950 kWh
  - Discharge 2 100 kW
  - Charge 1 000 kW
  - Weight 16 500 kg

Simulation cases



Case 1 – *Electric mode*

- Electricity as primary product, heat as secondary
- Aim of Case 1: to find suitable battery capacities for 4 fixed engine outputs so that the electricity demand is constantly met and the battery capacity is as small as possible

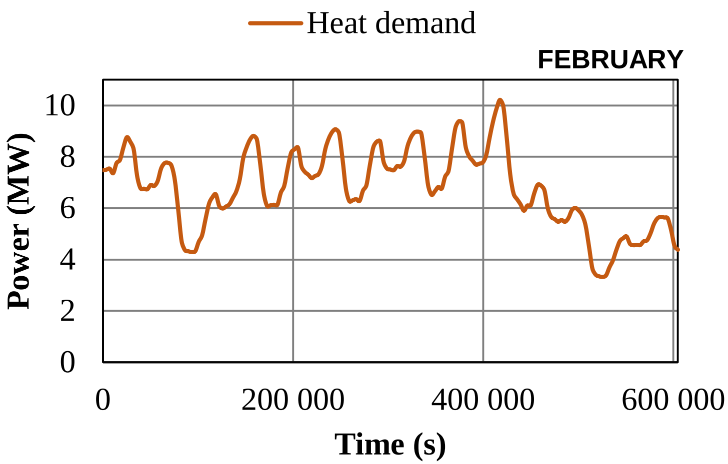


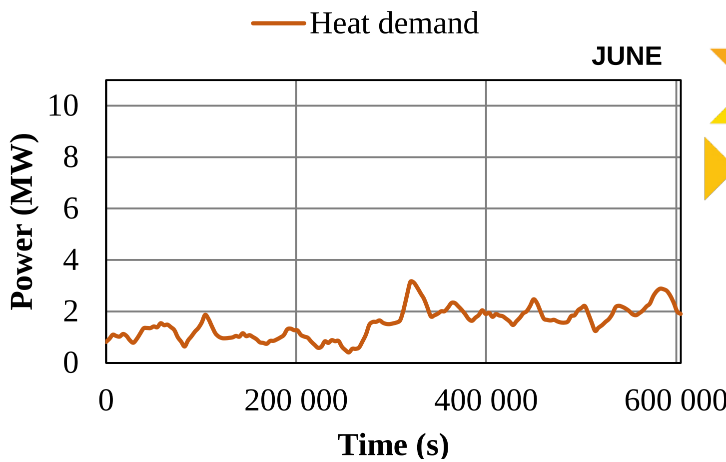
Cases 2,3 & 4

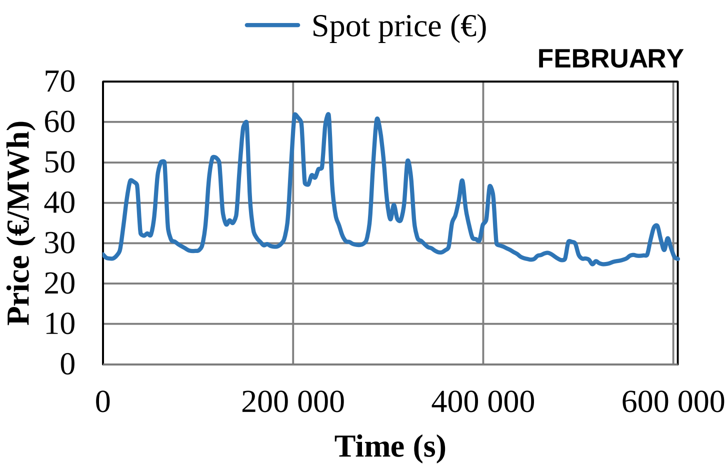
- Heat as primary product, electricity as secondary
- Main idea: heat accumulator responds to heat demand when it is not profitable to run the engine
- Simulations specification

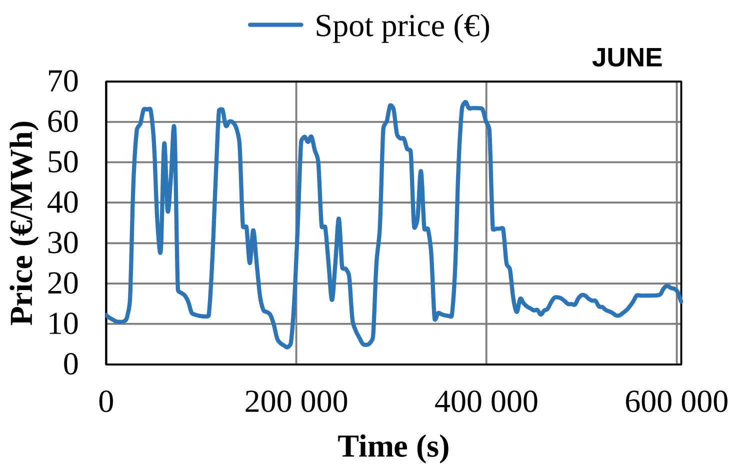
400–9 000 m^3	*ΔT = 45 °C*	*Heat demand June & February*
70, 80 & 90 €/MWh	*Nord Pool Spot 2015*	*71 €/MWh*

Heat demand & electricity prices



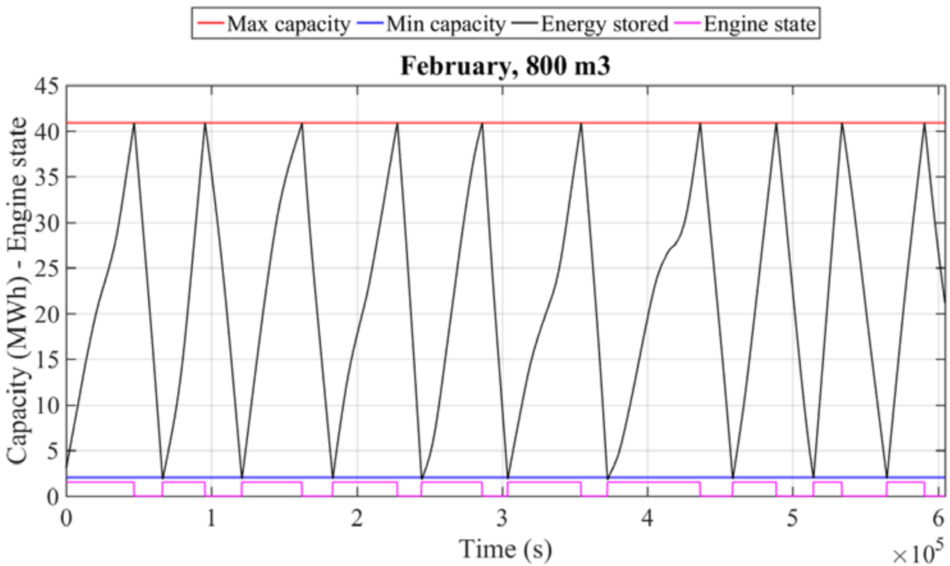






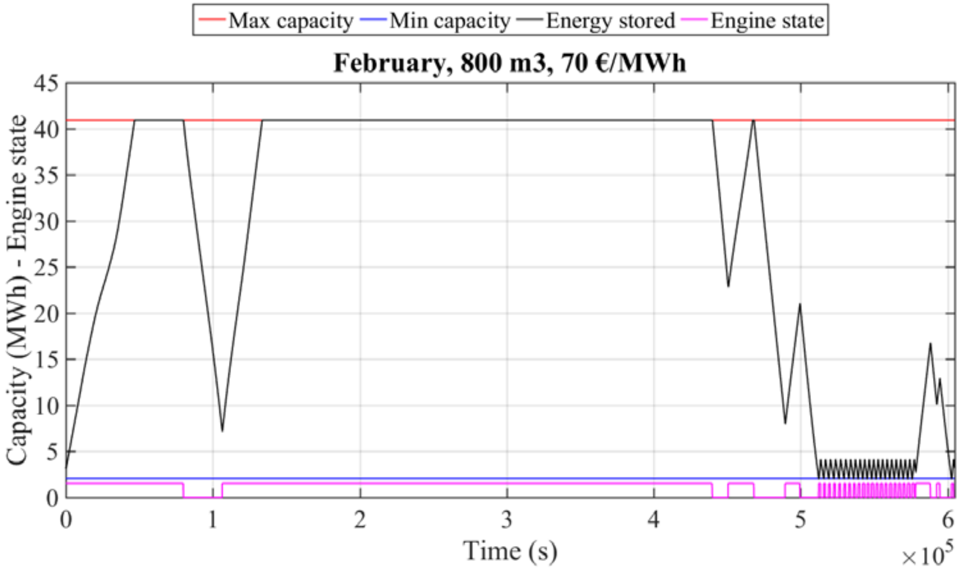
Case 2 – *Simple operation method*

- Engine is run only to increase stored energy from 5-% to 100-% of the maximum capacity



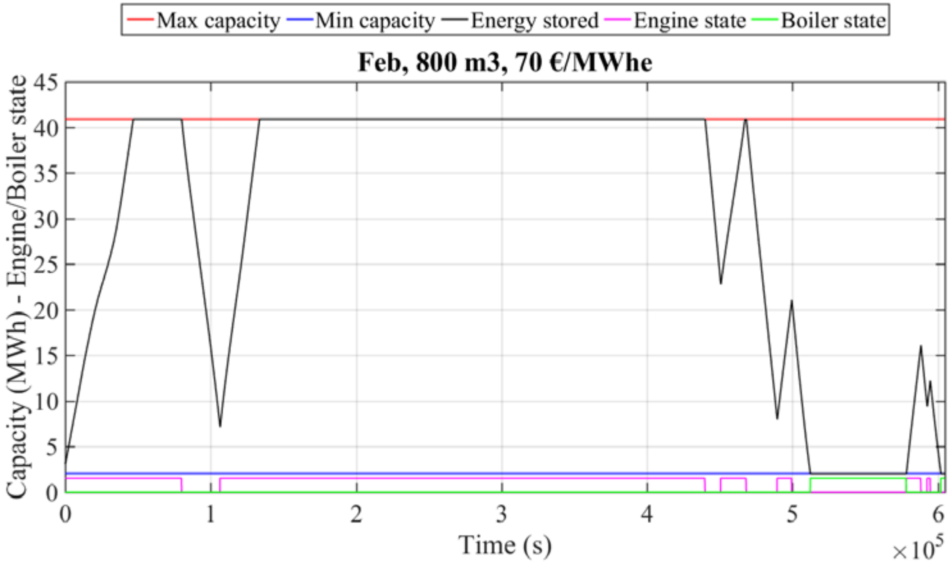
Case 3 – *Profitability limit*

- Engine runs in 2 occasions
  - Income from heat and electricity exceeds running costs
  - Stored energy lowers to 5-% of the maximum capacity
    - In this case accumulator is charged to 10-% of the maximum capacity regardless of the income



Case 4 – *Electric boiler*

- Electric boiler is added to the plant
  - Boiler responds to heat demand when the accumulator has emptied and it is not profitable to run the engine



Results

- Smallest battery capacity indicates the most suitable engine output
  - 8,5 MW output offered the smallest battery capacity: 30 MWh with price of 8,3 MEUR *(1 kWh ~ 273 €)*

- Shortest payback time for heat accumulator indicates the most promising accumulator volume
  - Payback time = accumulator investment cost divided by revenue of the plant
  - Accumulator investment cost = *V * 33 €* + *400 000 €*

- Results
  - Winter 400–1 200 m^3
  - Summer 800–2 500 m^3

Conclusion

- Electric mode
  - Battery price of 8,3 MEUR is rather expensive for smoothing fluctuations
- Heat mode
  - During the winter time it was more economical to utilize smaller heat accumulator volumes than in the summer
  - The average electricity price and heat demand were lower in the summer than in the winter
    - *Heat has to be stored for longer periods of time in the summer*
    - *Engine runs and produces more heat in the winter*

- Thesis can be found: https://www.tritonia.fi/fi/e-opinnaytteet/tiivistelma/7229
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