3rd International Conference on

Smart Energy Systems and 4th Generation District Heating

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AALBORG UNIVERSITY DENMARK

Maximum geothermal performance by MPC

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4DH

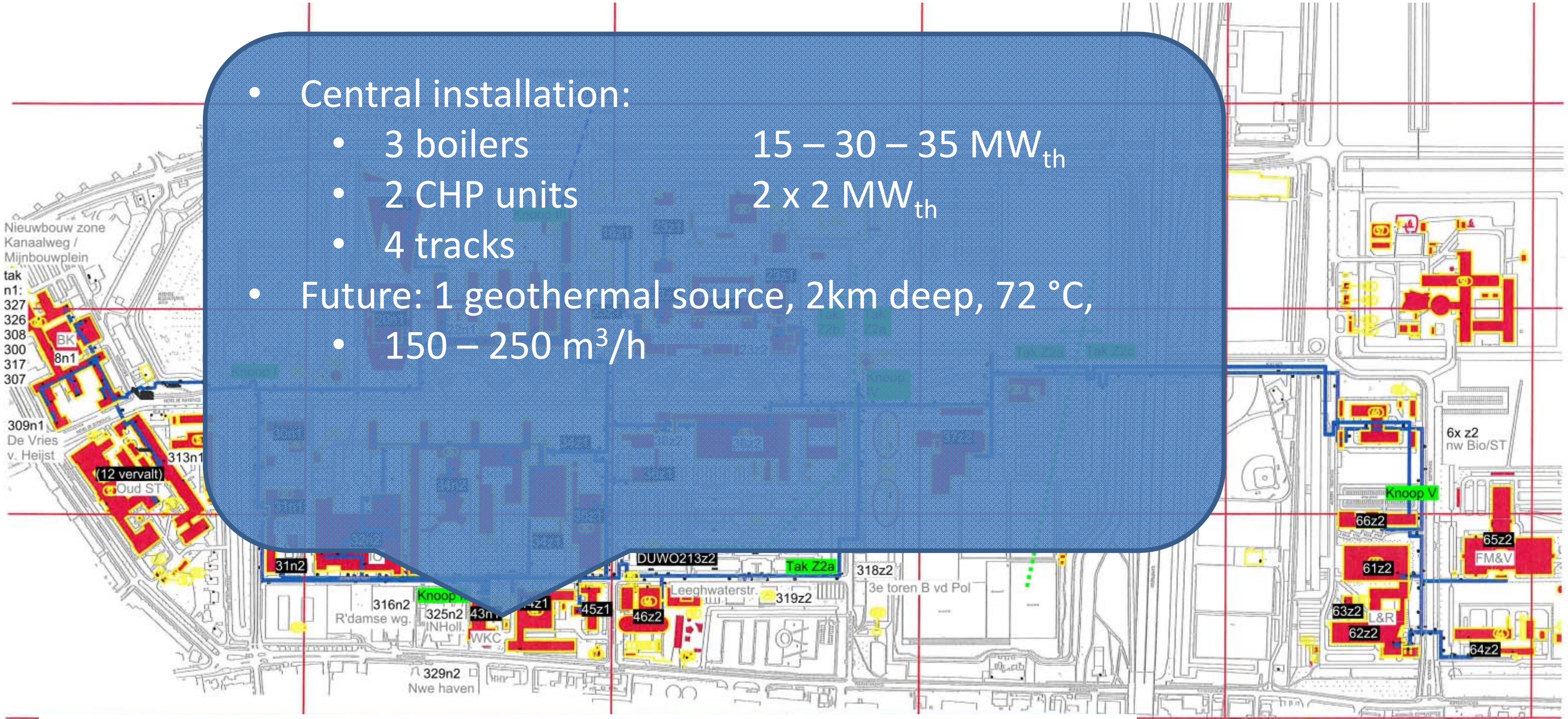
4th Generation District Heating Technologies and Systems

Deltares

- **Independent institute for applied research in the field of water, subsurface and infrastructure**
- **Motto: Enabling Delta Life, dare-to-share**
- **800 employees, 28 nationalities**
- **110 M€**
- **Expertise in this project**
  - **Hydraulics and control DH network,**
  - **MPC Toolbox RTC-Tools**

DHS Campus
Delft University of Technology

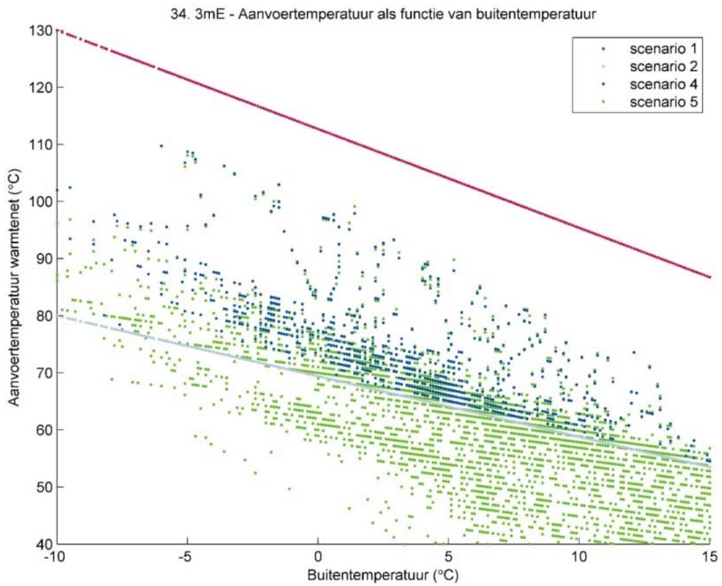
- Central installation:
  - 3 boilers 15 – 30 – 35 MW_{th}
  - 2 CHP units 2 x 2 MW_{th}
  - 4 tracks
- Future: 1 geothermal source, 2km deep, 72 °C,
  - 150 – 250 m^3/h



- 500.000 m^2 office, lecture halls, residential building
- 101 HEX
- Heat demand ~ 125.000 GJ

Last year's challenge

- **Transform conventional DHS (120 – 80°C) to novel MT DHS (dyn. °C) without modifying building envelopes**



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4DH 4th Generation District Heating Technologies and Systems

Kuijpers

Deerns

Deltares Enabling Delta Life

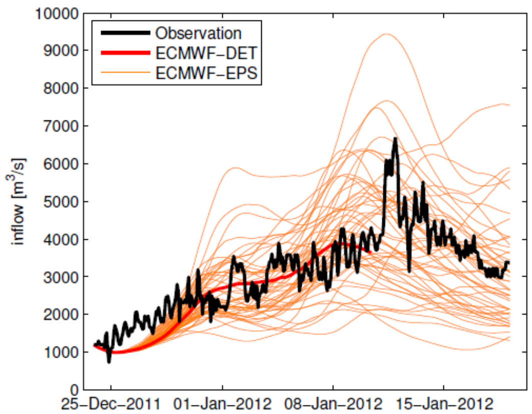
PRIVA

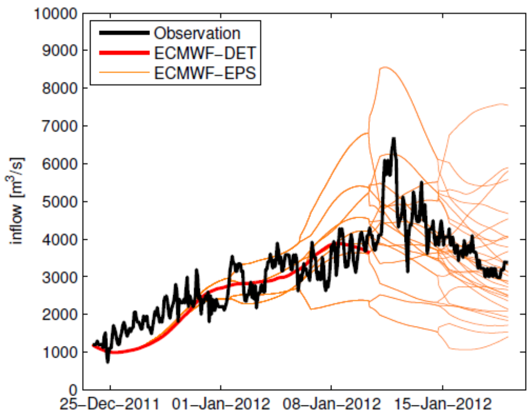
Challenge 2017

- Develop MPC solver for system-wide optimisation of CO_2 emission or energy cost
  - Balance between peak shaving and use of different sources (geothermal, CHP, boiler)
  - Use heat storage and building dynamics

RTC-Tools

- Generic toolbox for MPC
- Designed for real-time applications
  - Robust, fast algorithms
- RTC Tools is using open source Modelica, Casadi and various non-linear optimisation solvers





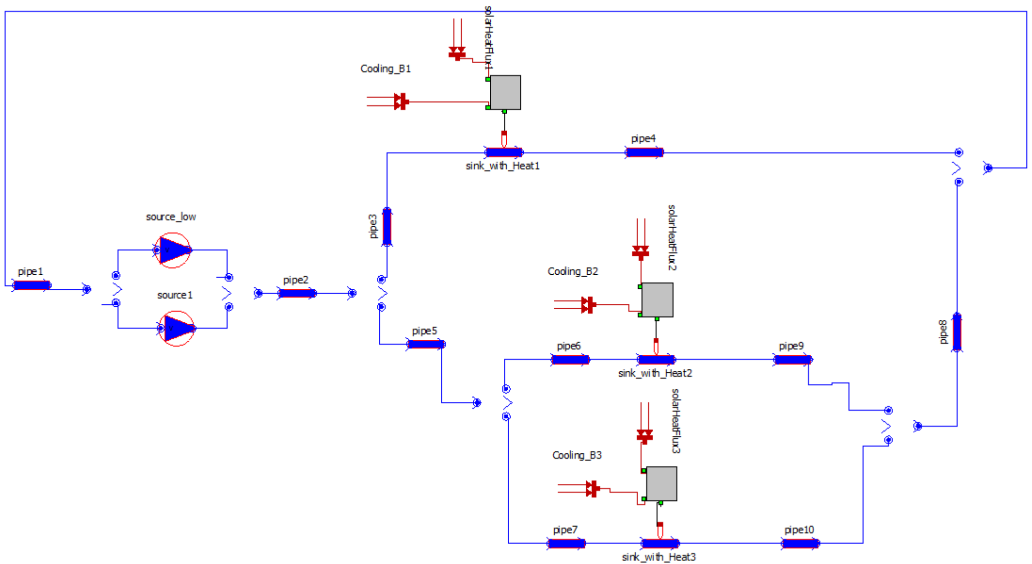
RTC Tools key features

- Ensemble forecasting and stochastic optimisation
- Multi-objective optimisation with priorities
  - Avoids different goals in 1 objective function
  - Goal programming

- Many applications in hydropower production and flood management

System optimization model

- Optimisation goals + priorities
- Modelling components to define generic constraints
  - Building
  - Pipe
  - Source
- Specific constraints



Optimisation modelling

- …… is an art
- Choose decision and constraint variables
  - To avoid non-linearities
  - Define convex optimisation problem

Models

- Pipe
  - To connect sources to buildings
  - No heat loss, friction, delay time
- Building
  - 1D linear model with storage, solar radiation, heat loss by diff. temp and wind
  - Heat supply from DHS is limited by supply temp.
  - Multiple layers in walls for heat storage

Source model

- Supplies heat to DHS
- Costs can be time dependent (cheap by night expensive by day)
- Heat supply may be limited by DHS return temperature
  - E.g. geothermal temp. is 74 °C.
  - CHP needs T < 83 °C

Multi-ojective goals

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4th Generation District Heating Technologies and Systems

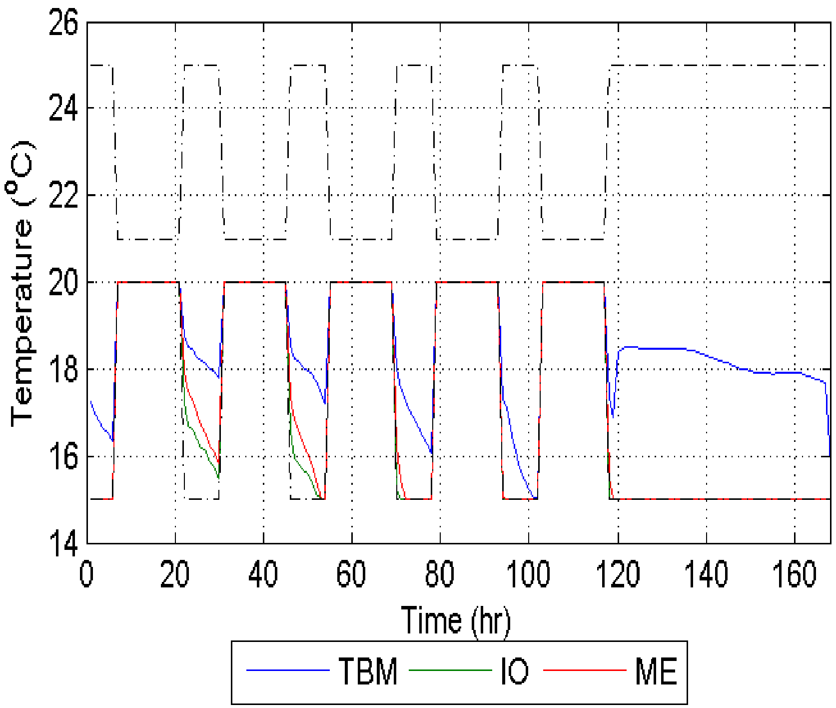
- Main purposes of goal programming
  - Avoid fake balances due to weights
  - Priority setting
  - Robust solutions
- Level 1: minimise building temperature exceedance
  - → maybe modified building temperature envelope
- Level 2: Minimise supply temperature
- Level 3: Minimise cost/CO2 emission

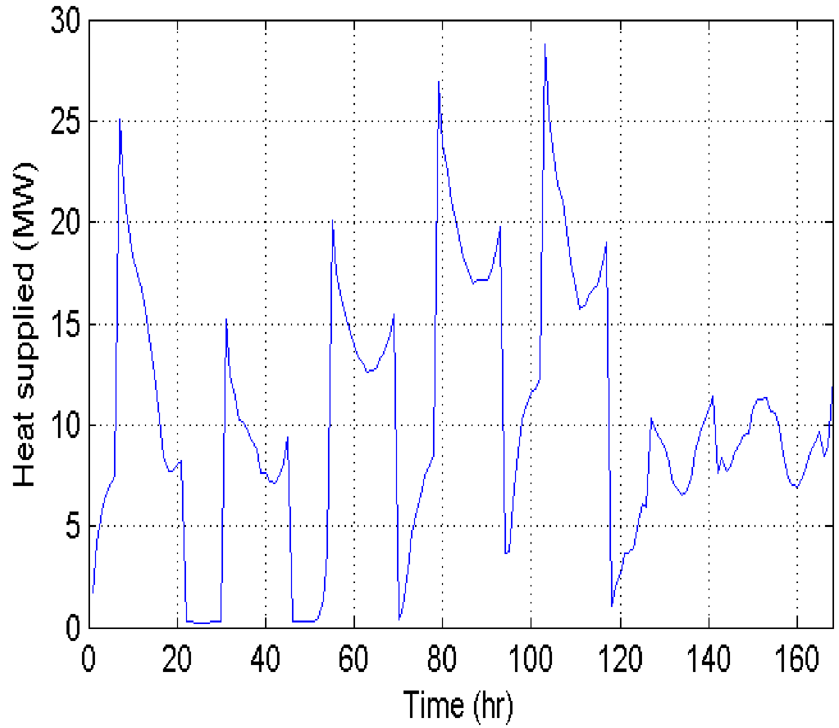
Problem size, solver performance

- Delft University Campus
  - 4 supply temperatures
  - 2 sources
  - 23 buildings with heat (or cooling) demand
- 29 decision variables per timestep
- 1 week → 4872 decision variables
- Performance
  - < 5 minutes on 3.2 GHZ Intel Xeon 4 cores in parallel on Linux

One source constant costs

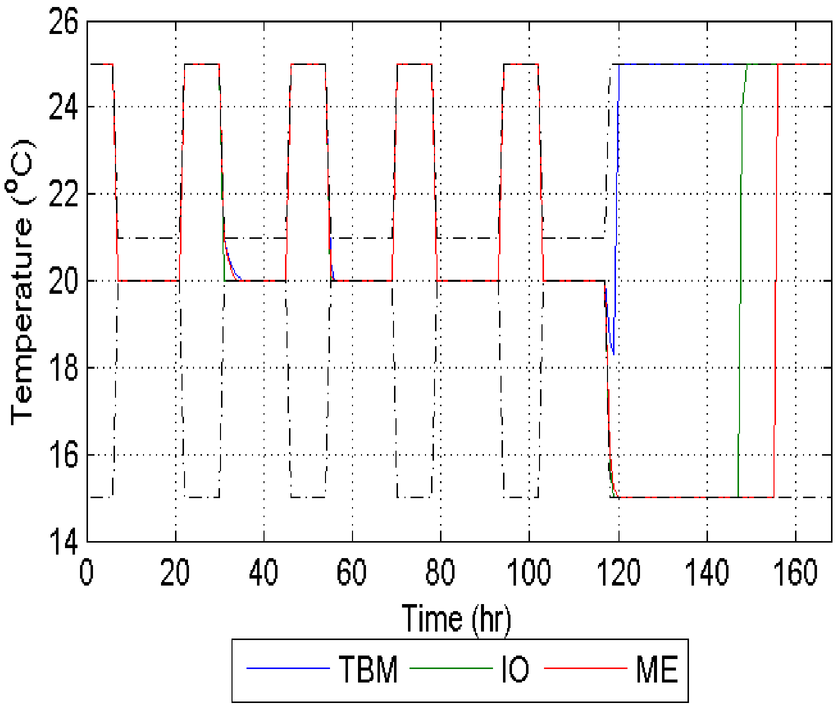
- Total energy used: 6,258 GJ
- Peak supply 29 MW in cold week in January
- conventional profile

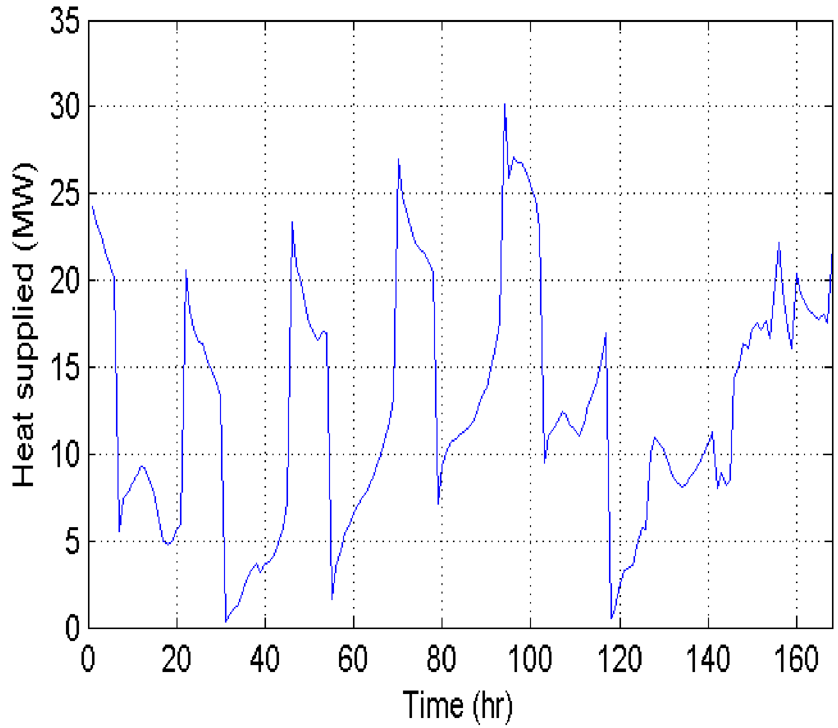




One source with day/night tariffs

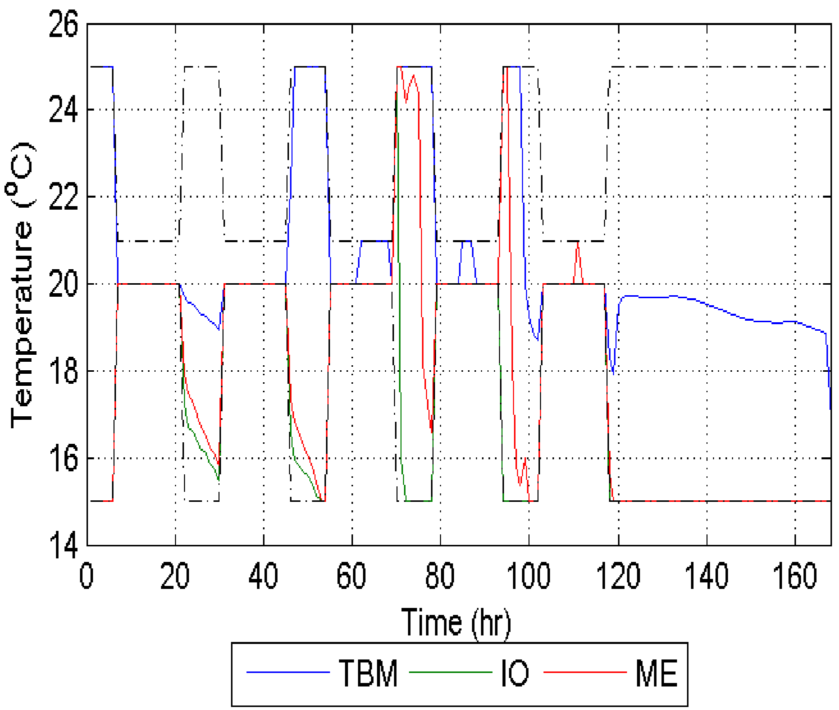
- Total energy used: 7,729 GJ (ref 6258 GJ)
- Peak supply 30 MW (ref 29 MW)

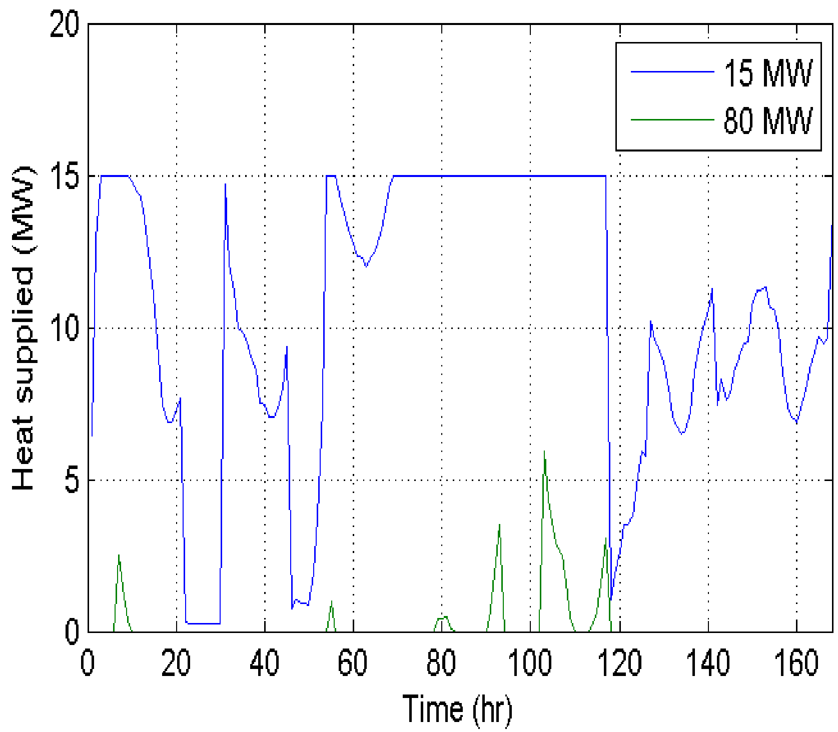




Two sources, different prices

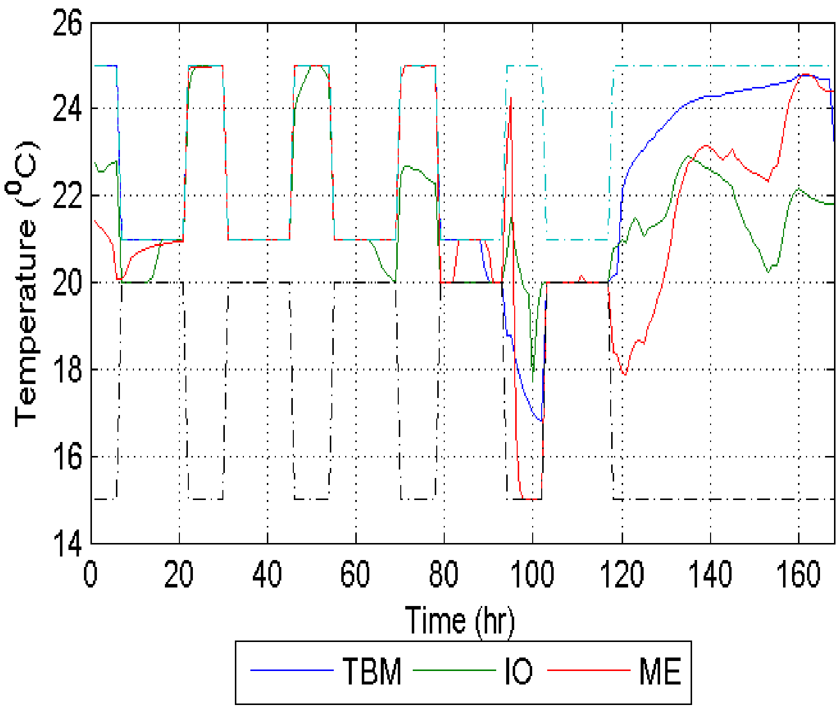
- 15 MW source at 50% of price of 80 MW source
- Total energy used: 6,269 GJ (ref 6,258 GJ)
- Peak supply 21 MW (ref 29 MW)

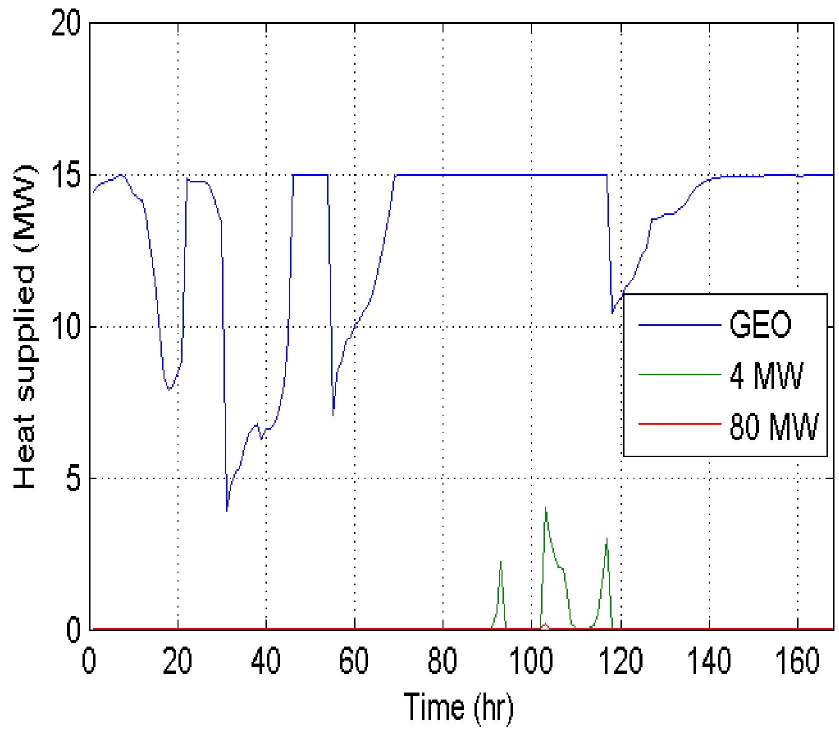




Two sources, different prices

- 15 MW source at 10% of price of 80 MW source
- Total energy used: 8095 GJ (ref 6,258 GJ)
  - Due to preheating in weekend
- Peak supply 19 MW (ref 29 MW)





Conclusions

- Peak shaving → higher energy consumption
- Energy costs or CO2 emission go down and drive the amount of effective preheating/peak shaving.
- Optimiser finds proper balance between peak shaving and goals.