Thermal energy storage in district heating systems: 
A case study of Gothenburg, Sweden

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Motivation for the research

Variability in heat demand
- Part-load operation
- High number of start-ups and stops
- Requires peaking generation (usually fossil based)

Interplay with power sector
- Variable operation of CHP plants and heat pumps

Examples of hot water tanks

Hot water tank.
Power Plant Ljubljana, Slovenia.

Hot water tank.
District heating system of Borås, Sweden.
http://publications.lib.chalmers.se/records/fulltext/186016/186016.pdf
Heat storage in buildings

Göteborg, Sweden.
http://helikopterfoto.nu/flygfoto-over-goteborg-soluppgang/
Aim and scope

Aim:
To compare operation of a district heating (DH) system when either a hot water tank or a thermal capacity of building stock is used as a thermal energy storage

Scope:
✓ Find optimal heat generation strategy in the DH system of Gothenburg using a unit commitment computer model
✓ Evaluate operation of the studied DH system when:
  ✓ no energy storage is available
  ✓ hot water tank (HWT) is used as storage technology
  ✓ Storage-in-buildings (SIB) is used for storing energy
Main findings

✓ Both storage types provide good service in moderation of daily heat demand fluctuations

✓ Both storage types lead to lower number of start-ups and increased full-load hours of the heat generation units

✓ Decreased total system running cost

✓ Yet, SIB shows higher response sensitivity to short-term heat demand fluctuations (compared to HWT)
Methodology
(unit commitment model)

**Input:**

- Technical unit parameters:
  - Capacity limits
  - Efficiencies (COP)
  - Ramp up/down limits
  - Start-up and shut down limits
  - Minimum up/down time constraints

- Economic unit parameters:
  - Fuel prices
  - Taxes and fees
  - Renewable Energy Certificates

- Hourly heat demand

- Hourly electricity prices

**Output:**

- Total system operating cost
- Hourly heat generation
- Hourly electricity generation/consumption
- Unit operational hours
- Number of start-ups and stops
- ...
Energy storage modelling

**Hot water tank**
- Maximum capacity (1000 MWh)
- Charge/discharge ramp limits (130 MW)
- Charge/discharge efficiencies (90 %)
- Losses based on energy content
- Static losses (unusable heat)

**Storage-in-buildings**
- Storage capacity in buildings is divided in:
  - shallow storage (SS)
  - deep storage (DS)
- Maximum capacity:
  - SS≈300 MWh
  - DS≈1800 MWh
- Charge/discharge ramp limits of SS depend on outdoor temperature (max 63 MW)
- Energy exchange between SS and DS depends on instant energy level in both SS and DS

\[ F_h = \left( \frac{E_{SS,h}}{E_{SS,\text{max}}} - \frac{E_{DS,h}}{E_{DS,\text{max}}} \right) \cdot K \]
Hourly heat generation

4 consecutive weeks starting in mid November 2012

Hourly heat generation [MW/wh]

| Waste Heat | Heat Pumps | Bio CHP | Gas CHPs | Pellet HOBs | Gas HOBs |

Hourly heat generation [MW/wh]

Heat demand | HWT level | Shallow SIB level | Deep SIB level

0 100 200 300 400 500 600

0 100 200 300 400 500 600

Relative daily variation of heat generation calculated for each day during the year and placed in descending order.
Number of start-ups
Economics

- Total system running cost [MSEK]
- Electricity generation [GWh]
- Electricity consumption [GWh]

Legend:
- NO storage
- Hot water tank
- Storage-in-buildings
Conclusions

✓ Both storage types provide benefits to the DH system by moderating daily heat demand fluctuations

✓ Storage-in-buildings is more responsive to short-term heat demand fluctuations

✓ Usage of the thermal storage results in decreased number of start-ups and increased number of full-load hours of the heat generation units

✓ Decrease in total system running cost
Future research

✓ Run case studies with different energy storage capacities

✓ Improve representation of storage-in-buildings by adding energy loss factor

✓ Evaluate DH system’s operation with and without storage options applying future electricity price profiles