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Thermal energy storage in district heating systems:

A case study of Gothenburg, Sweden

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4DH
4th Generation District Heating Technologies and Systems

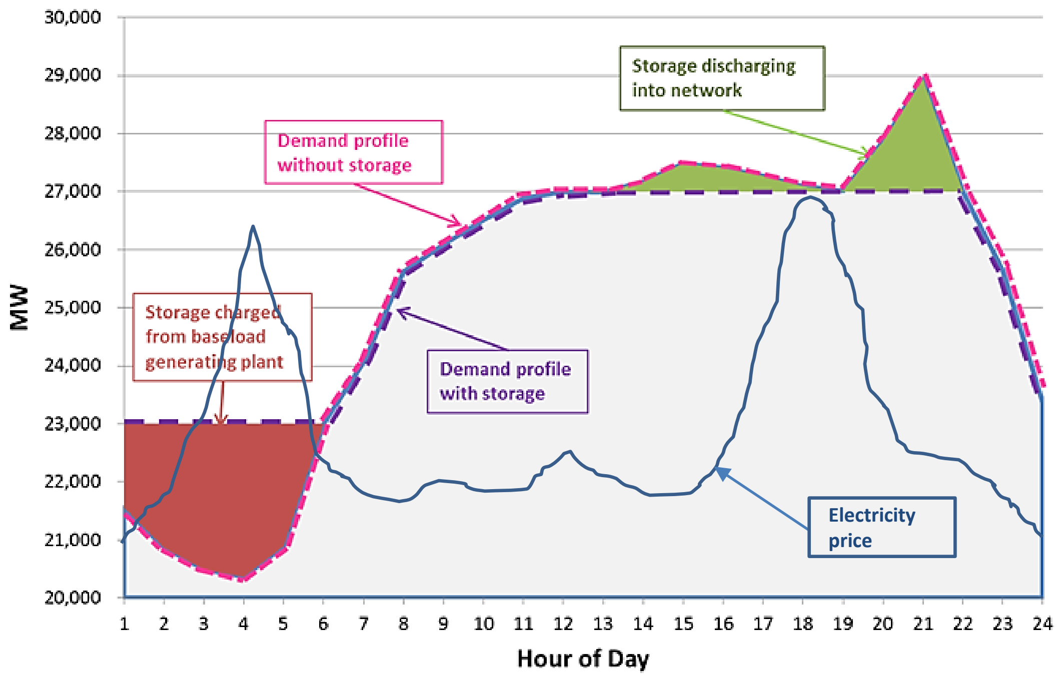
Motivation for the research

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



https://energyclub.stanford.edu/deploying-battery-storage-in-commercial-buildings-opportunities-and-challenges-kavousian/

Examples of hot water tanks

Hot water tank.
Power Plant Ljubljana, Slovenia.
http://khia.belzona.com/EN/view.aspx?id=2466

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

⇒

Optimization model
Minimizing total system operating cost (GAMS)

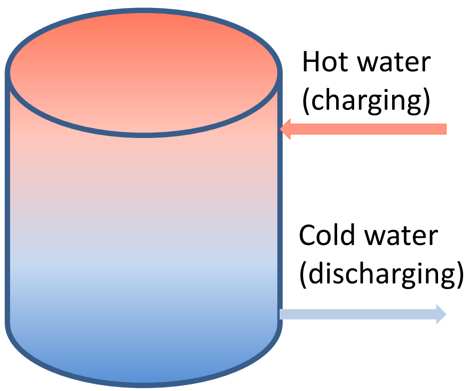
⇒

Output:

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

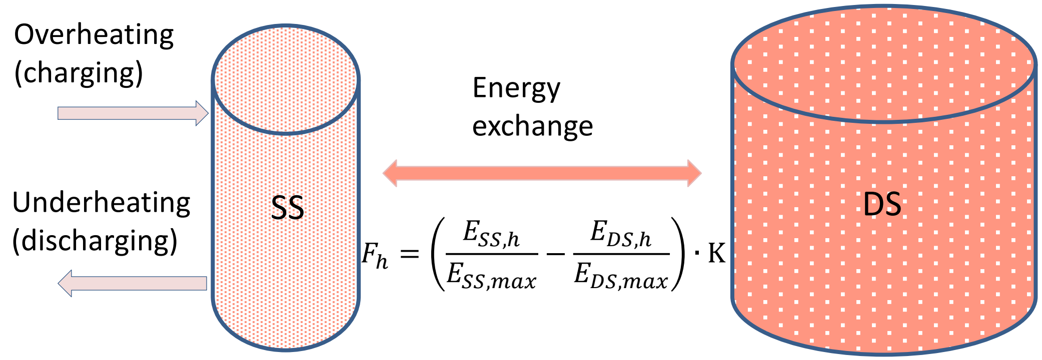
Energy storage modelling

Hot water tank



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

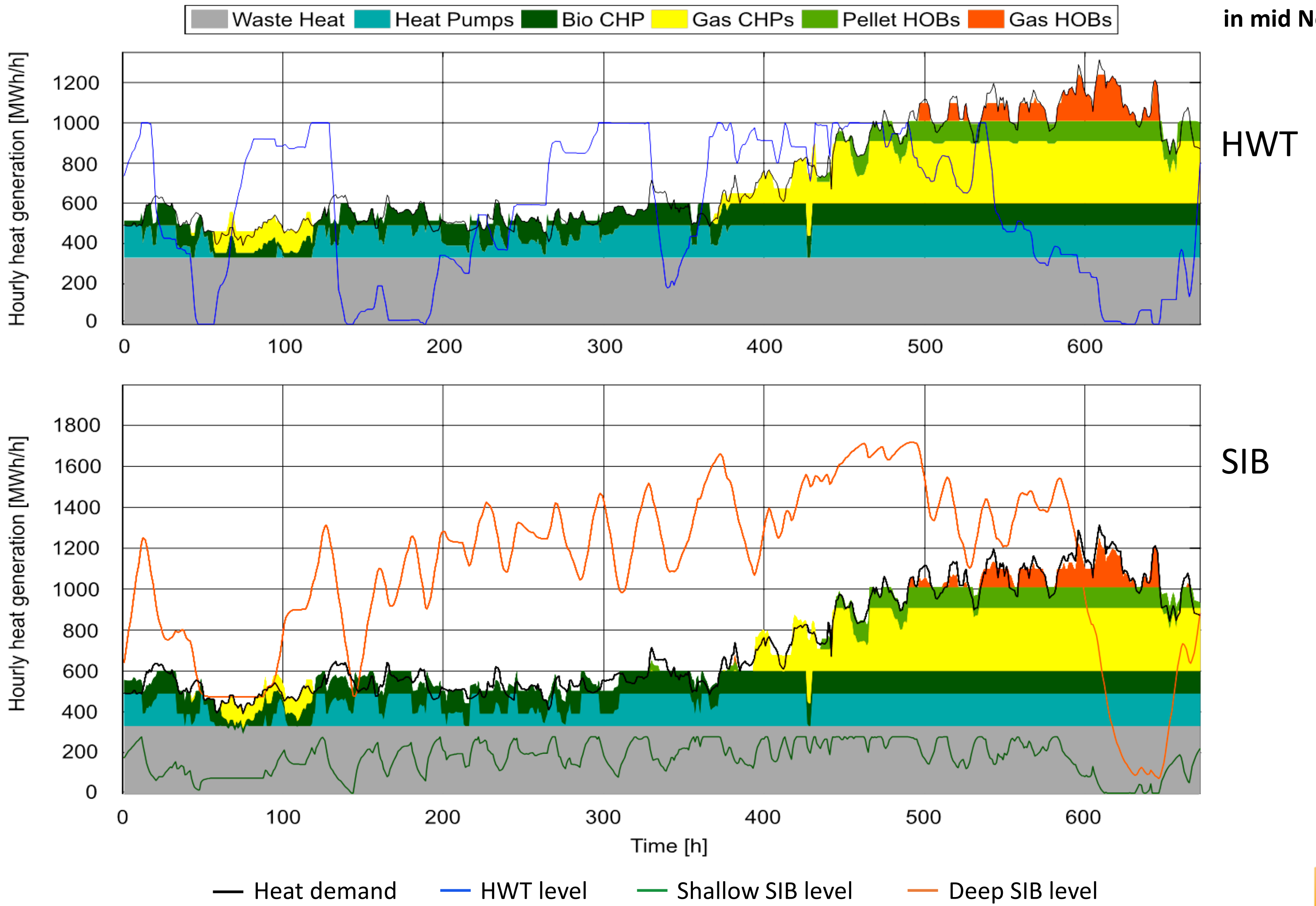
Storage-in-buildings



- 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 *<u>(max 63 MW)</u>*
- Energy exchange between SS and DS depends on instant energy level in both SS and DS

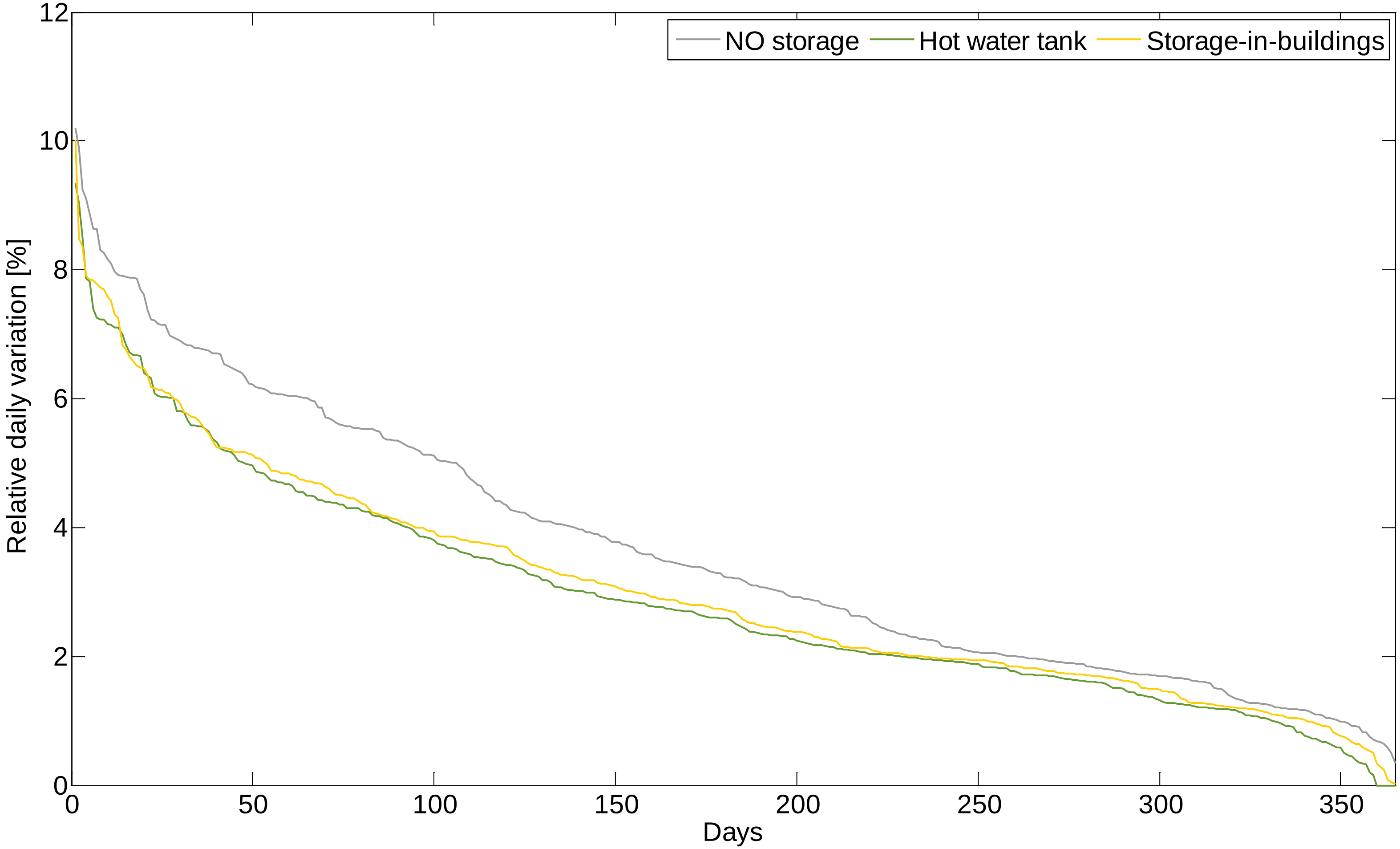
Hourly heat generation

4 consecutive weeks starting in mid November 2012

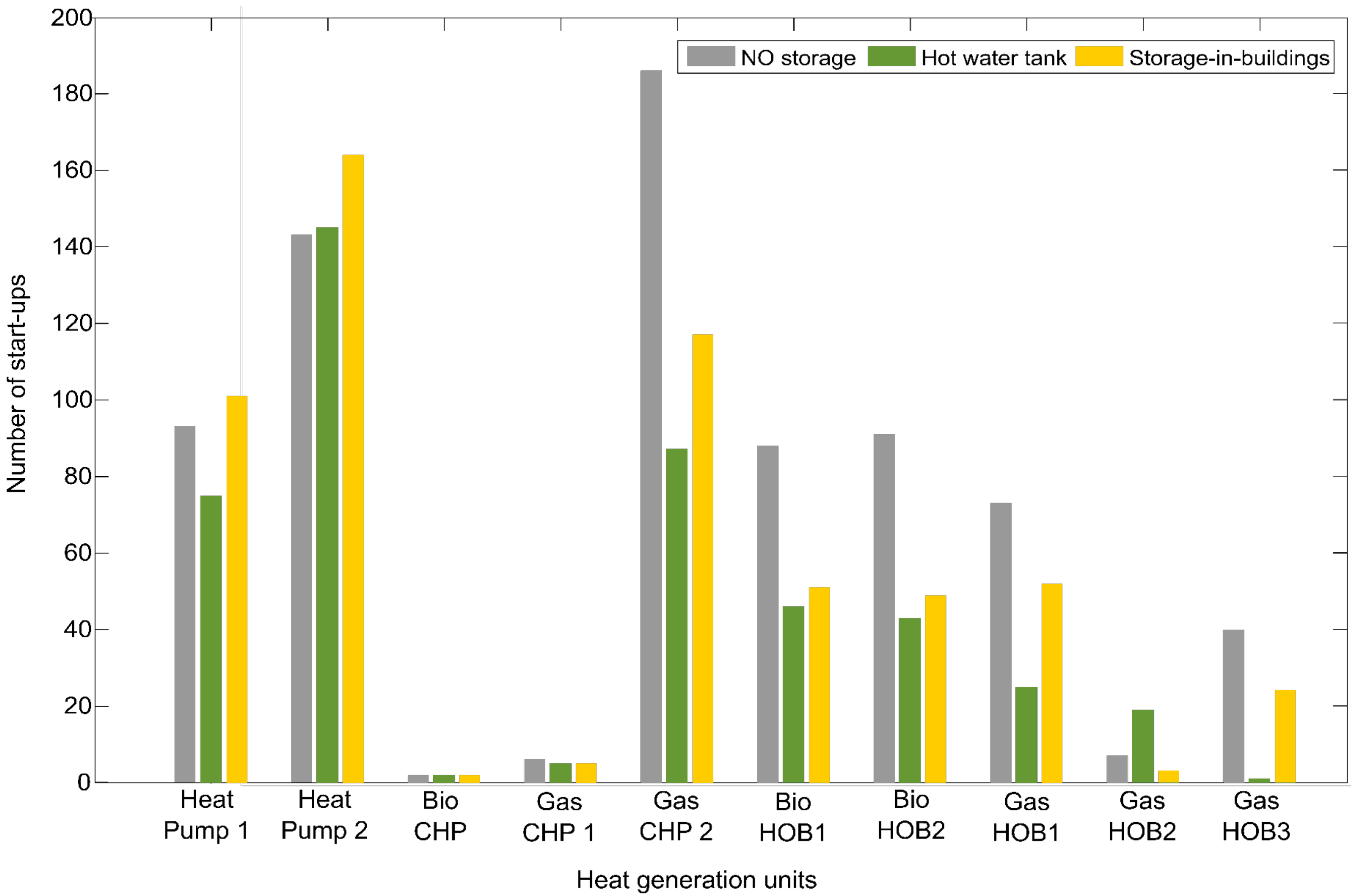


Relative daily variation

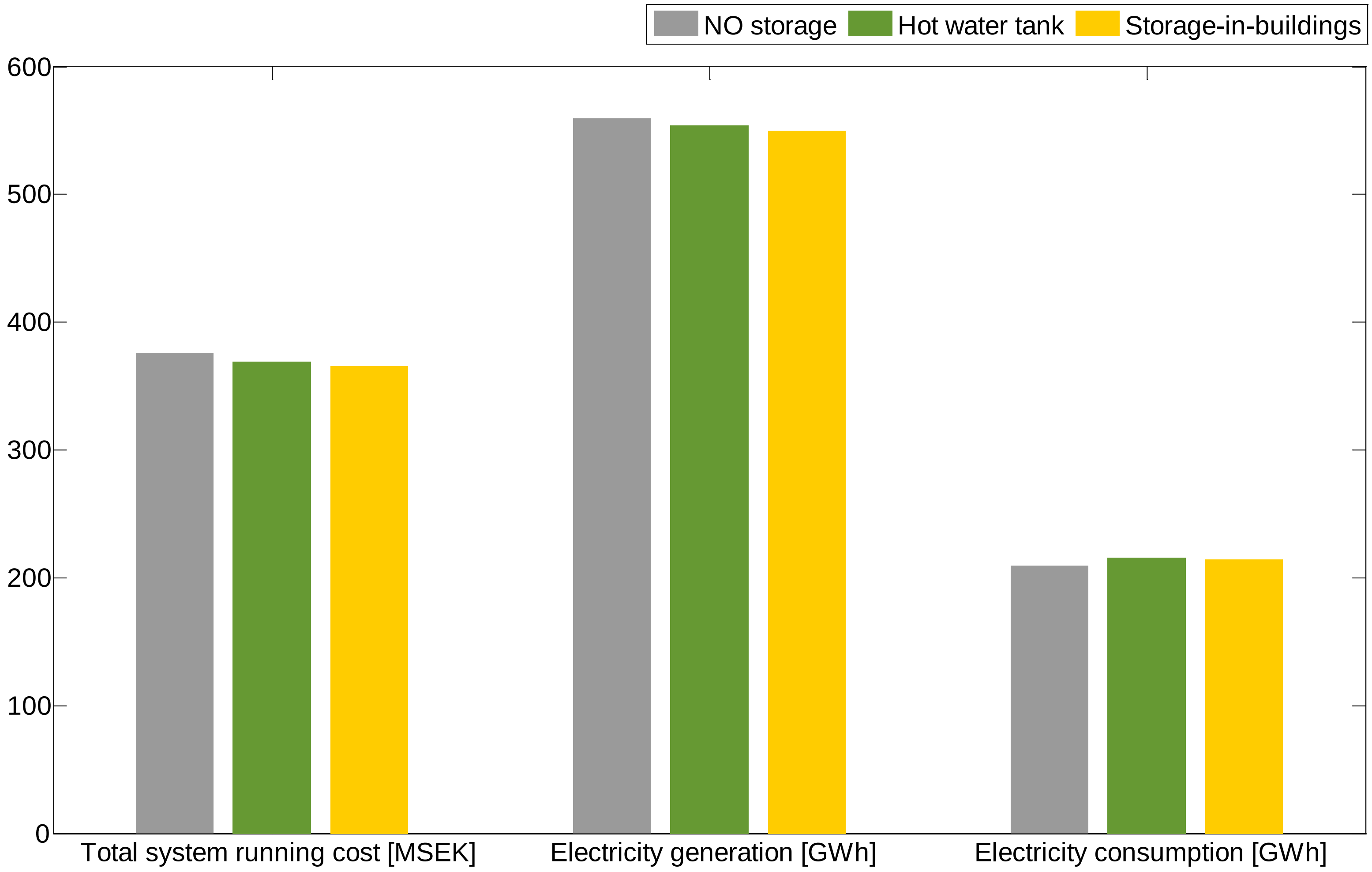
Relative daily variation of heat generation calculated for each day during the year and placed in descending order.



Number of start-ups



Economics



NO storage
Hot water tank
Storage-in-buildings
600
500
400
300
200
100
0
Total system running cost [MSEK]
Electricity generation [GWh]
Electricity consumption [GWh]

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