Modelling thermal energy storage in district heating:

a comparison of centralised storage and thermal inertia of buildings

D. Romanchenko, M. Odenberger and F. Johnsson

Department of Space, Earth and Environment, Chalmers University of Technology, SE 412 96 Göteborg, Sweden

Background

- **55% of the total space heating and hot water demand in Swedish residential and service sectors is covered by district heating (DH)**
- **Variations in heat load result in frequent starts and stops *and* part-load operation of heat generation units**
- **Employment of thermal energy storage (TES) can improve the imbalance between the heat load and supply**
- **Two thermal storage types are considered:**
  - centralised storage in the form of a hot water tank (HWT)
  - decentralised storage in the form of thermal inertia of buildings (BITES)

Case study

- **DH system of Gothenburg, Sweden**
- **28 heat generation units, including 3 CHP plants**
- **Total yearly heat delivered to customers in 2015 – 3,300 GWh**
- **Centralised thermal storage – HWT** (hot water tank):
  - capacity: 2,000 MWh
  - max. charge/discharge rate: 200 MWh/h
- **Decentralised thermal storage – BITES** (building thermal inertia):
  - shallow storage capacity: 278 MWh
  - deep storage capacity: 1,758 MWh
  - max. charge/discharge rate: 280 MWh/h

Methodology

HWT – hot water tank **BITES** – building inertia thermal energy storage

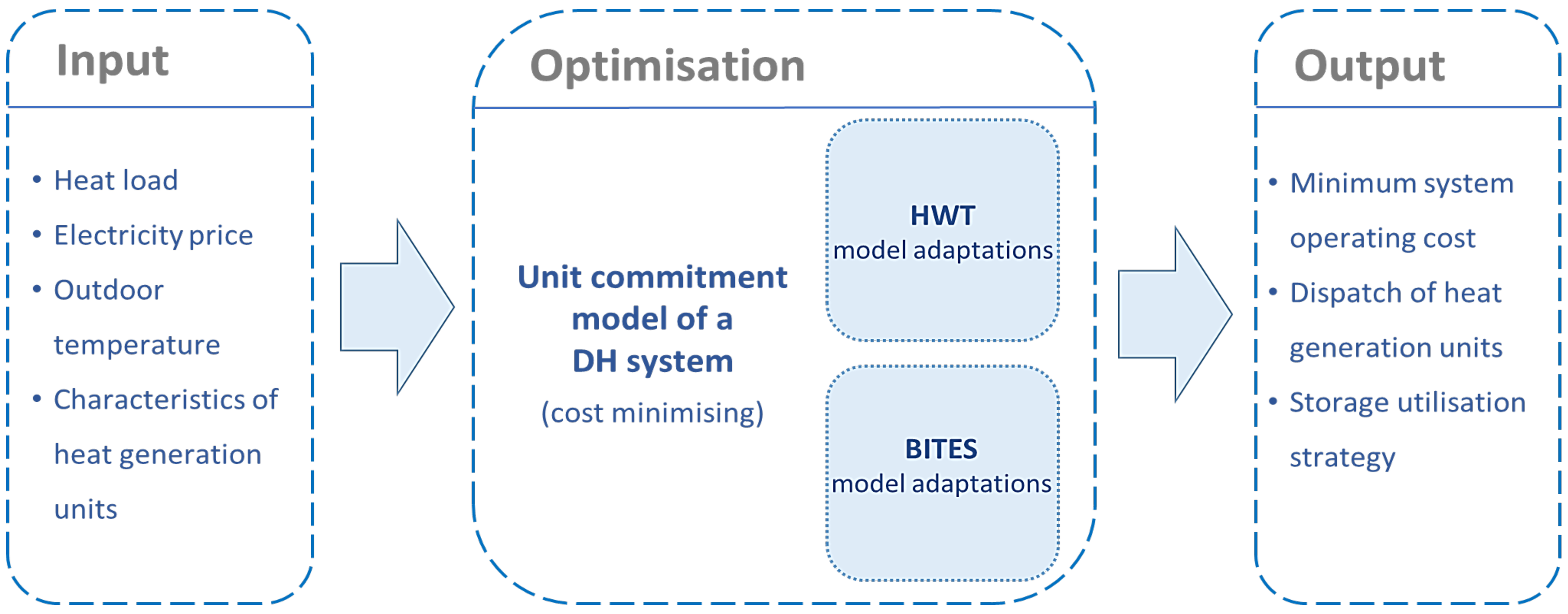

Fig. 1. *Overview of the modelling approach*

Shallow storage – indoor air and building internals ***Deep storage*** – building core

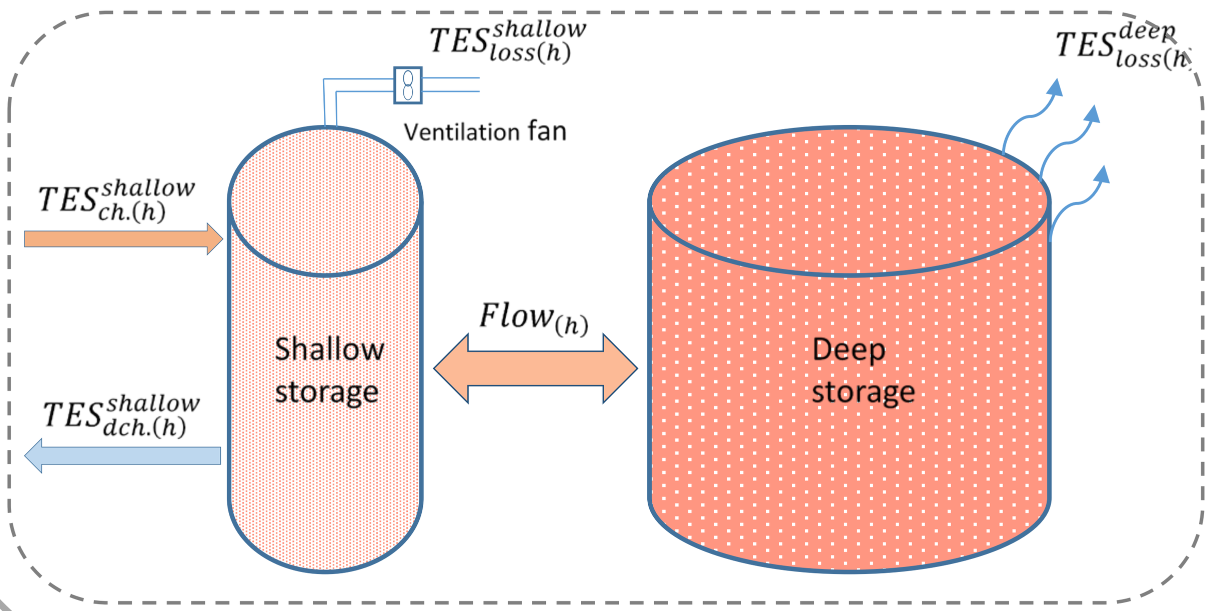

Fig. 2. *Schematic of the shallow and deep storage components of BITES*

- **Mixed-integer optimisation modelling**
- **1 year model run, hourly time resolution**
- **High level of details**

  - ramp limits, start-ups, minimum on/off times, variable power-to-heat ratio
- **Investment costs are not included**
- **Perfect foresight**
- **HWT –** one node storage
- **BITES –** two node storage

$$Flow_{(h)} = \left(\frac{TES^{shallow}_{stored(h)}}{TES^{shallow}_{cap}} - \frac{TES^{deep}_{stored(h)}}{TES^{deep}_{cap}} \right) \cdot K$$

Results

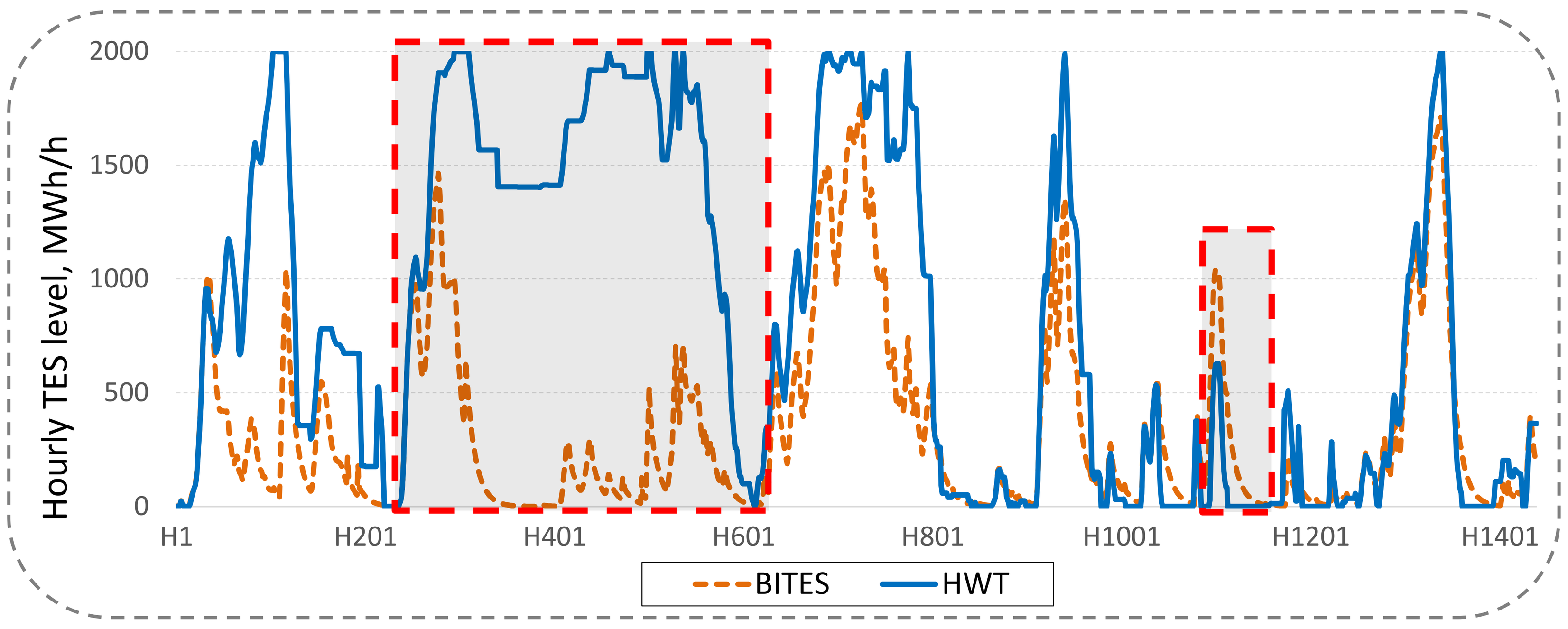

Fig. 3. *Hourly levels of energy stored in HWT and BITES for two winter months in Year 2012 (the levels of the shallow and deep storage components of the BITES are aggregated)*

- **Both storage types (HWT and BITES) have similar dynamics of utilisation**
  - in terms of frequency and rate of charging/discharging
- **HWT stores twice as much heat over the modelled year than BITES**
  - owing to lower energy losses
- **Heat transfer between the building core *and* the indoor air and internals is found to limit the instant capacity of BITES for charging/discharging**
- **Both storage types benefit operation of heat generation units**
  - fewer starts and stops, increased average output
- **Total system yearly operating cost decreases by 1% when BITES and by 2% when HWT is added to the DH system**

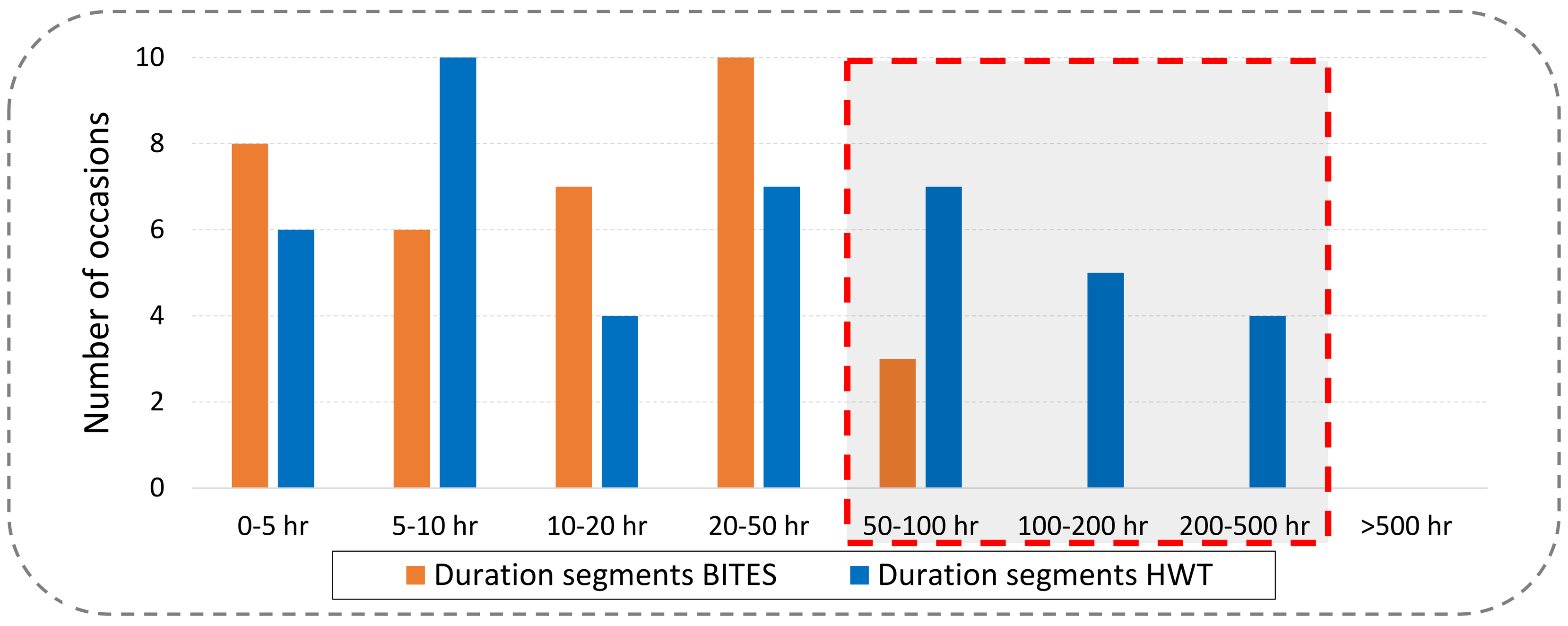

Fig. 4. *Number of occasions (classified in duration segments) during which HWT and BITES remained charged at a level ≥1,000 MWh*

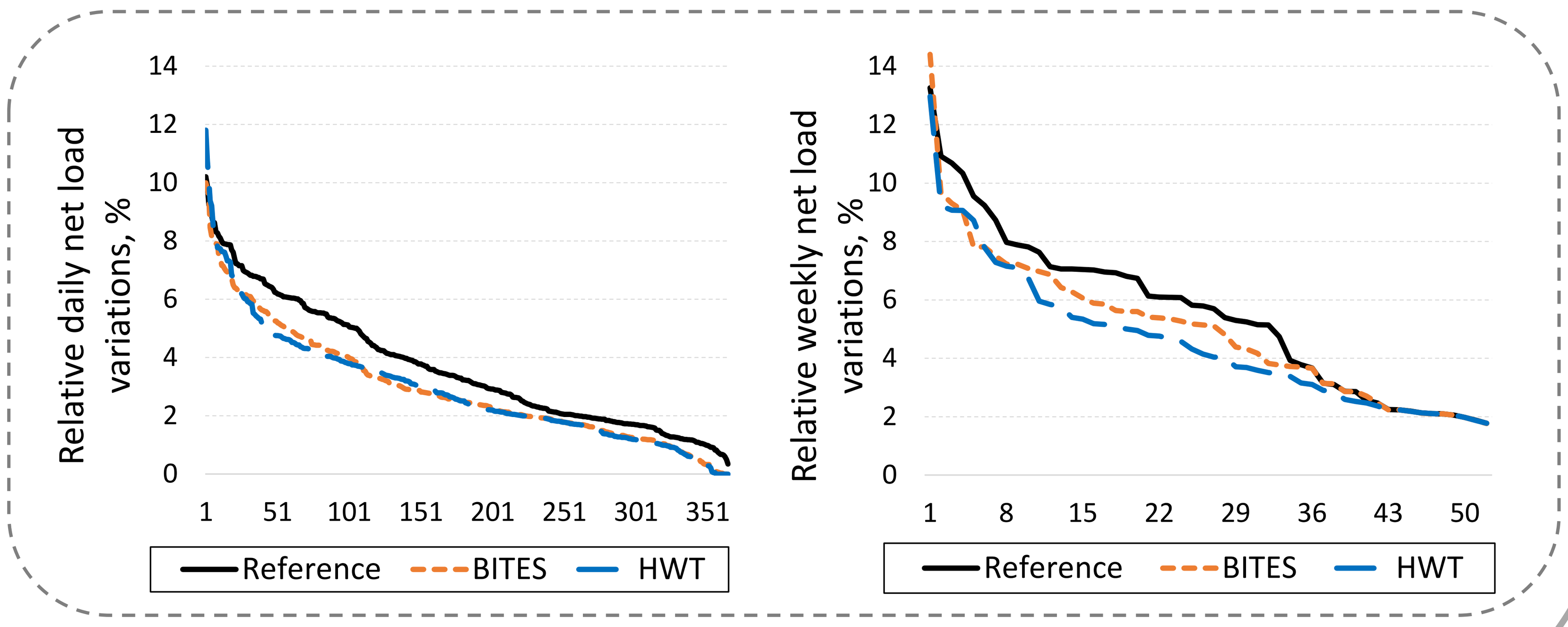

Fig. 5. *The a) relative daily net load variations and b) relative weekly net load variations of the investigated DH system in the reference, BITES, and HWT scenarios (in descending order)*

Conclusions

- **Both storage types provide technical and economic benefits to the investigated DH system**
  - improve the imbalance between the heat load and supply
  - result in lowered yearly system operating cost
- **Both storage types have similar utilisation patterns but HWT stores twice the amount of heat than BITES**
- **Only HWT is used for storing heat for periods of time longer than few days**
- **Our modelling approach shows the impact of charge/discharge limitations of BITES (due to the heat exchange between the building core and indoor environment) on its utilisation in DH systems**

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