Performance evaluation of utility plant and booster heat pumps in ultra low temperature district heating system at varying flow temperatures of the network

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Outline for Presentation

- Introduction
  - Two different energy system scenarios
  - Design of LT and ULTDH substations
- Analysis of new/revised LT- or ULTDH systems
- Summary of findings

Introduction to low and ultra low temperature DH

Low temperature DH:

Carrier Higher temperature than required for direct heat exchange to heat demand. Eg. 50 - 70 °C hot water supply temperature

Space heating Floor heating or low-temperature radiators.

Hot water production Efficient local heat exchanger heating DHW.

Ultra low temperature DH

Carrier Lower temperature than required for direct heat exchange to heat demand. Eg. 30 - 50 °C hot water supply temperature

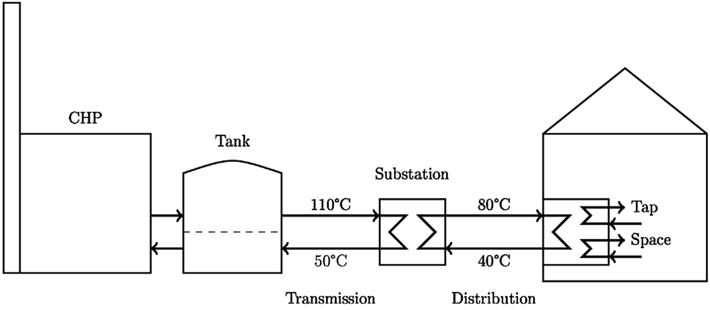
Space heating Floor heating or low-temperature radiators.

Hot water production Heat pump (or electric heater) increases DHW temperature to acceptable level by utilising DH as heat source (other sources possible).

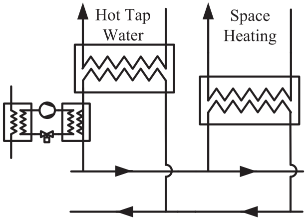
Two different energy system scenarios

The use of ULTDH has been proposed for two quite different energy scenarios:

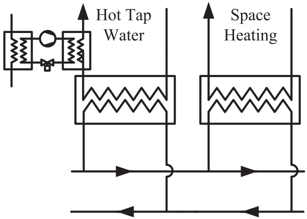
1. Expansion of existing DH networks (eg. 90 °C - 50 °C), where troublesome capacity constraints may be addressed by lowering return temperature, by connecting LT or ULT DH networks at remote positions.
   - Elmegaard et al. (2016) show optimum for cost and exergy at LTDH
2. The design of new or updated systems with better performance of utility units according to the production temperatures and low losses in DH network. A key aspect of lowering DH temperature is the increased performance for renewable technologies at lower forward temperatures.
   - Ommen et al. (2016) suggest LTDH, Østergaard and Andersen (2016) suggest ULTDH.



Basic design of ULTDH HP units



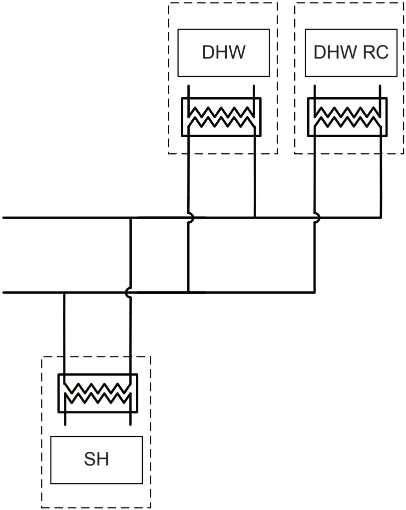
(a) Heat pump on primary side of the tap water heat exchanger.



(b) Heat pump on secondary side of the tap water heat exchanger.

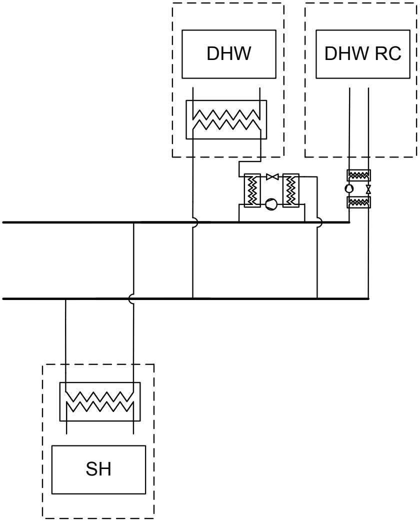
Current design for LTDH

- Various heat demands are connected to DH supply in parallel.
- The return flow of each demand is mixed. Low return temperature is desired for low capacity requirements in the network.
- DHW is often stored to lower capacity requirements in network. Temperature requirement to avoid Legionella Pneumophila.



ULTDH design with two HPs

- Two HPs are introduced due to different temperature requirements of DHW and DHW RC.
- For each HP, the return temperature is a free system performance variable for optimization.
- Storage is included on the primary side of DHW production, between HP and DHW storage.
  - Capacity of DHW HP much higher (eg 4-6 times) than required.
- Heat source for HPs is DH as default. Other possibilities include:
  - Surplus heat in building.
  - Return of SH.
  - Undesired heat transfer in storage tank.
  - External heat sources (difficulties due to water as heat transfer media)



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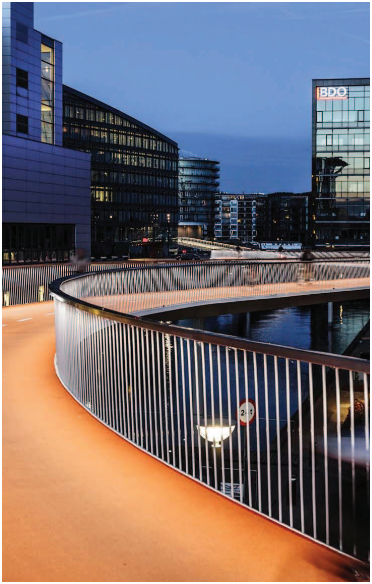

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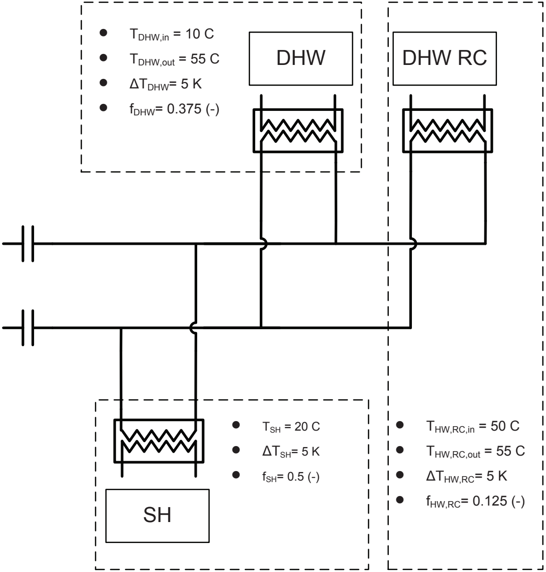
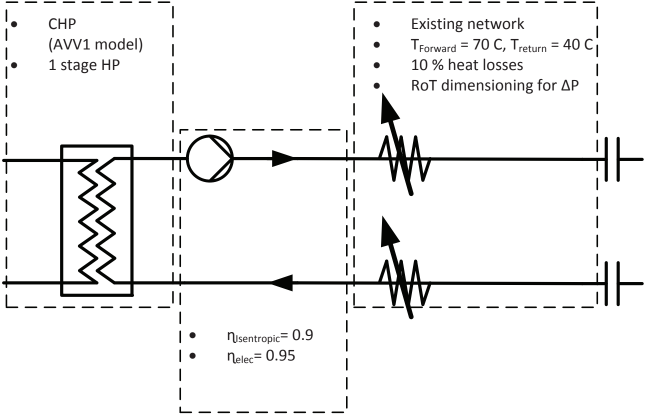
LTDH configuration, and technical assumptions for consumption

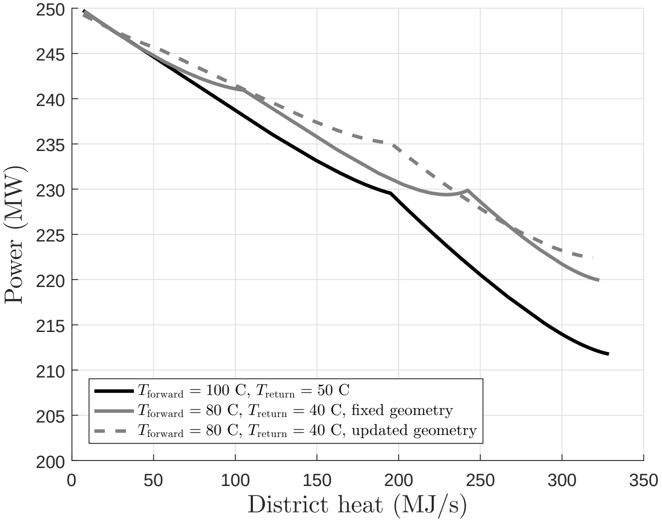


Utility plant and DH assumptions, COSP definition

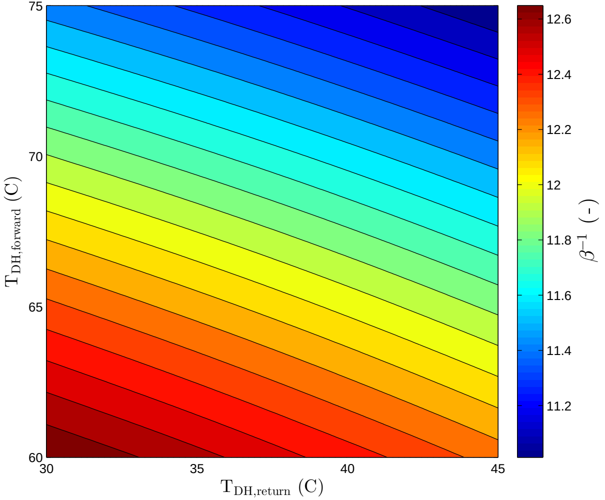


$$\mathrm{COSP}_{\mathrm{demand,elec}} = \frac{\sum \dot{Q}_{\mathrm{HP}} + \Delta \dot{Q}_{\mathrm{CHP}} - \dot{Q}_{\mathrm{DH,loss}}}{\sum \dot{W}_{\mathrm{HP}} + \Delta \dot{W}_{\mathrm{CHP}} + \dot{W}_{\mathrm{Pump}}} = \frac{\dot{Q}_{\mathrm{Demand}}}{\sum \dot{W}}$$

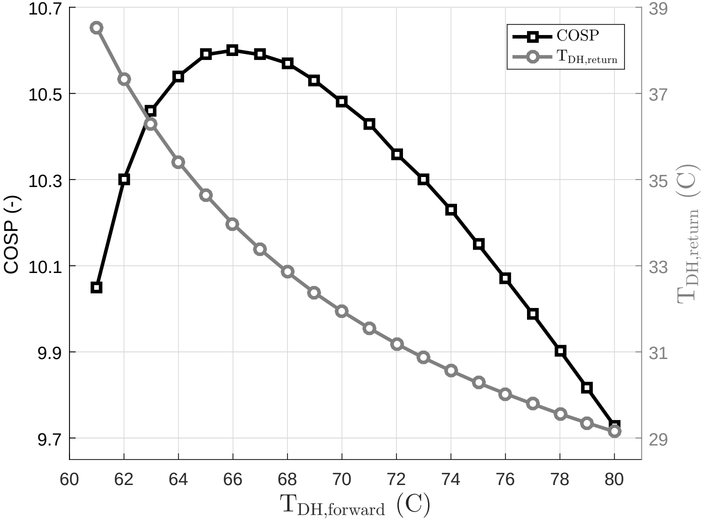
CHP (AVV1), extraction line



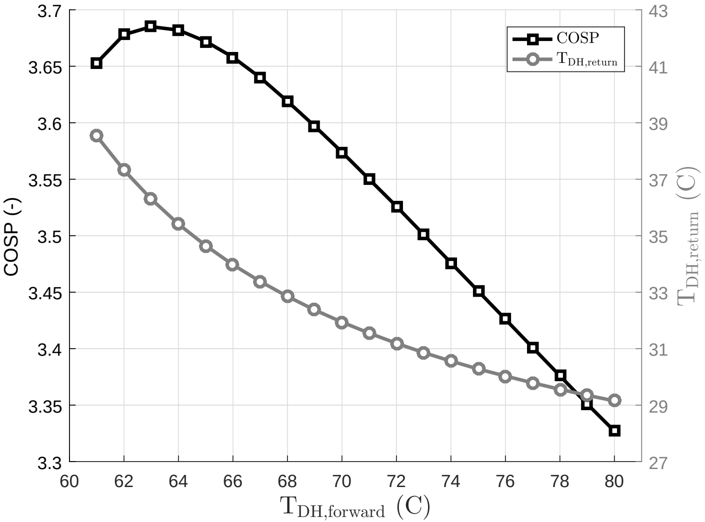
CHP (AVV1), beta values at LTDH



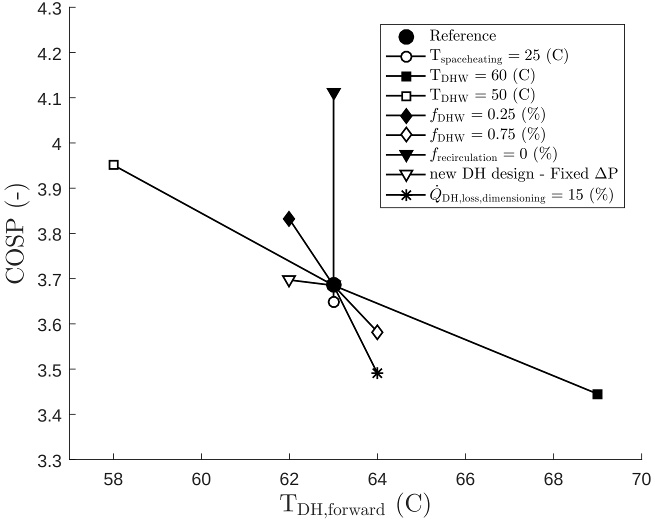
LTDH, heat supplied by CHP



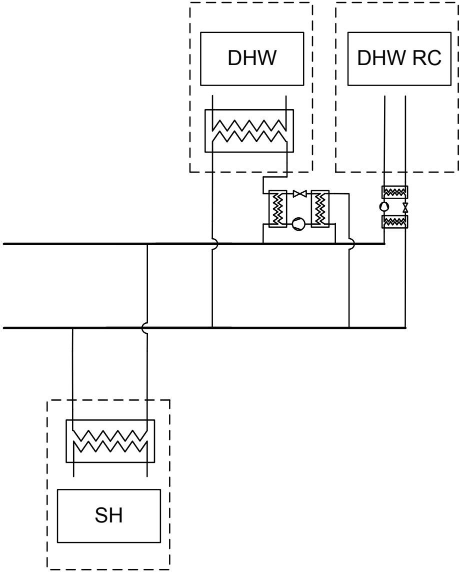
LTDH, heat supplied by HP



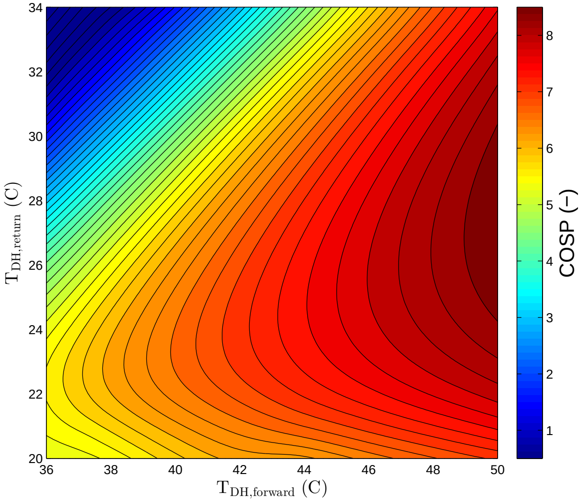
LTDH, heat supplied by HP, influence of various assumptions



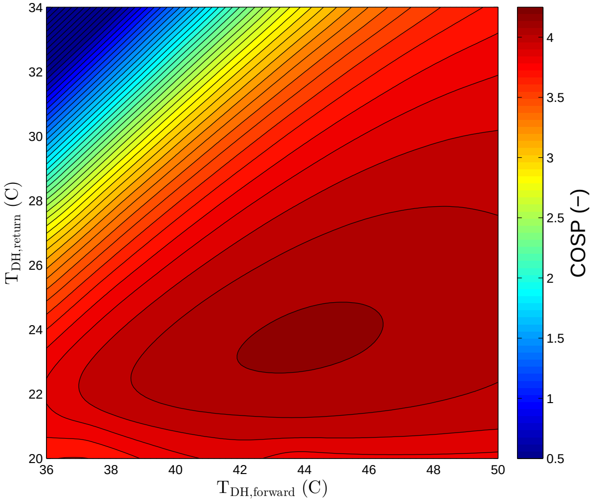
ULTDH with booster heat pumps



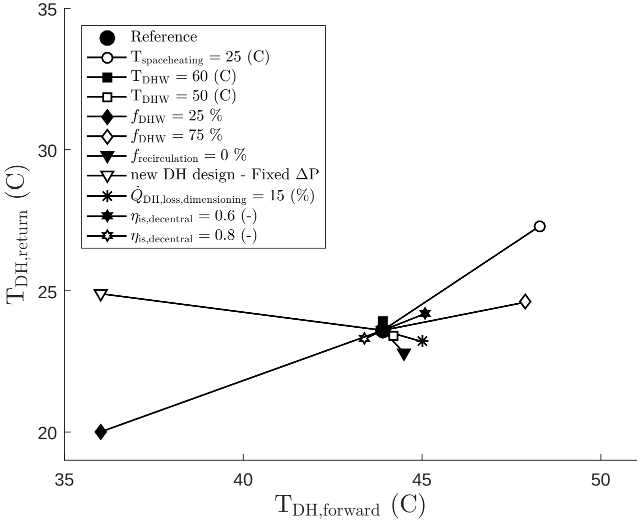
ULTDH, heat supplied by CHP



ULTDH, heat supplied by HP

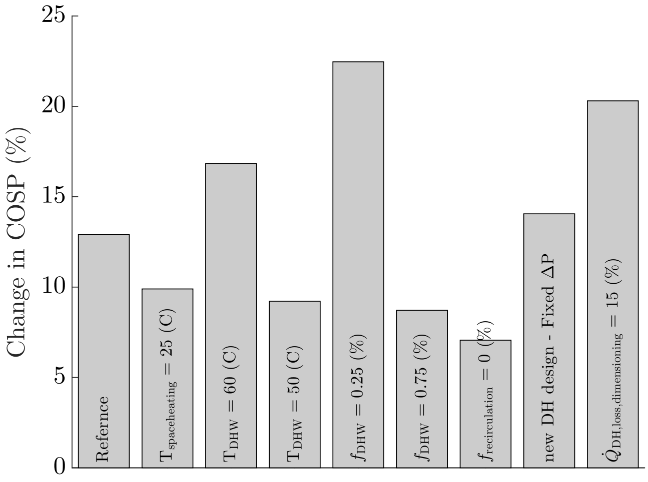


ULTDH, heat supplied by HP, influence of various assumptions



ULTDH optimum compared to LTDH, influence of various assumptions

Performance increase between ULTDH optimum and LTDH optimum



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Summary of findings

- In networks supplied by CHP-plants, the use of ULTDH and booster HPs decreases COSP significantly, compared to LTDH.
  - Heat from CHP-plant, no additional heat sources utilized.
  - COP of booster HPs lower than corresponding performance change for the CHP-plant.
  - For CHP-plants designed for ULTDH, the performance gain of CHP-plant over HP would further increase.
- For heat supply by central HPs, a performance increase of 7-23 % (12 % in reference conditions) is possible for ULTDH compared to LTDH.
  - Heat from central HP, no additional heat sources utilized.
  - COP of booster HPs similar than corresponding performance change for the central HP, but utilisation only for part of the demand.
- From a system perspective, COSP may be optimized by setpoints of booster HPs corresponding to a minimal total electricity consumption. For end-users economic optimum may be opposite.

Thank you for your attention

- If questions, new ideas or interest in collaboration: tsom@mek.dtu.dk

References I

Elmegaard, B., Ommen, T., Markussen, M., and Iversen, J. (2016). Integration of space heating and hot water supply in low temperature district heating. *Energy and Buildings*, 124:255–264.

Ommen, T., Markussen, W., and Elmegaard, B. (2016). Lowering district heating temperatures – impact to system performance in current and future danish energy scenarios. *Energy*, 94:273–291.

Østergaard, P. A. and Andersen, A. N. (2016). Booster heat pumps and central heat pumps in district heating. *Applied Energy*, pages –.