Demand-side management for reducing peak-heating costs in a local low-temperature district-heating grid with waste-heat utilization

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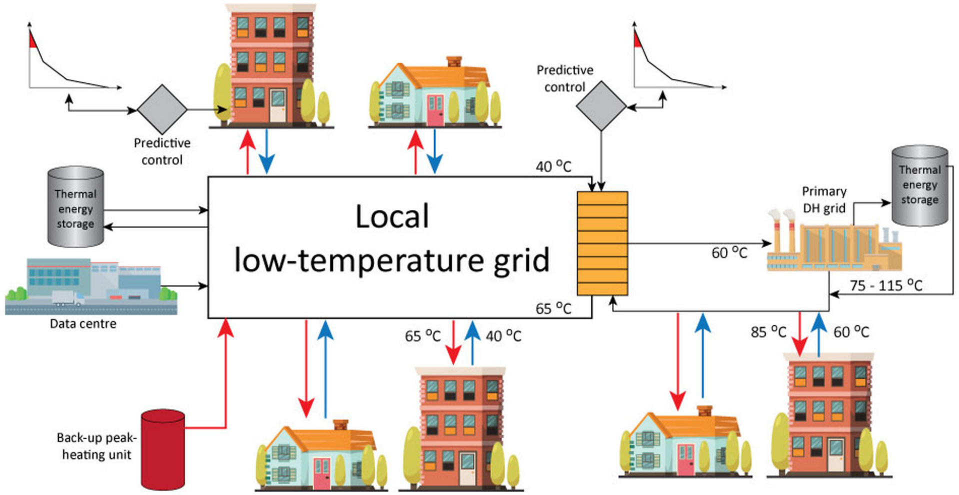

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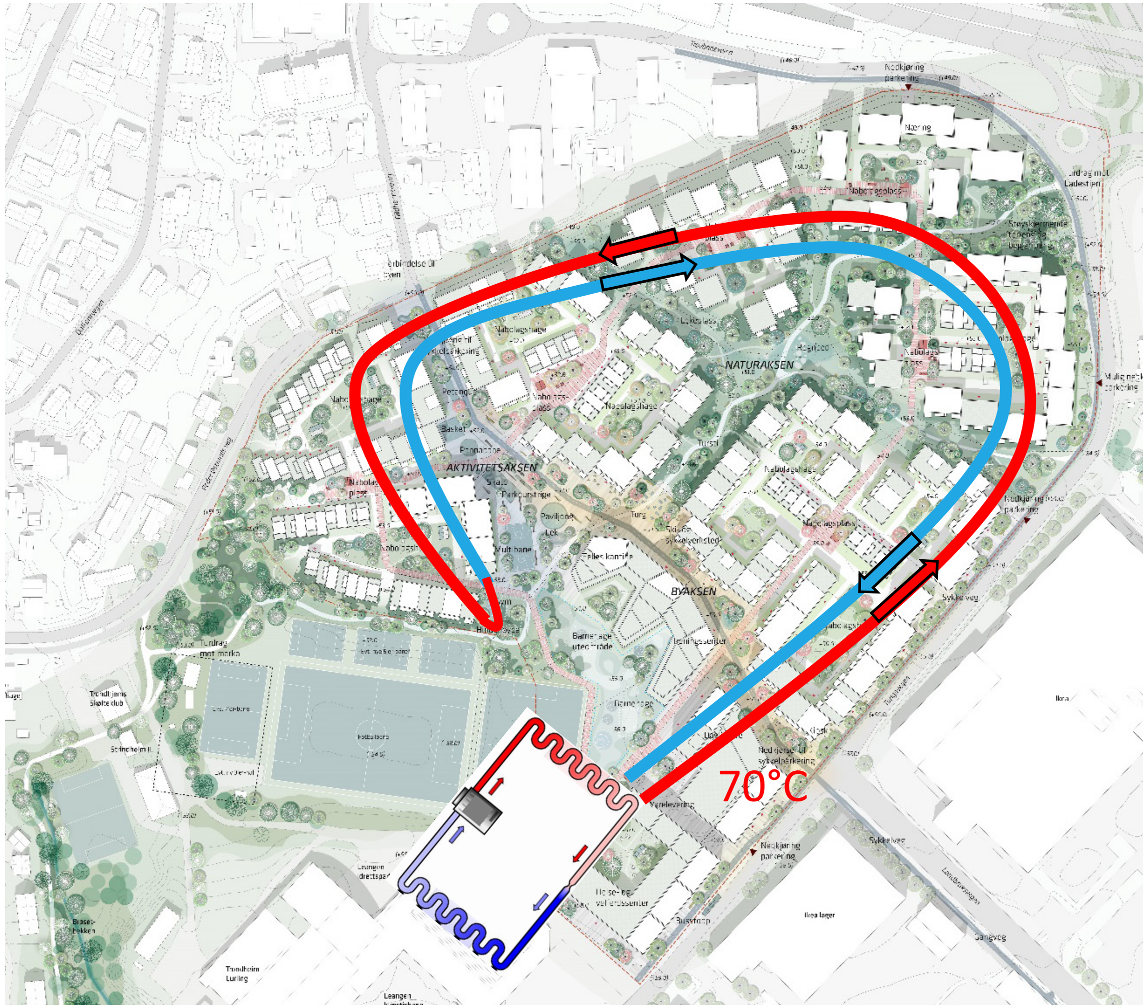
Case description: New building area in Trondheim, Norway

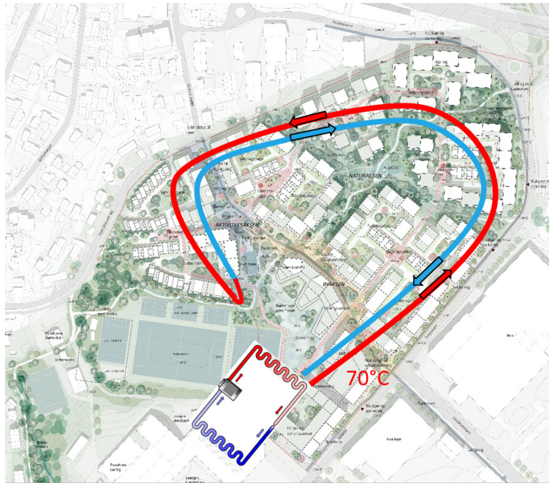
- New building area under development in Trondheim, Norway:
  - 139 000 m^2 BRA apartment buildings.
  - 42 000 m^2 BRA other buildings (office, commercial, school ++)
- Waste heat available from a nearby ice skating rink.
- A low/medium-temperature thermal grid (LTTG) is planned with either 40°C or **70°C** distribution temperature[1].



[1] Kauko et al., 2020. Local heating networks with waste heat utilization: Low or medium temperature supply? *Energies*, 13(4): 954;

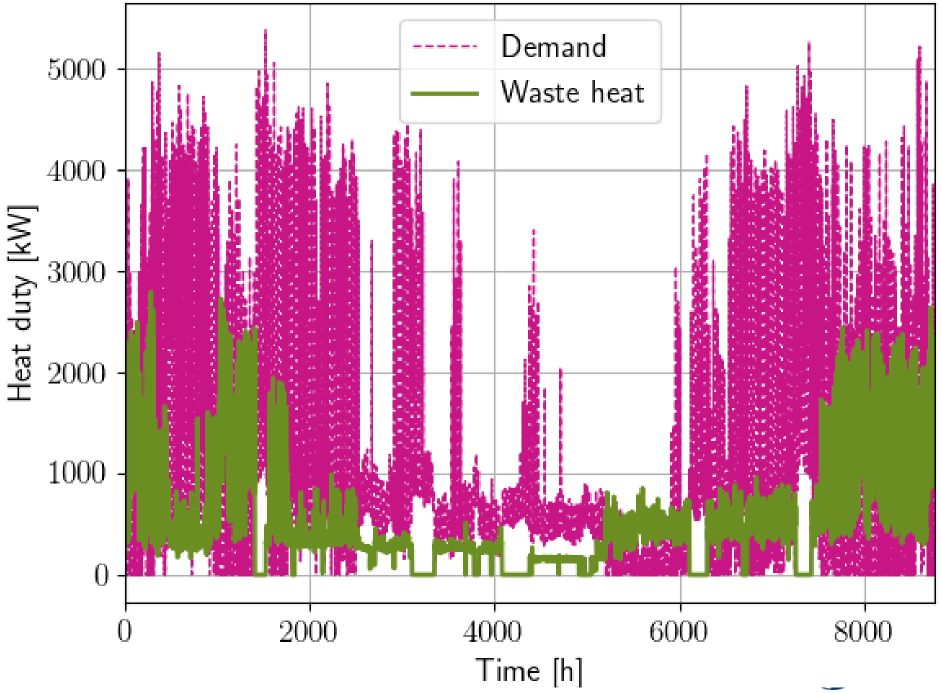
Problem description

- Utilize local waste heat source; **Large daily and seasonal variations.**
- Remaining heat demand will be covered by the primary (conventional) DH network.



Challenge:

How does a new, connecting LTTG with local waste-heat utilization affect heat production in primary DH network, the production mix and heat-provision costs?



Methodology - concept

Considered control policies for residential building block:

1. Constant temperature 22°C in buildings.
2. Minimum energy use.
3. Load shift – demand side management (**DSM**) of space heating by means of **price signal from DH operator.**

Demand for hot water and space heating for non-residential buildings are given.

Demand-side mangament: numerical approach

DH operator: Solve **economic dispatch** problem:

$$\min \sum_{k\in\mathcal{K}} c_{jk} Q_{jk}^{\text{source}} \Delta_k$$

Demand constraint

$$\text{s.t.} \quad Q_k^{\text{WH}} + \sum_{j\in\mathcal{J}} Q_{jk}^{\text{source}} = \hat{Q}_k^{\text{SH-DSM}} + \hat{Q}_k^{\text{SH-fixed}} + \hat{Q}_k^{\text{DWH}}, \quad k \in \mathcal{K},$$

$$0 \le Q_{jk}^{\text{source}} \le \bar{Q}_{jk}^{\text{source}}, \quad k \in \mathcal{K}, j \in \mathcal{J},$$

$$0 \le Q_{jk+1}^{\text{source}} - Q_{jk}^{\text{source}} \le R_{jk}^{\text{source}}, \quad k \in \mathcal{K} \setminus K, j \in \mathcal{J}$$

Buildings: MPC-based optimization of energy use for space heating in buildings:

$$\min\left[\sum_{k=1}^{N_c} (c_k^{var} u_k + \rho\delta_k)\,\Delta t\right]$$

$$s.t. \quad x_{k+1} = Ax_k + Bu_k + Ed_k$$

RC building model

$$y_k = Cx_k$$

$$\underline{y}_k - \delta_k \le y_k \le \overline{y}_k + \delta_k$$

Comfort constraints

$$\underline{u}_k \le u_k \le \overline{u}_k$$

$$\delta_k \ge 0$$

Price signal for DSM**: dual variables of demand constraints** (i.e. DH operator marginal cost) + **fixed base price**.

Evaluation procedure

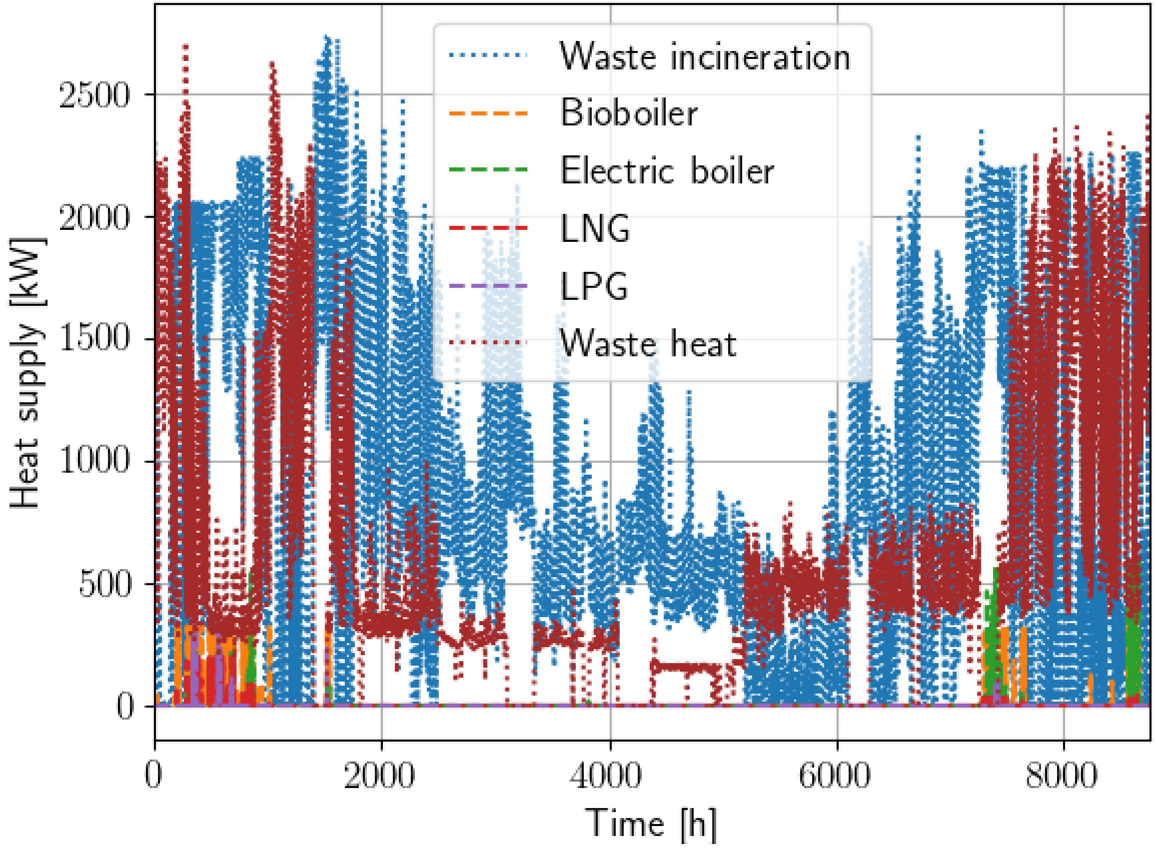
Use waste heat, energy prices, temperature, and demand data for one year (2019).

Compare two scenarios:

i. Remaining heat demand covered by given heat-production mix of primary DH network.

ii. Remaining heat covered by electric boiler only.

Evaluate heat-production costs, energy consumption and max peak heating.



Primary DH production mix and local waste heat availability

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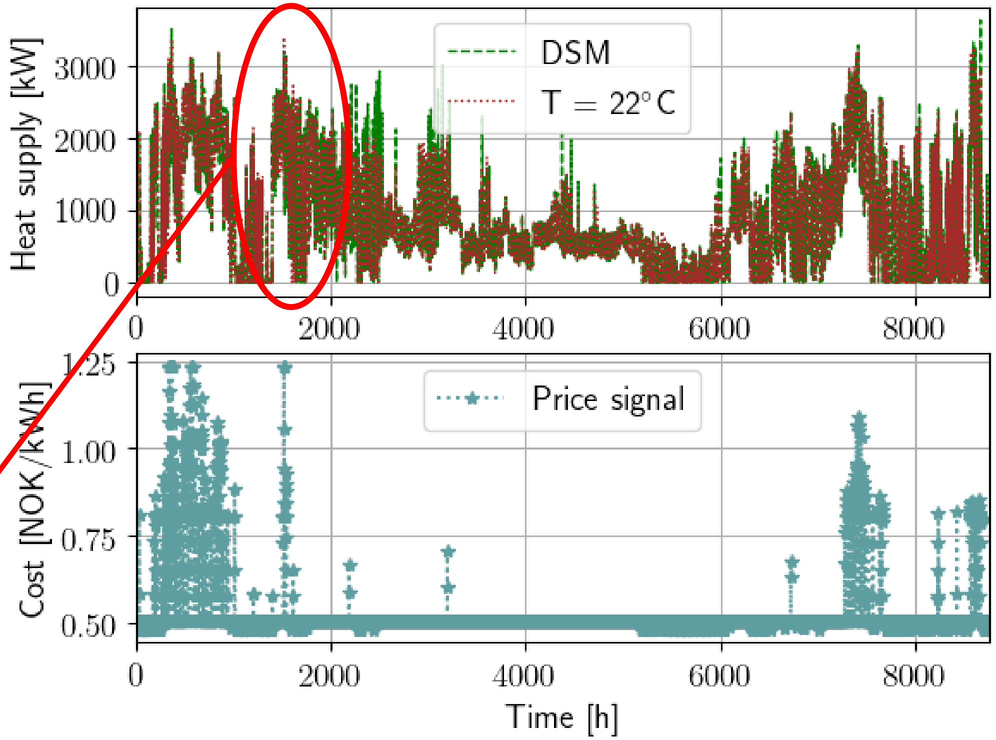
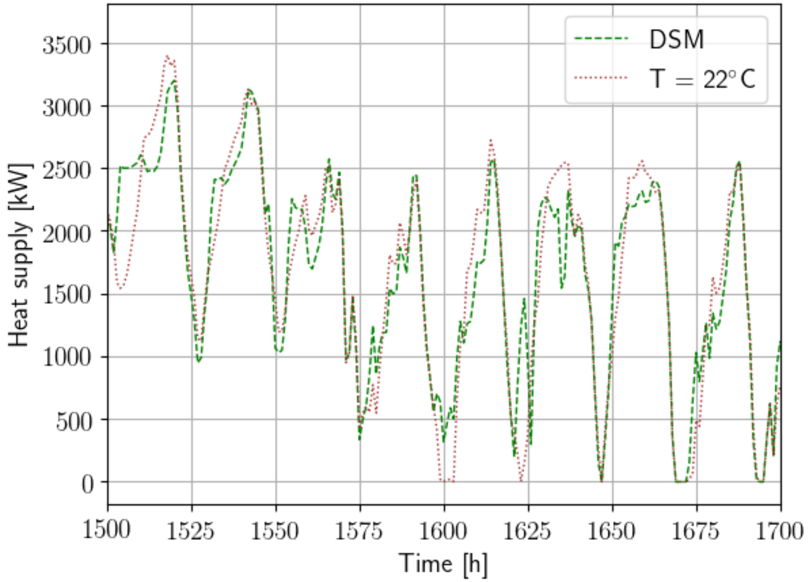
Results: Waste heat + given generation mix of primary DH network

Control policy	Building energy use (MWh)	Max peak (MW)	Variable DH operator costs (NOK)	Cost relative to T=22°C [%]
Constant T=22°C	7702	3.4	231443	-
Minimum energy	7324	4.2	211670	**-8.5**
DSM	7592	3.6	223441	**-3.5**





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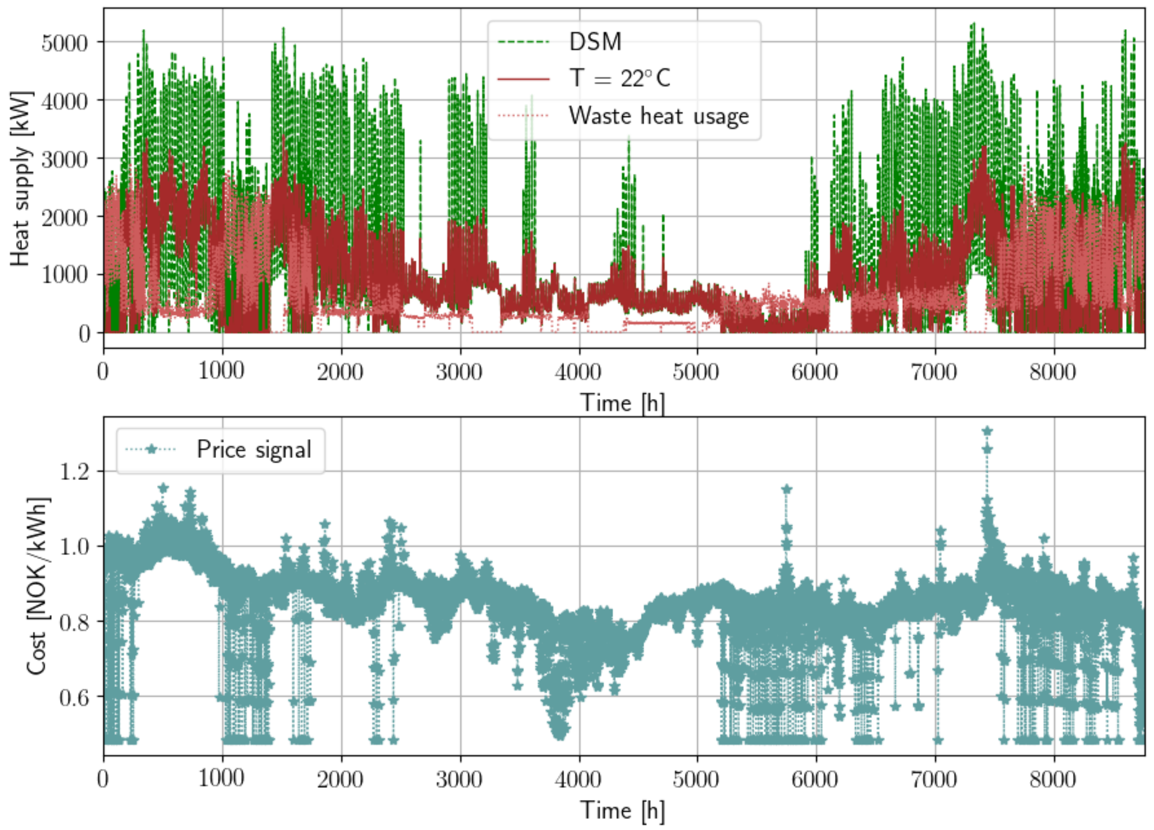
Results: Waste heat + electric boiler only

Control policy	Building energy use (MWh)	Max peak (MW)	Variable DH operator costs (NOK)	Cost relative to T=22°C [%]
Constant T=22°C	7702	3.4	3073643	-
Minimum energy	7324	4.2	2906330	-5.44
DSM	7582	5.3	3083597	0.32



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Conclusions

- DSM shifts time of heating consumption: **price signal must be carefully designed to achieve desired effect.**
- The effect of building load shifting in LTTGs on DH costs depends highly on the prevailing production composition and connection to grid.
- In practice: **must include feedback to DH operator** for updating price signal (future work).

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