LOCAL THERMAL GRIDS WITH WASTE HEAT UTILIZATION: LOW- OR MEDIUM-TEMPERATURE SUPPLY?

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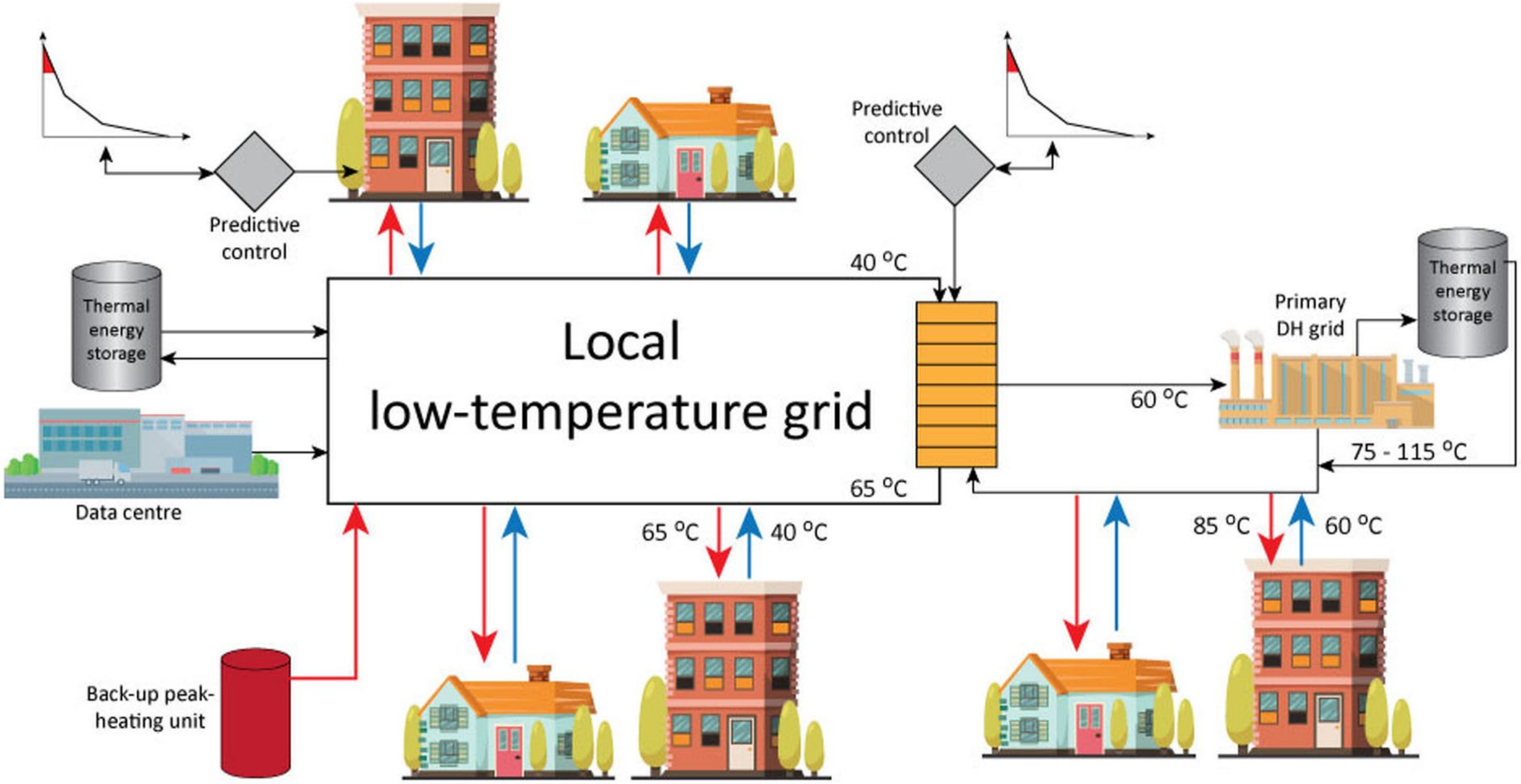
LTTG+ – Low-Temperature Thermal Grids with surPlus heat utilization

- Duration: 2018-2020
- Budget: 6.25 MNOK
  - 80% from the Research Council of Norway
- Partners:
  - Statkraft Varme AS
  - Fortum Oslo Varme AS
  - Trondheim Municipality
  - Gjøvik Municipality
  - Koteng Eiendom AS



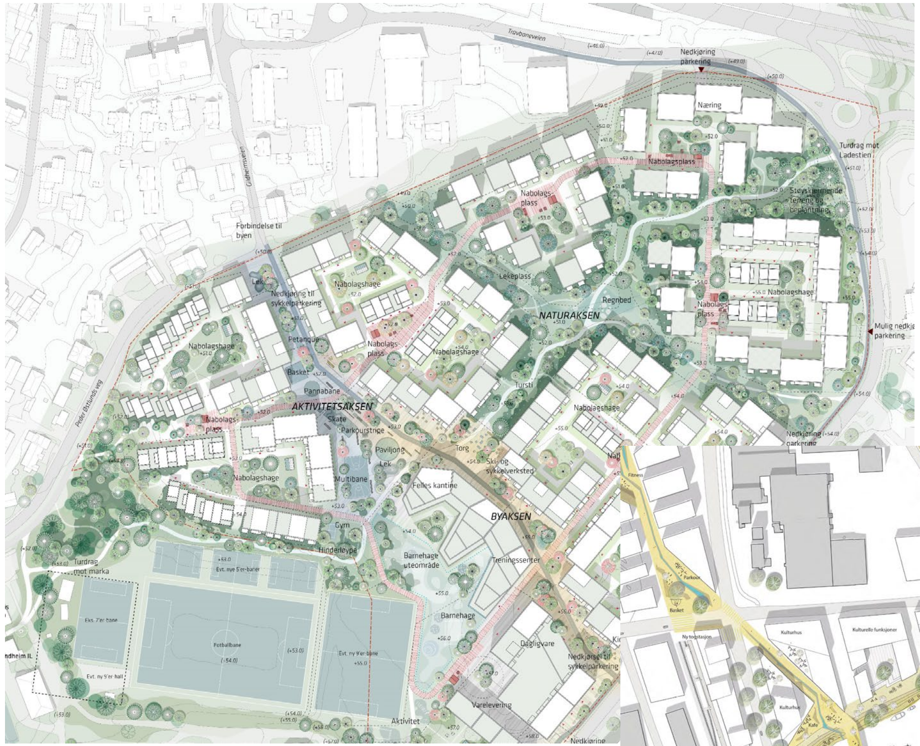
3 case study areas:

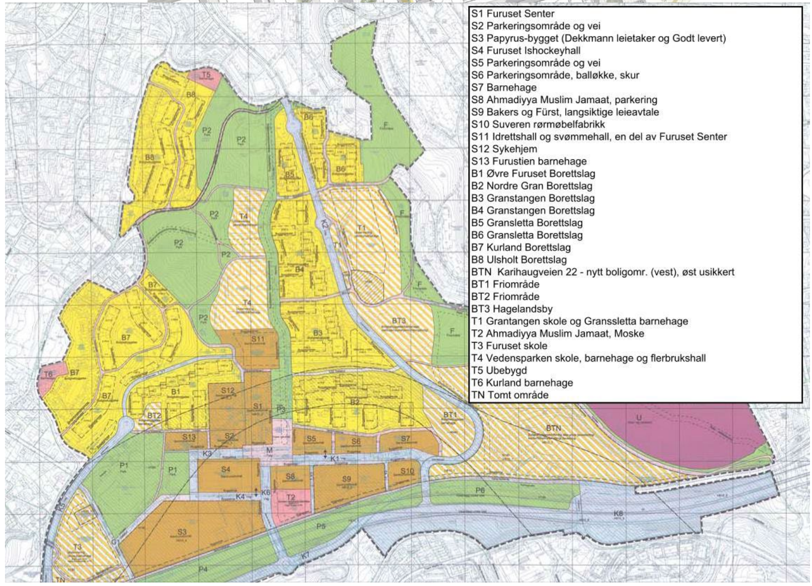
New building areas in 3 Norwegian cities

- Trondheim – Leangen
  - Waste heat from an indoor ice rink

- Gjøvik – Huntonstranda
  - Waste heat available from a potato processing factory

- Oslo – Furuset
  - High-temperature seasonal storage in boreholes
  - Charging over the summer with excess heat from the DH grid (municipal waste combustion)

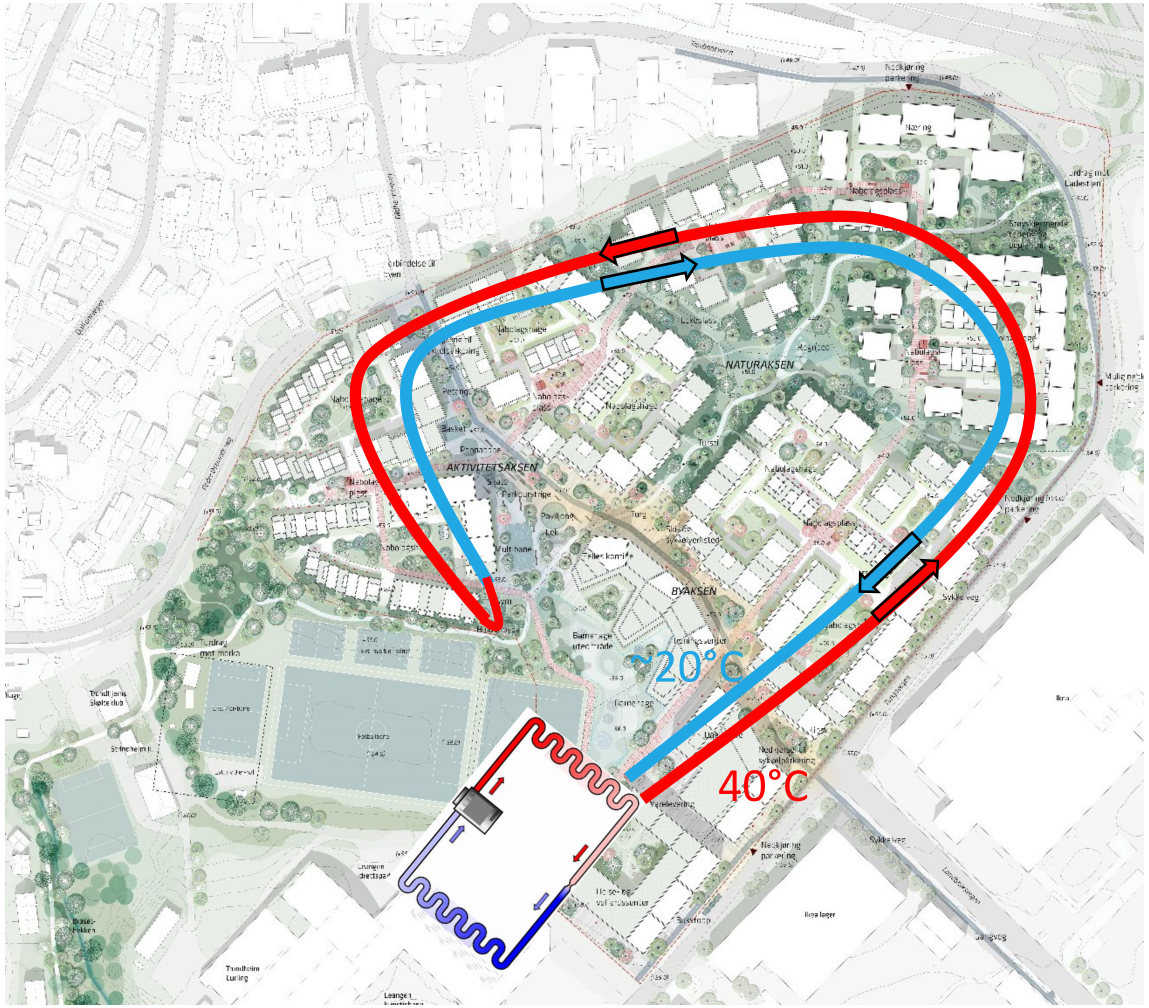


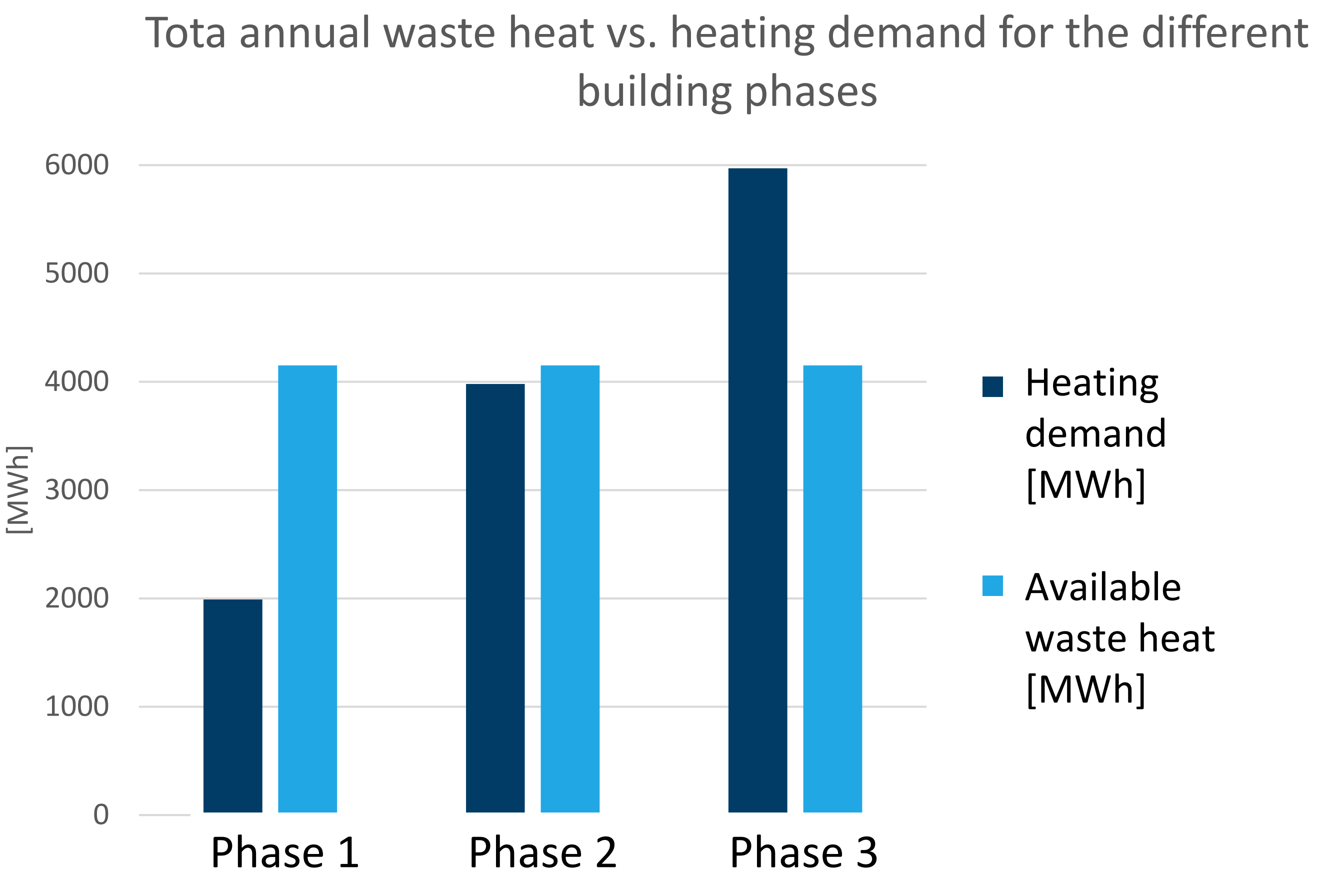


Case Leangen

Building type	BRA [m²]
Apartment	139 300
Nursing home	12 000
Nursery	2 000
School	4 000
Office	10 000
Commercial	7 000
Sports	7 000
Tot	**181 300**

Case Leangen





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Problem description

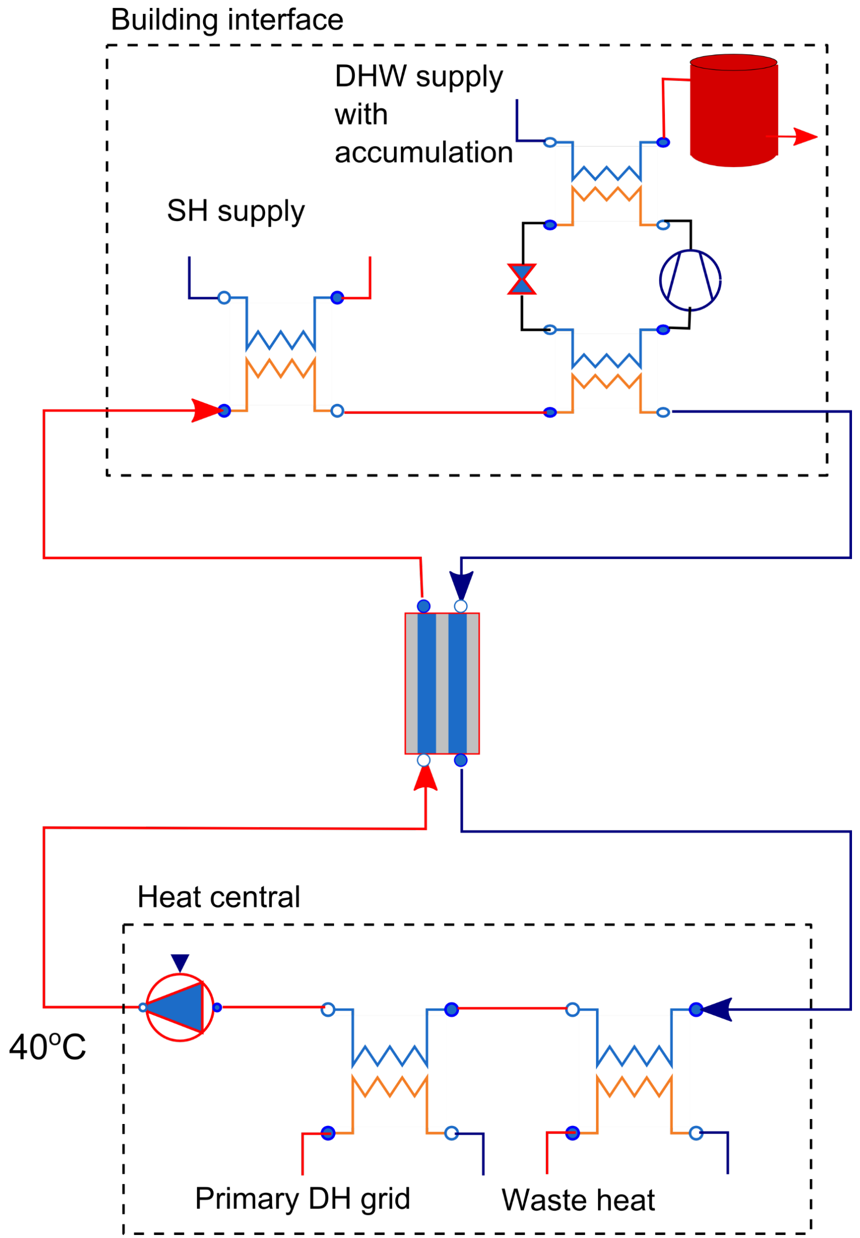
Low vs. medium temperature distribution?

- Low-temperature distribution: T_{supply} ~ 40°C
  - Waste heat from ice rink can be utilized directly
  - Low heat losses
  - Local CO_2 heat pumps needed for domestic hot water (DHW) production

- Medium temperature distribution: T_{supply} ~ 70°C
  - The local heating grid can cover the entire heating demand (space heating + DHW)
  - Centralized NH_3 heat pump to increase the temprature of the waste heat to the required level

Problem description

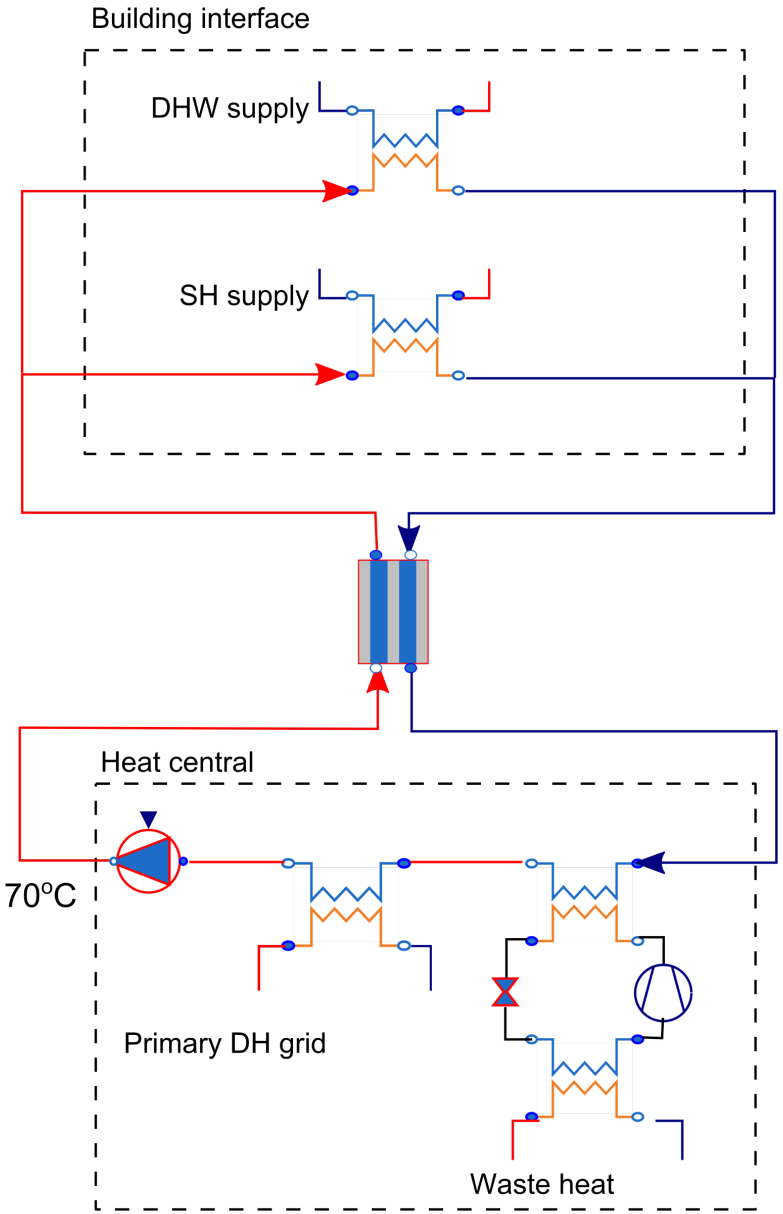
Case 40



- Heat central
  - Exchanges heat directly with the waste heat source
  - Supplementary heat from the primary DH grid
- Building substation
  - Space heating heat exchanger supplying heat to a floor heating loop at 35°C
  - CO_2 heat pump
    - DHW setpoint 85°C due to accumulation
    - Dimensioned to produce 1.5 m^3 hot water at a constant mass flow rate for a building block of 1400m^2 / 20 apartments

Problem description

Case 70



- Heat central
  - NH_3 heat pump to lift the temperature of the waste heat source
  - Supplementary heat from the primary DH grid
- Building substation
  - Regular substation with parallel heat exchangers towards space heating and DHW production
  - DHW setpoint 65°C (no accumulation)
  - Space heating setpoint 35°C

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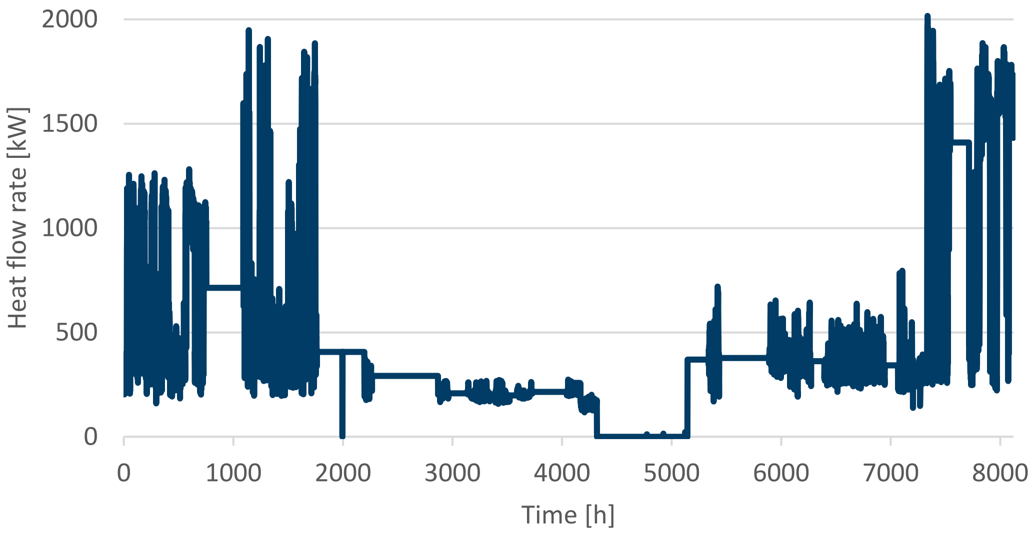
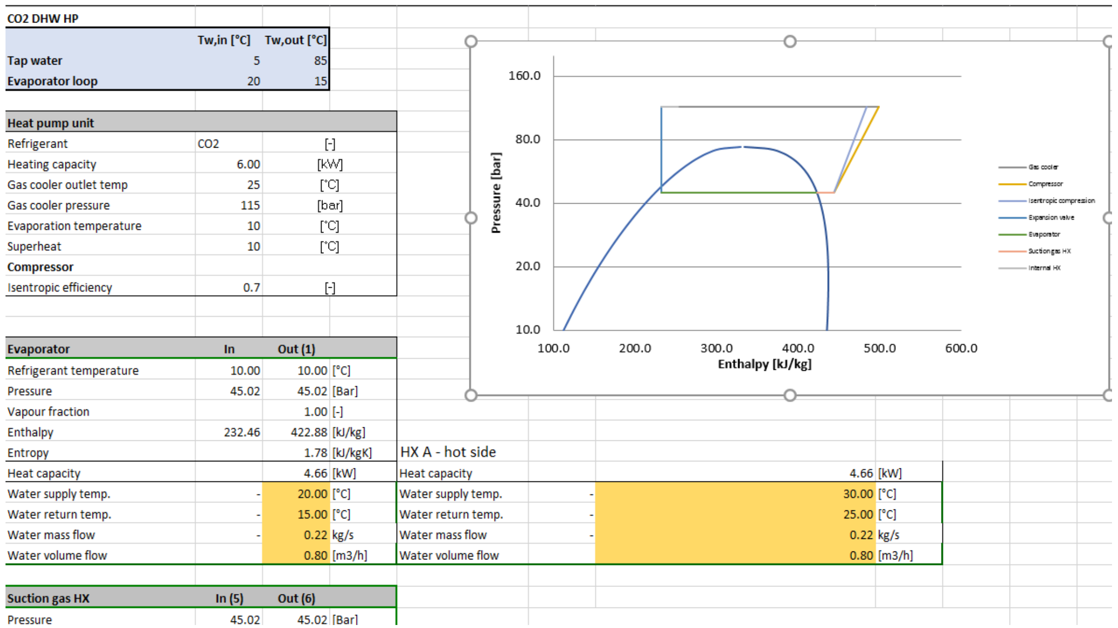
Methodology

- Aggerageted load profile obtained using a load profile generator developed in SINTEF Community/FME ZEN[1]
- Data for waste heat obtained from the ice rink operator
- Steady-state heat pump models in Excel to verify modeling results





CO2 DHW HP

	Tw,in [°C]	Tw,out [°C]
Tap water	5	85
Evaporator loop	20	15

Heat pump unit		
Refrigerant	CO2	[-]
Heating capacity	6.00	[kW]
Gas cooler outlet temp	25	[°C]
Gas cooler pressure	115	[bar]
Evaporation temperature	10	[°C]
Superheat	10	[°C]
Compressor		
Isentropic efficiency	0.7	[-]

Evaporator	**In**	**Out (1)**	
Refrigerant temperature	10.00	10.00	[°C]
Pressure	45.02	45.02	[Bar]
Vapour fraction		1.00	[-]
Enthalpy	232.46	422.88	[kJ/kg]
Entropy		1.78	[kJ/kgK]
Heat capacity		4.66	[kW]
Water supply temp.	-	20.00	[°C]
Water return temp.	-	15.00	[°C]
Water mass flow	-	0.22	kg/s
Water volume flow		0.80	[m3/h]

HX A - hot side

Heat capacity		4.66	[kW]
Water supply temp.	-	30.00	[°C]
Water return temp.	-	25.00	[°C]
Water mass flow	-	0.22	kg/s
Water volume flow		0.80	[m3/h]

Suction gas HX	**In (5)**	**Out (6)**	
Pressure	45.02	45.02	[Bar]

[1] Lindberg et al., 2019. Modelling electric and heat load profiles of non-residential buildings for use in long-term aggregate load forecasts. Journal of Utilities Policy, Vol. 28, pp. 63-88, 2019.

Methodology

Modelling with Modelica/Dymola

- Component models for thermal grid modeling from a house-made library built in previous projects[2,3]
- Heat pump model[3]
  - Based on the theoretical Lorentz cycle
  - Lorentz COP (COP_L) calculated from both inlet and outlet temperatures on the secondary sides

$$COP_L = \frac{T_{L\_evap}}{T_{L\_cond} - T_{L\_evap}} \qquad T_{L\_cond/evap} = \frac{T_{in\_sec\_cond/evap} - T_{out\_sec\_cond/evap}}{\ln\left(\frac{T_{in\_sec\_cond/evap}}{T_{out\_sec\_cond/evap}}\right)}$$

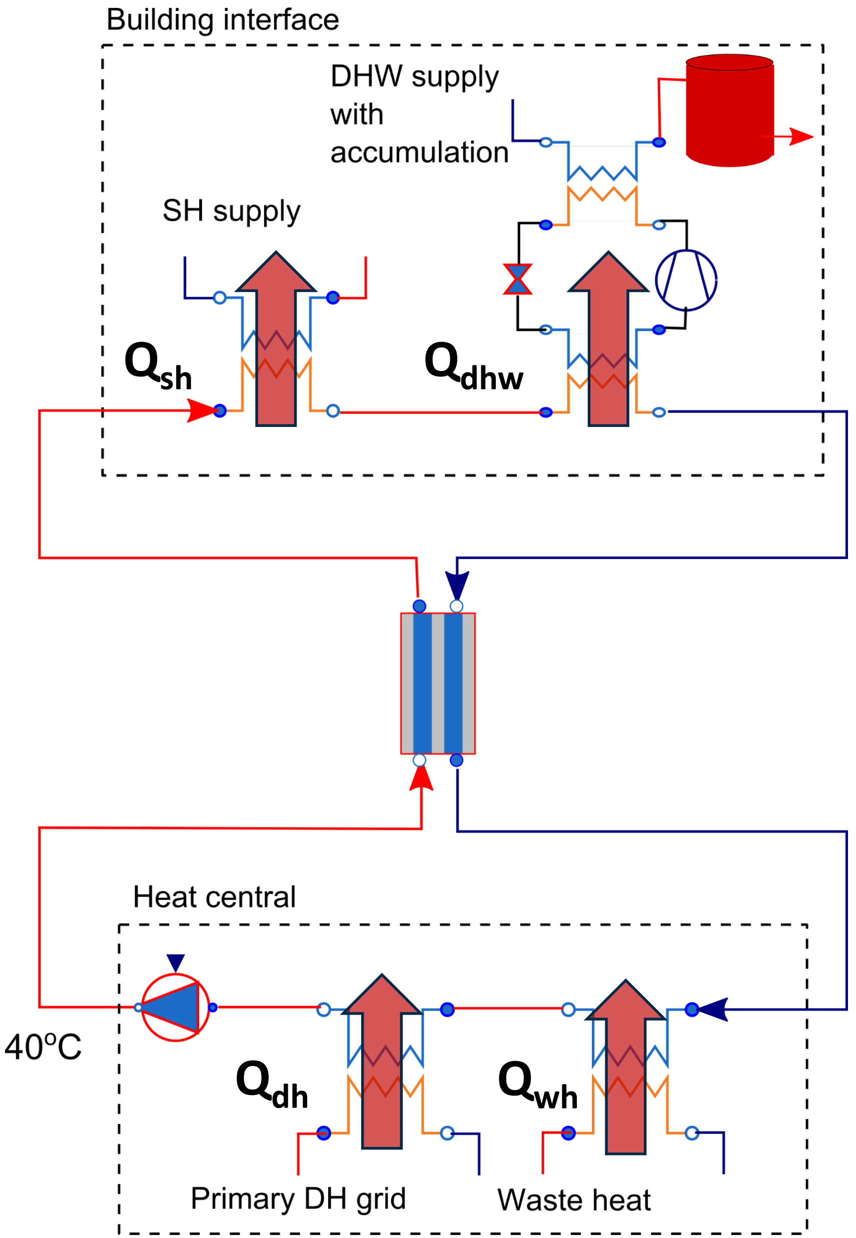
  - Heat pump COP calculated using a Lorentz efficiency of 0.15

$$COP_{HP} = COP_L \cdot \eta_L$$

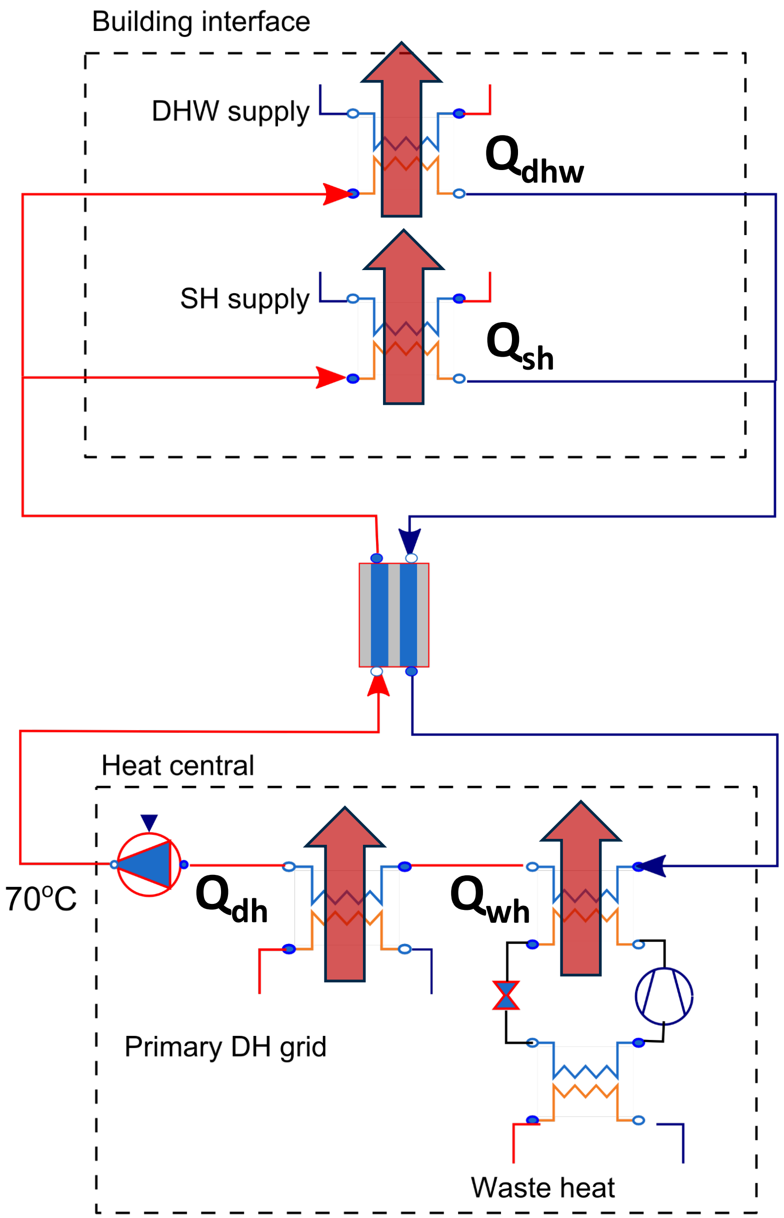
[2] Kauko, H., Kvalsvik, K. H., Rohde, D., Nord, N., & Utne, Å. (2018). Dynamic modeling of local district heating grids with prosumers: A case study for Norway. *Energy*, *151*, 261-271.
[3] Rohde, D., Andresen, T., & Nord, N. (2018). Analysis of an integrated heating and cooling system for a building complex with focus on long–term thermal storage. *Applied Thermal Engineering*, *145*, 791-803.

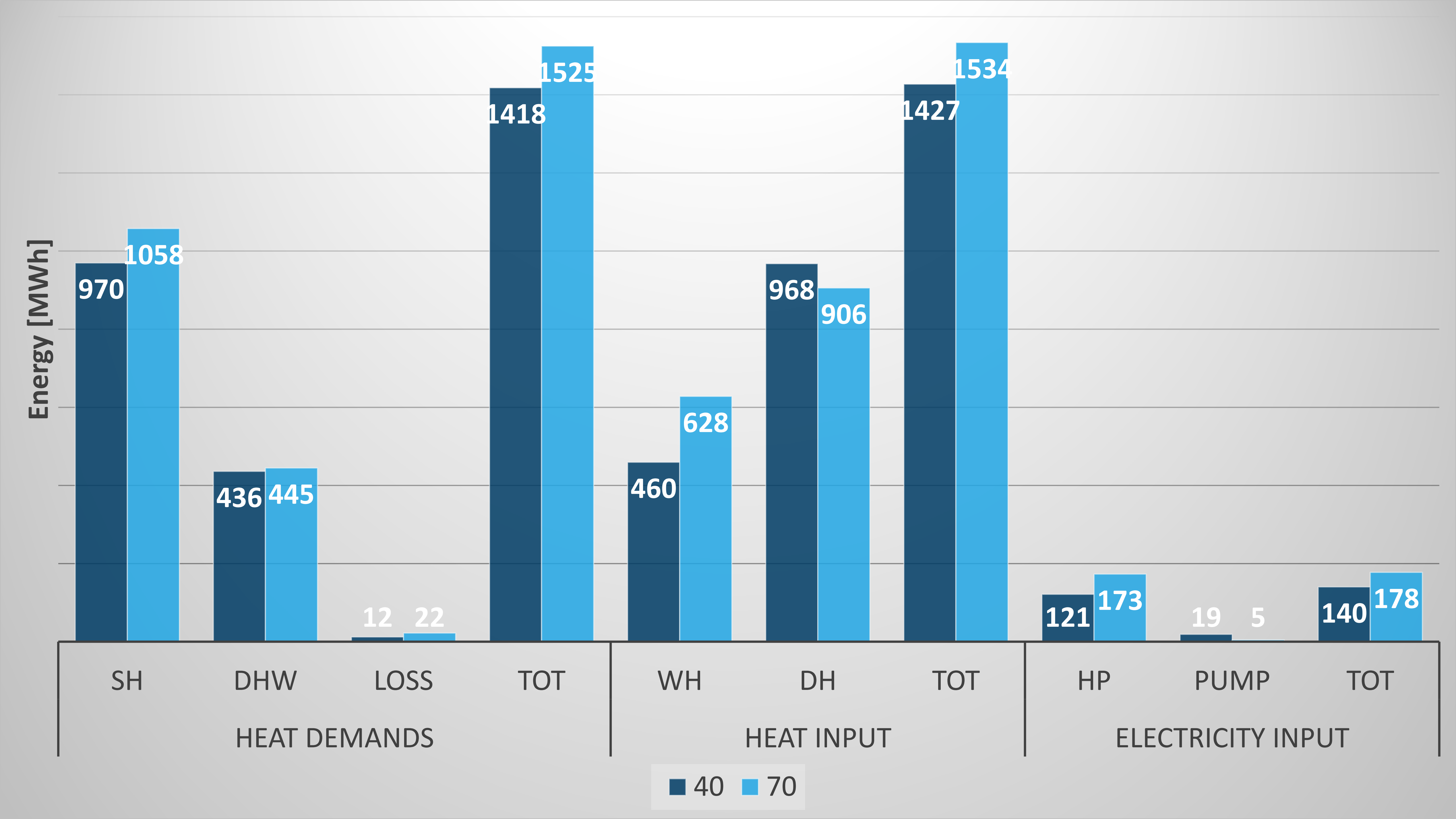
Results – heat inputs and outputs

Case 40

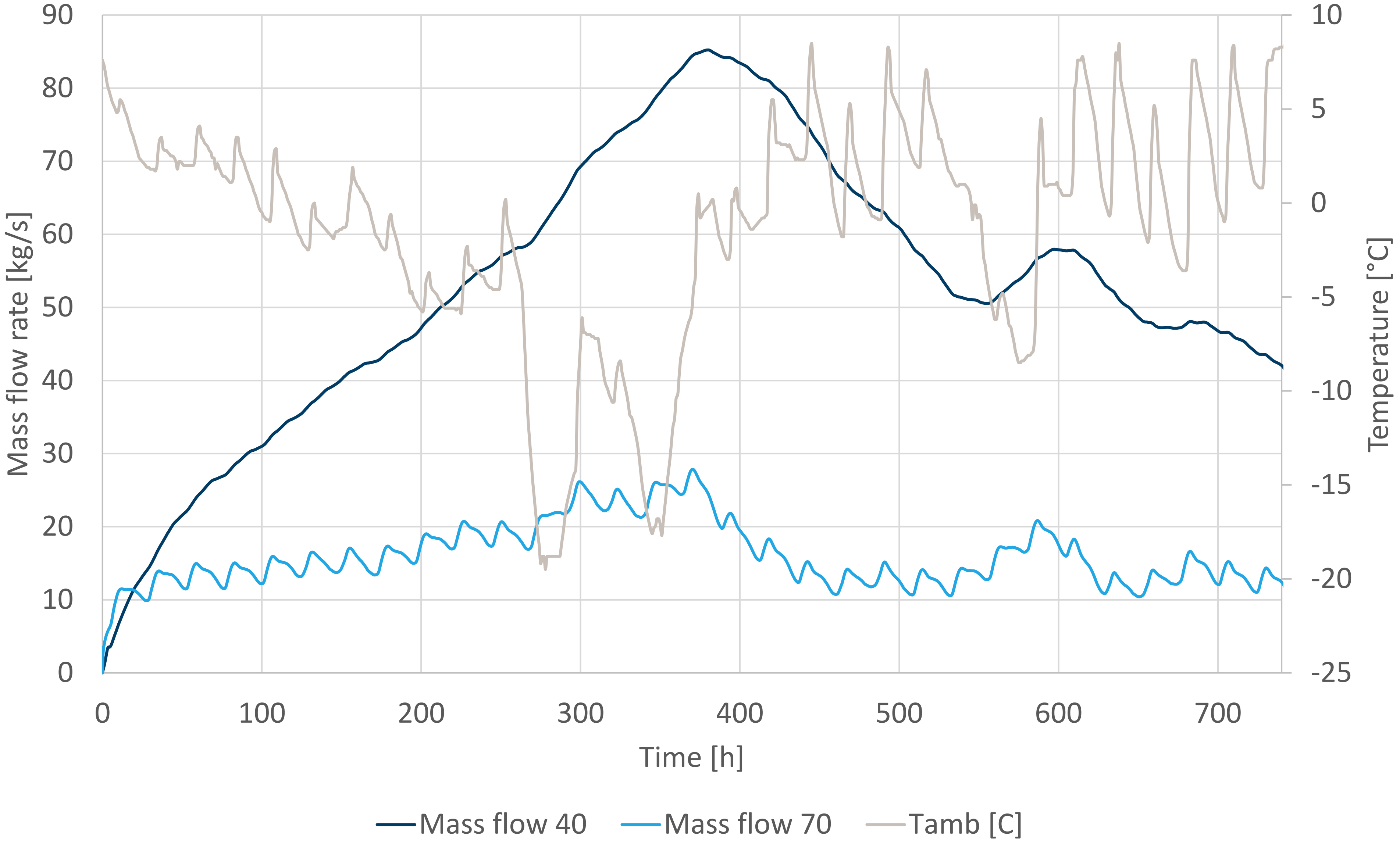


Case 70




Energy [MWh]
970
1058
436
445
12
22
1418
1525
460
628
968
906
1427
1534
121
173
19
5
140
178
SH
DHW
LOSS
TOT
WH
DH
TOT
HP
PUMP
TOT
HEAT DEMANDS
HEAT INPUT
ELECTRICITY INPUT
40
70

Mass flow



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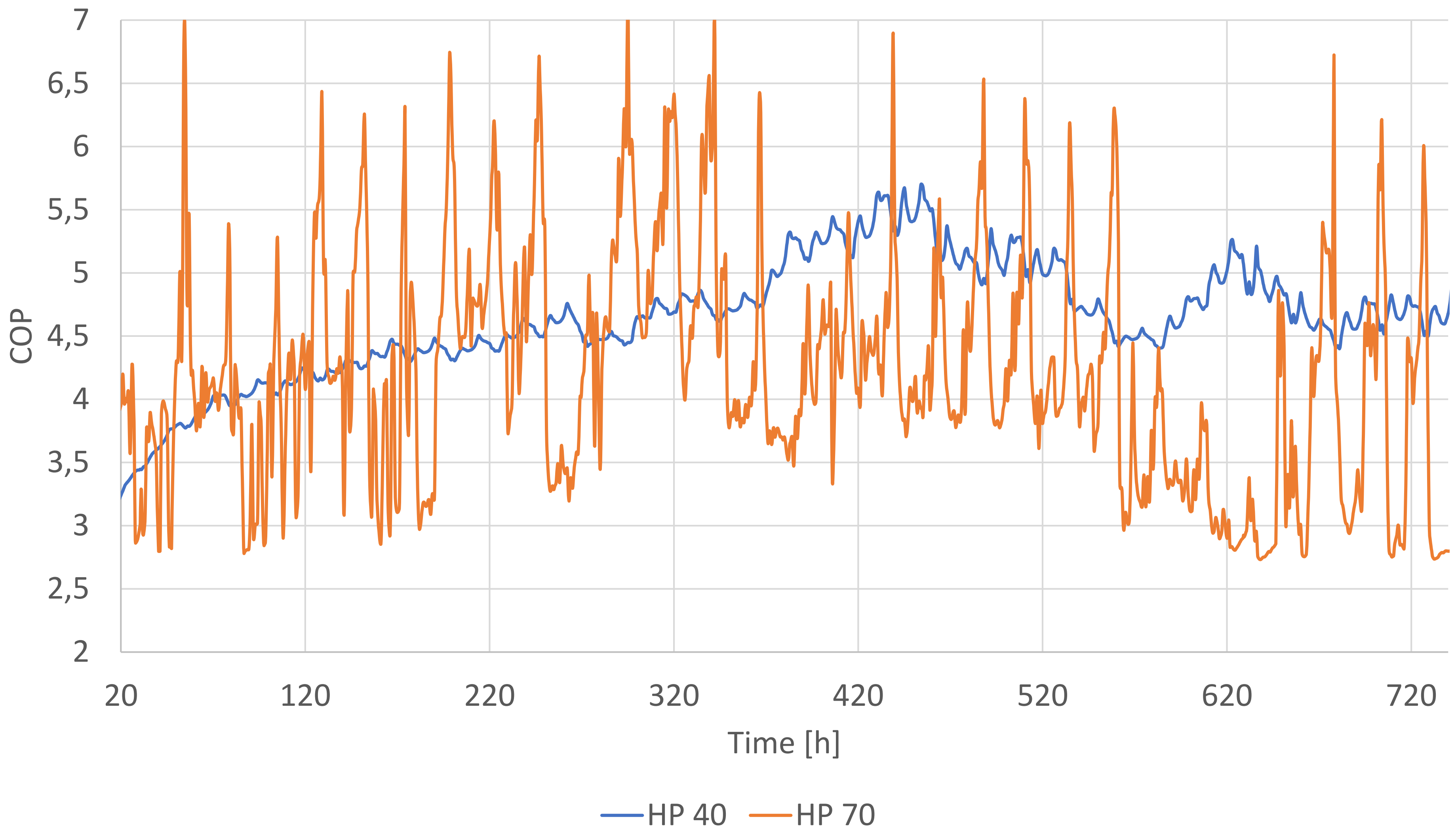
Heat pump COP



Conclusions

Collaboration between DH suppliers, real estate companies and municipalities + getting involved early in the planning process

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Conclusions

	Pros	Cons
40-decentralized	• Lower power demand • Lower heat losses • Low exergy losses in space heating • Easier to combine with cooling production	• More complex operation and maintenance → Need skilled staff • High costs: 25-30 k€ per unit • Higher DH demand
70-centralized	• Simpler O&M • Lower costs	• Higher power demand • High exergy losses in space heating • Higher heat losses

Future work

- More detailed modeling of the network
- Modeling and optimization of the DHW accumulation with respect to electricity prices?
- Studying the potential for thermal storage at the heat central to improve the utilization of waste heat
- Including the utilization of grey water

Thank you.

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The Research Council of Norway

Statkraft

Koteng

fortum

GJØVIK KOMMUNE

TRONDHEIM KOMMUNE