Assessment of Borehole Sizing and Integration with District Heating: A Case Study in Trondheim, Norway

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TRAINING

Thermal energy storing and digitalization in district heating to enable transition to renewable and resource efficient energy systems

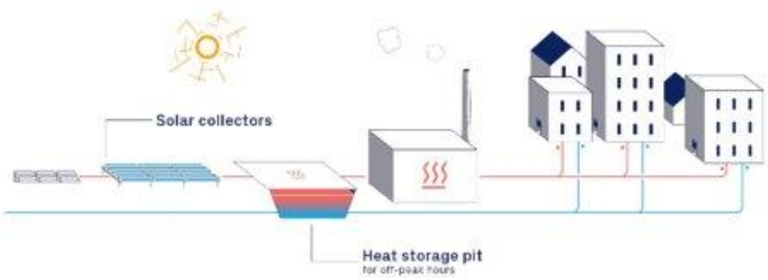
Trondheim, Norway

NTNU

Asplan Viak

Norsk energi

Härnösand, Sweden



Högskolan Dalarna

Utilifeed

Absolicon Solar Collector AB

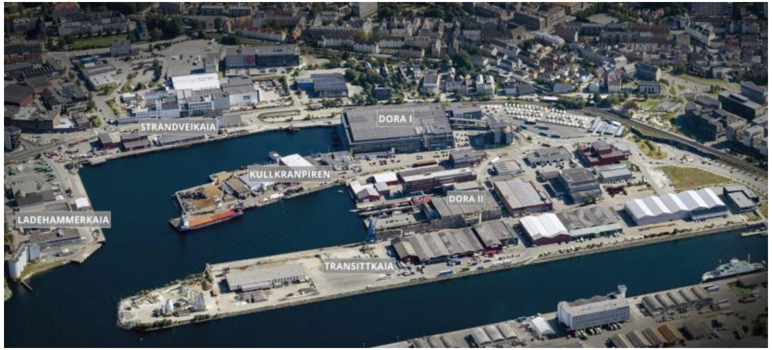
Kassel, Germany

smart!place SmartrPlace

Fraunhofer Institute for Energy Economics

Case Description

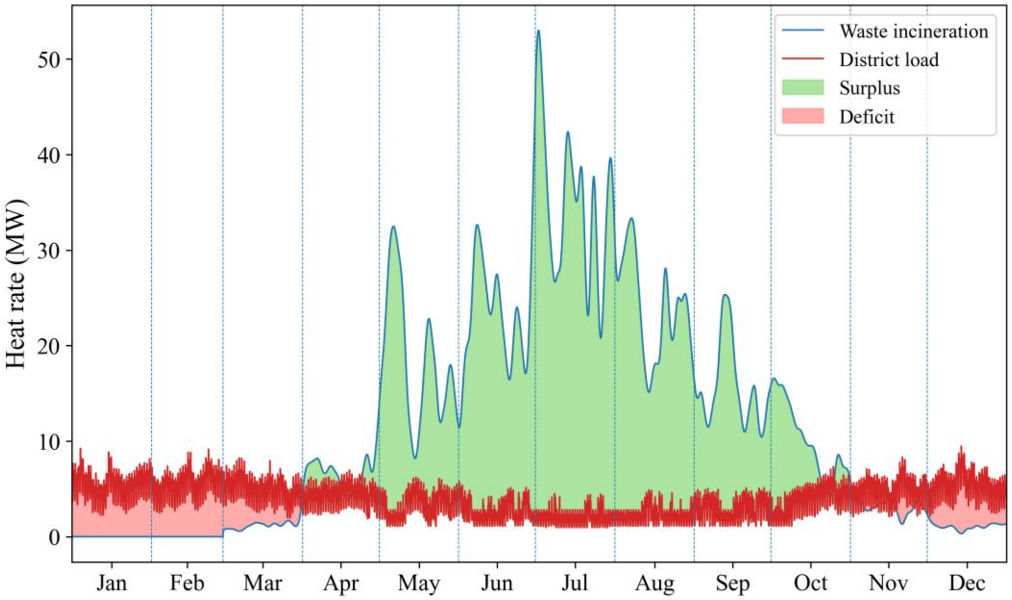
- Transition from industrial zone to a vibrant city-center district
- Comprises 10 distinct sub-areas
- Total built-up area exceeds 450,000 m²
- 60 % residential and 40 % commercial
- Accommodates 5,200 residents and 4,000 jobs
- Fully self-sufficient in heating and electricity, without adding demand to existing networks



- Photos from nyhavna.no

Heat Demand and Supply

- Estimated 34 GWh/ year energy demand for space heating and domestic hot water
- 120 GWh/ year surplus waste heat from the waste incineration plant
- Potential for seasonal thermal energy storage



- District load provided by Sintef AS using PROFet model

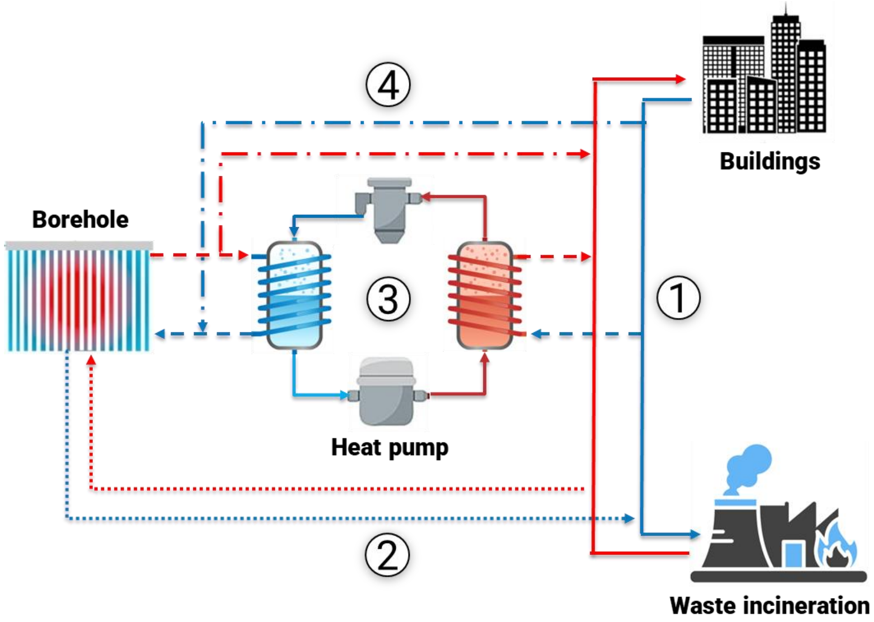
Local District Heating Network

① Heat demand direct supply by surplus heat

② Borehole charging by surplus heat

③ Borehole discharging by ground-source heat pump

④ Heat demand direct supply by high-temperature borehole discharge



BTES Model

- Long-term g-function:

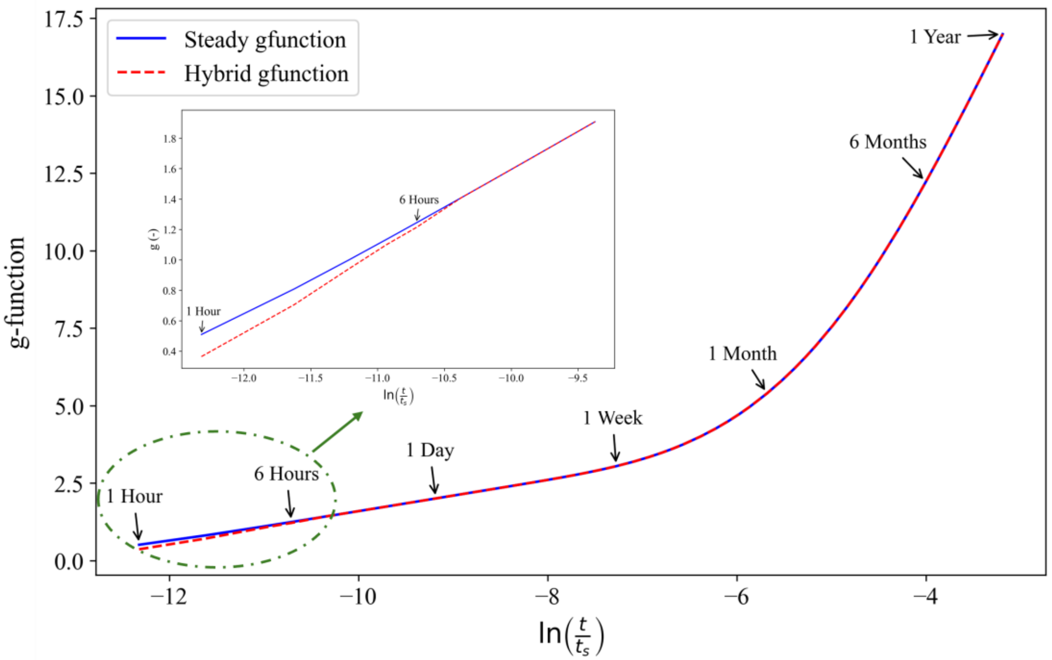
$$T_{BH,w}(t) = T_g - \frac{\dot{q}_{BH}}{2\pi k_s} . g(t/t_s),\ t \geq \frac{5r_b^2}{\alpha_s}$$

- Heat transfer fluid energy balance:

$$\dot{m}c_p \frac{dT_{1,i}}{dz} = \frac{T_{b,i} - T_{1,i}}{R_{w,i}} + \frac{T_{2,i} - T_{1,i}}{R_{12,i}}$$

$$\dot{m}c_p \frac{dT_{2,i}}{dz} = \frac{T_{b,i} - T_{2,i}}{R_{w,i}} + \frac{T_{1,i} - T_{2,i}}{R_{12,i}}$$

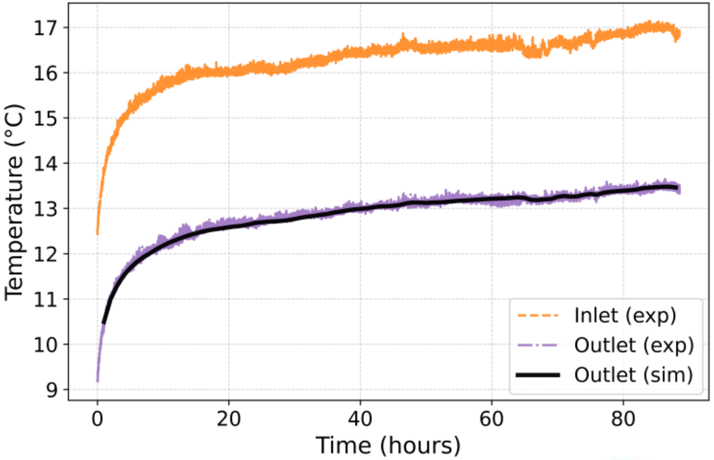
$$\dot{q}_{BH} = \frac{\dot{m}c_p}{L}\left(T_{1,0} - T_{2,0}\right)$$

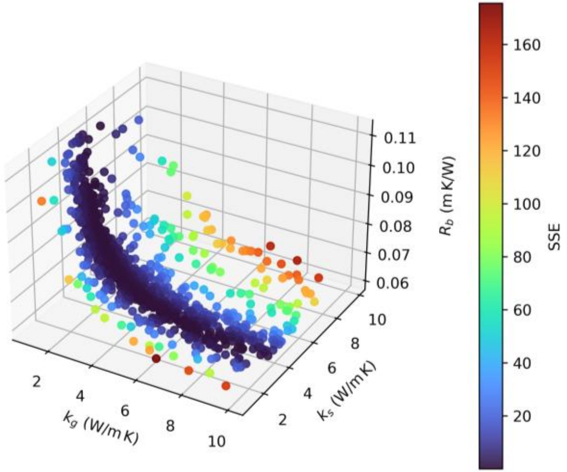


Parameter Estimation

$$\min_{k_g, k_s} SSE = \sum_{i=1}^{N} \left(T_{\mathrm{BH,out},i}^{\mathrm{sim}} - T_{\mathrm{BH,out},i}^{\mathrm{exp}} \right)^2$$

k_g	$2.15\ W/m\,K$
k_s	$3.92\ W/m\,K$
R_b	$0.082\ m\,K/W$
SSE	6.117×10^{-2}

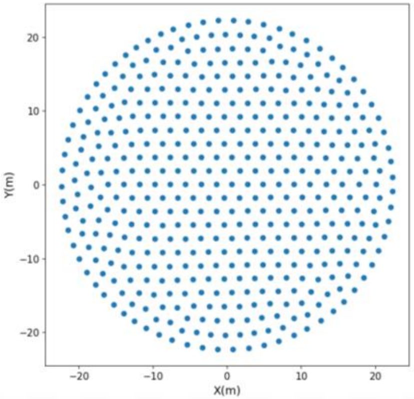




Simulation Model

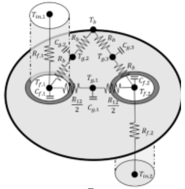
Model Definition

Boundary temperatures
Material properties
Fluid&Flow
Operation plan
Demand& Supply
System components



Model Calibration

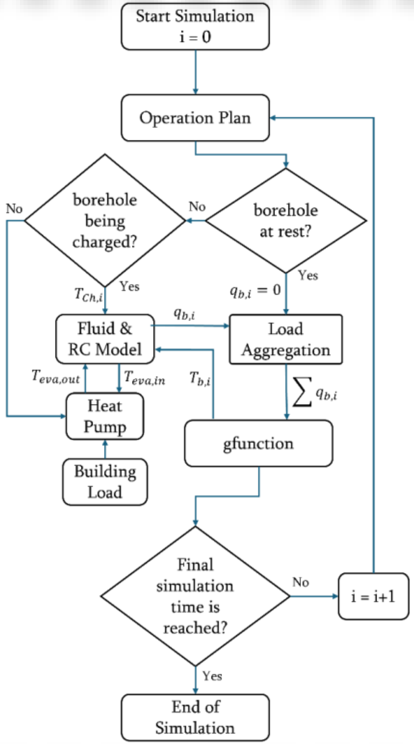
pygfunction



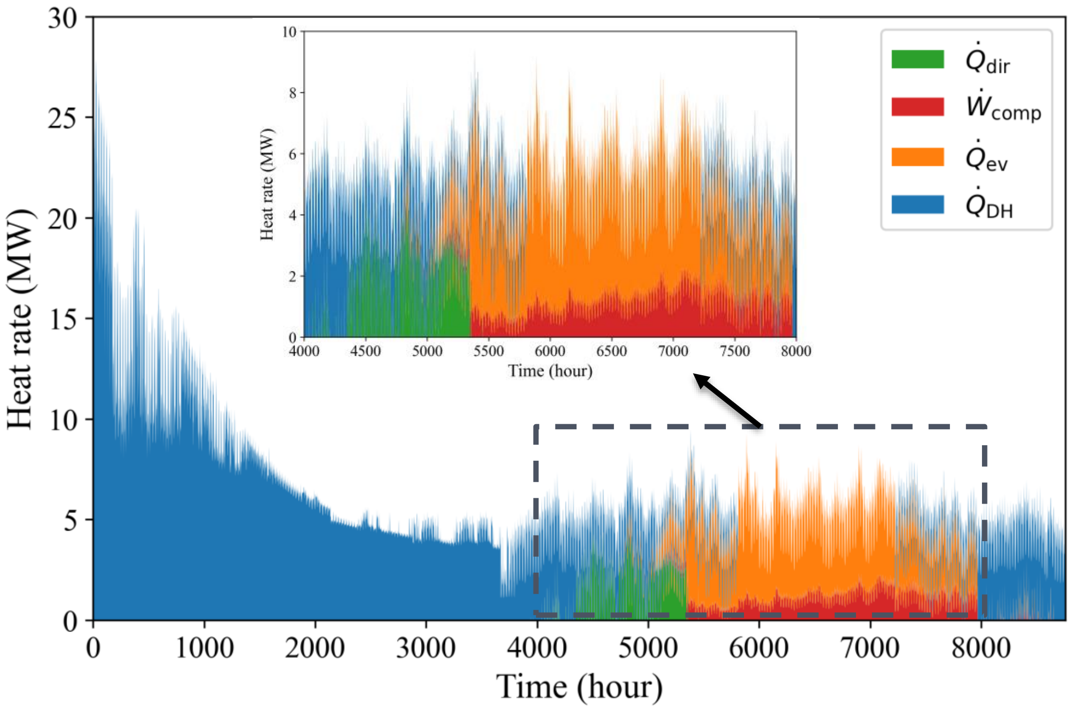
g-function
TRT data
Parameter estimation

k_g
R_b
k_s

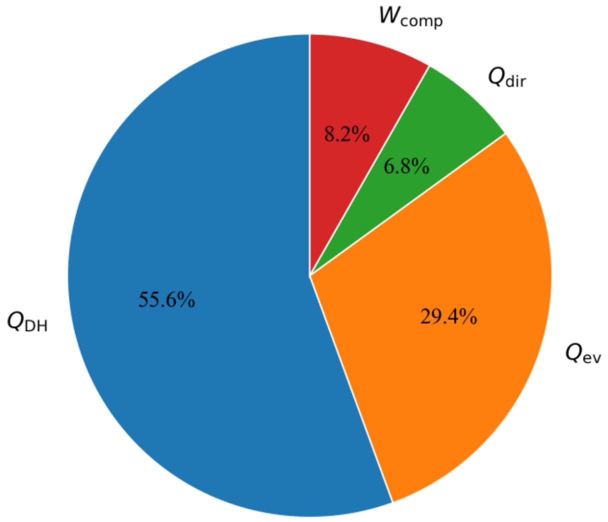
Simulation



Results



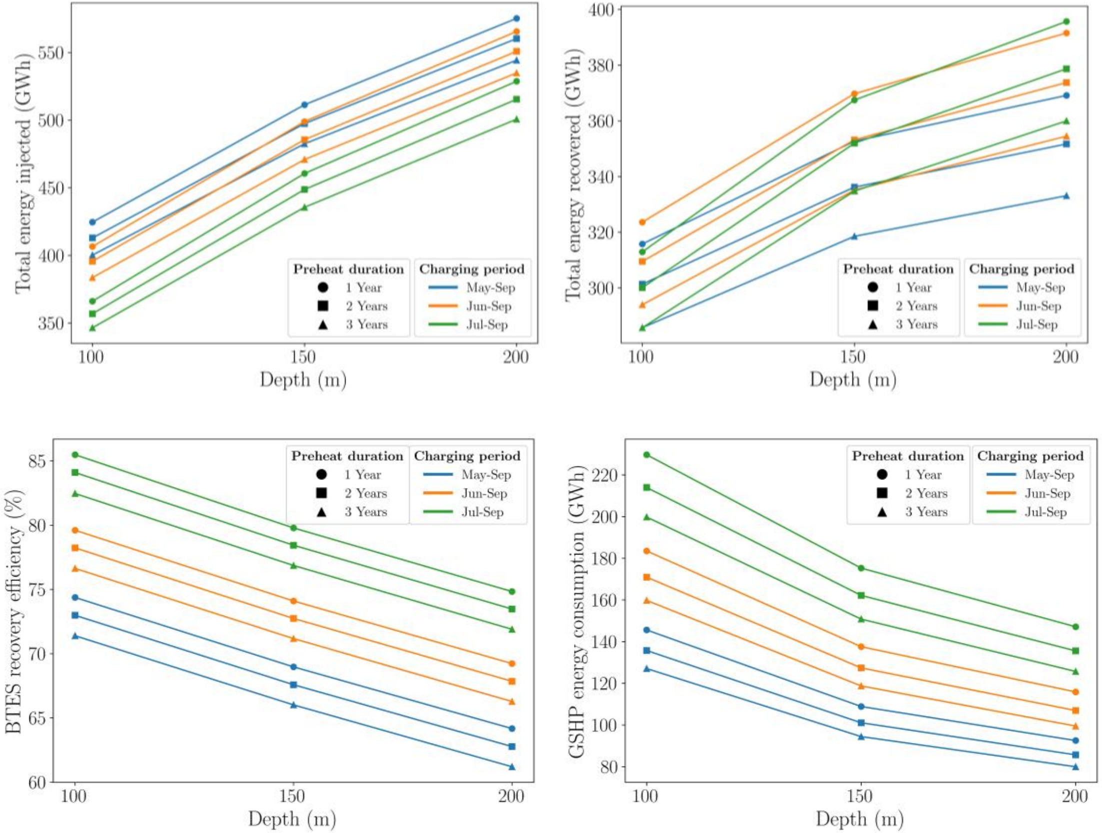
Heat rate (MW)
Time (hour)
Heat rate (MW)
Time (hour)
$\dot{Q}_{dir}$
$\dot{W}_{comp}$
$\dot{Q}_{ev}$
$\dot{Q}_{DH}$



W_{comp}
Q_{dir}
Q_{ev}
Q_{DH}
8.2%
6.8%
29.4%
55.6%

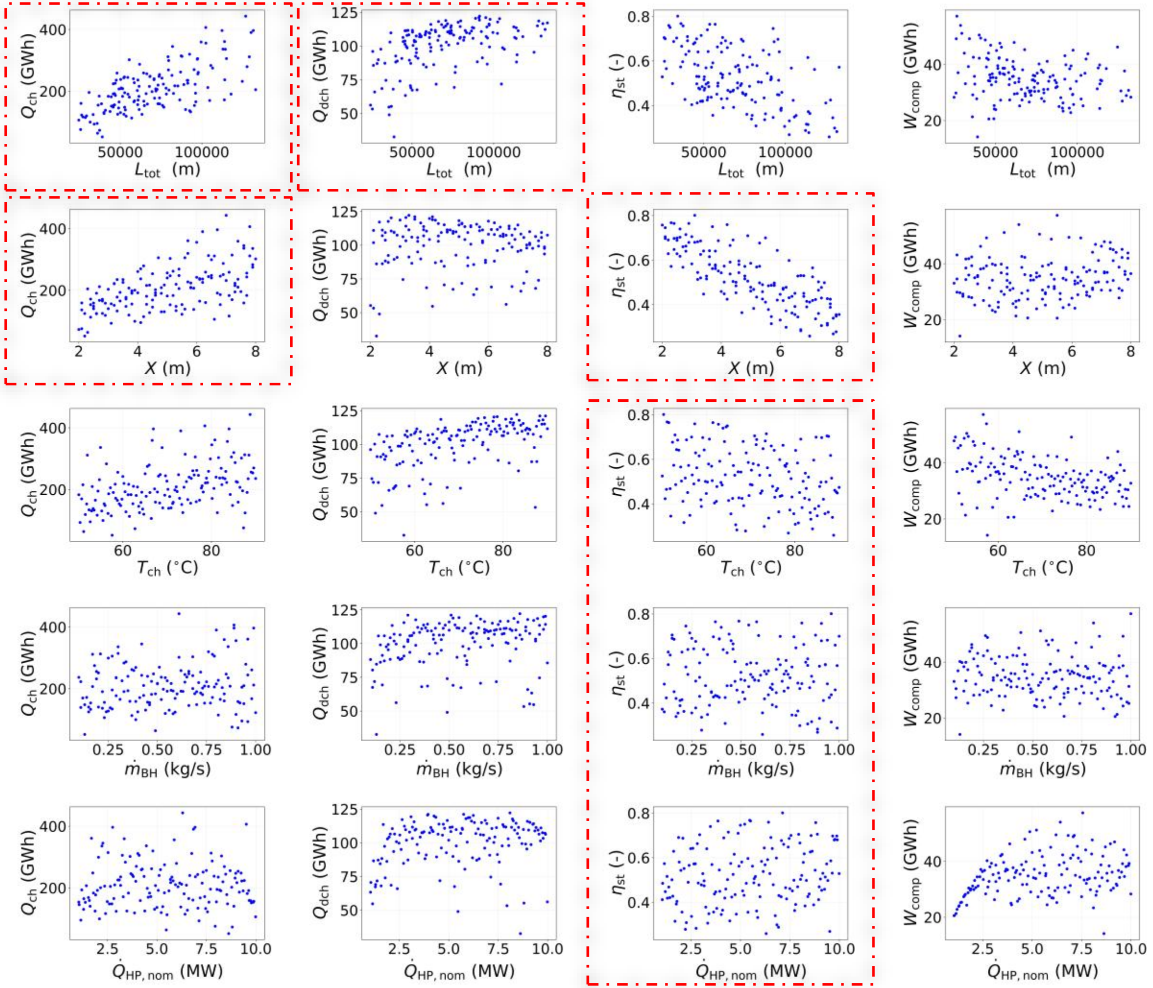
Results

- 20-year simulation reveals long-term trade-offs
- Longer borehole stores more heat, but the gain diminishes with depth.
- Energy recovery lags injection in deeper wells, driving storage efficiency down.
- Design trade-off: shallow wells maximise efficiency, while deeper wells cut heat-pump power demand.
- Extended pre-heat/charge windows further lower GSHP work, but at the cost of additional efficiency loss.



Results

- Global sensitivity of design & operation parameters
- Linear, monotonic, and non-monotonic trends identified
- Guides system understanding and optimum design



Contributions & Next Steps

- Impacts So Far
  - Multiscale simulation framework, accounting for long-term effects and hourly fluctuations
  - Calibrated to site-specific data, replicating the case study
  - Sensitivity analysis to rank the most influential design and operating variables

- Path Ahead
  - Design and control optimization exploring various objectives
  - Techno-economic assessment of the entire heating network
  - Development of a transferable, case-specific design

Thank You for Your Attention!

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