Techno-economic Assessment Of Distributed Heat Pumps Integration Within a Swedish Neighborhood

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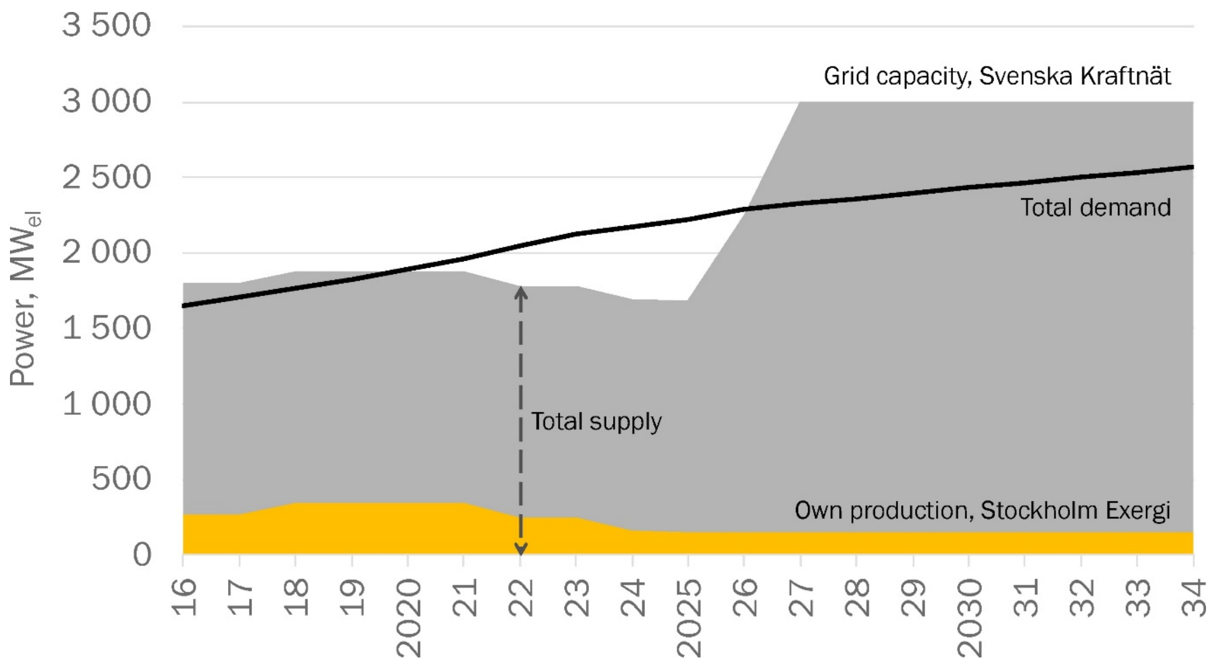
KTH – Energy Technology –

Integrated Smart Energy Systems

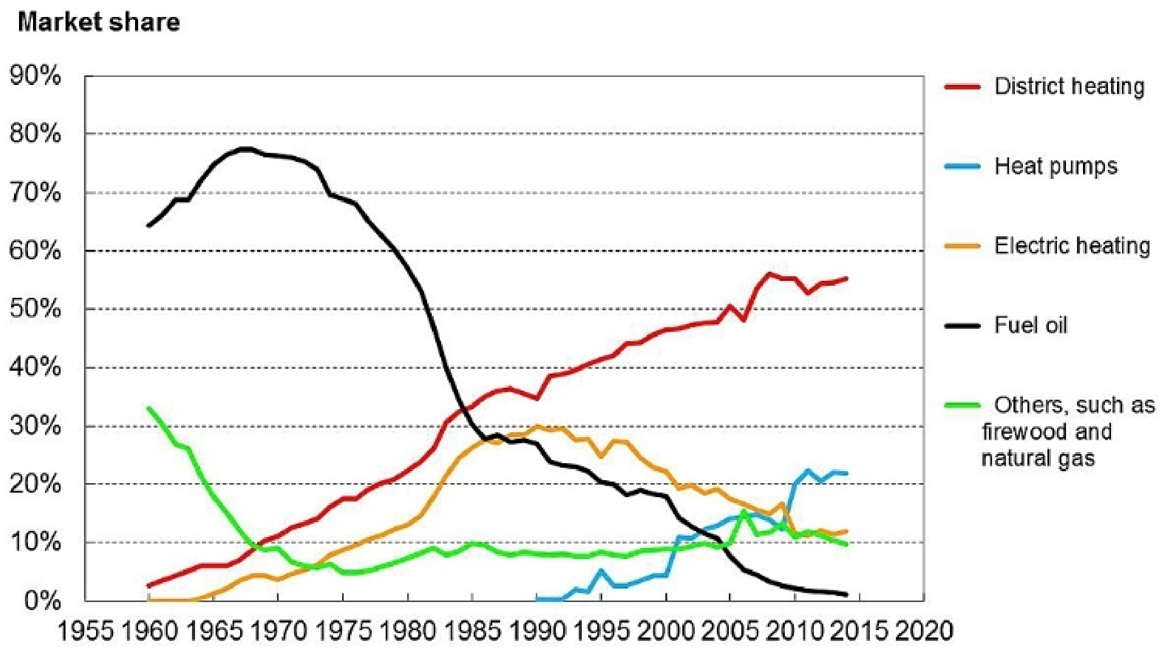
- Background
- Case Study
- Scenarios
- Models
- Results
- Outlook

The power grid infrastructure in Stockholm



[1]

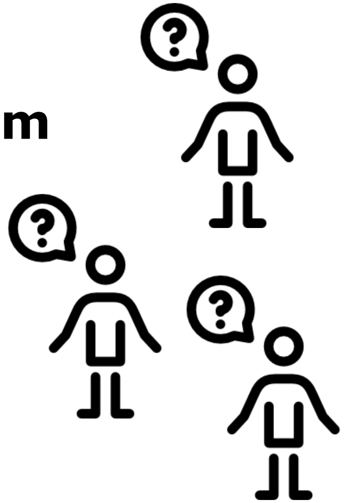
The electrification trend of the heating in Stockholm



[2]

The power grid infrastructure in Stockholm

The electrification trend of the heating in Stockholm



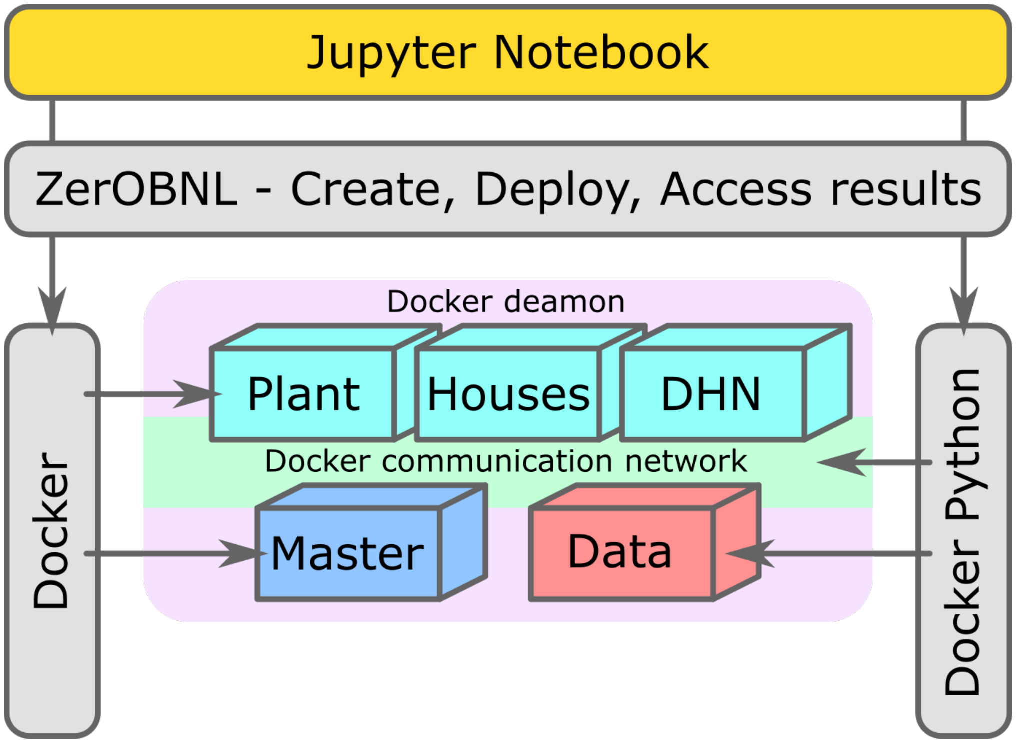
Study interactions among integrated energy systems

Design cost-effective and emissions-free infrastructures

Modeling and simulation based on co-simulation

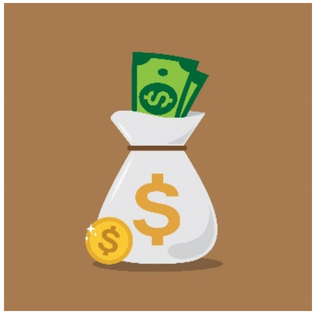
ZerOBNL

co-simulation tool



[3]

Analysis based on techno-economics



$$LCOH = \frac{\sum_{t=1}^{n}[(CAPEX_t + OPEX_t + Fuel_t) * (1+r)^{-t}]}{\sum_{t=1}^{n} Q_{th} * (1+r)^{-t}}$$

Capital expenditures (CAPEX)

Operational expenditures (OPEX)

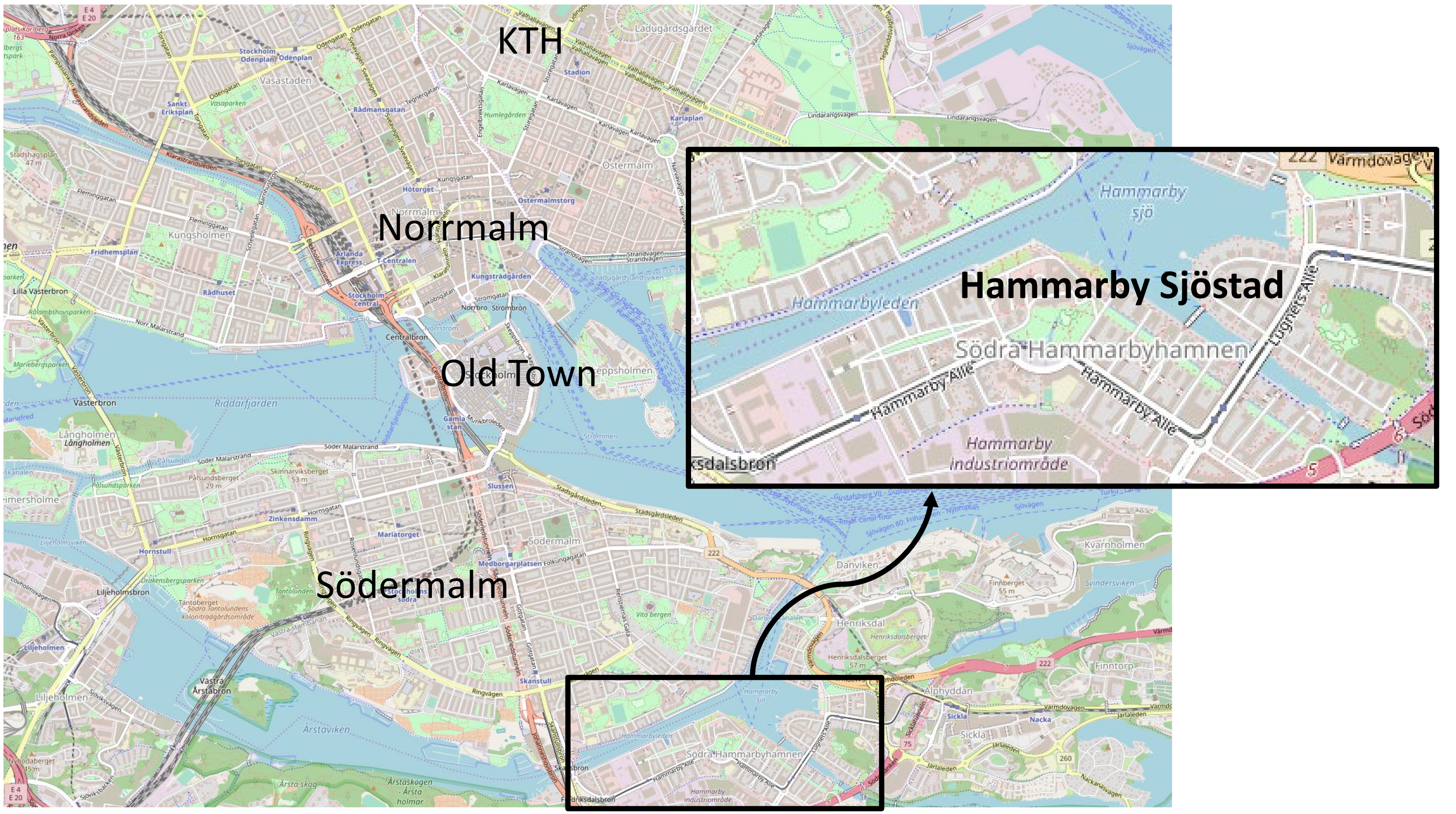
Fuel costs (Fuel)

Discount rate (r)

Technical lifetime (n, t)

Net energy generation (Qth)

FreePik


KTH
Norrmalm
Old Town
Södermalm
Hammarby Sjöstad
Hammarbyleden
Södra Hammarbyhamnen
Hammarby sjö
Hammarby Allé
Lugnets Allé
Hammarby industriområde

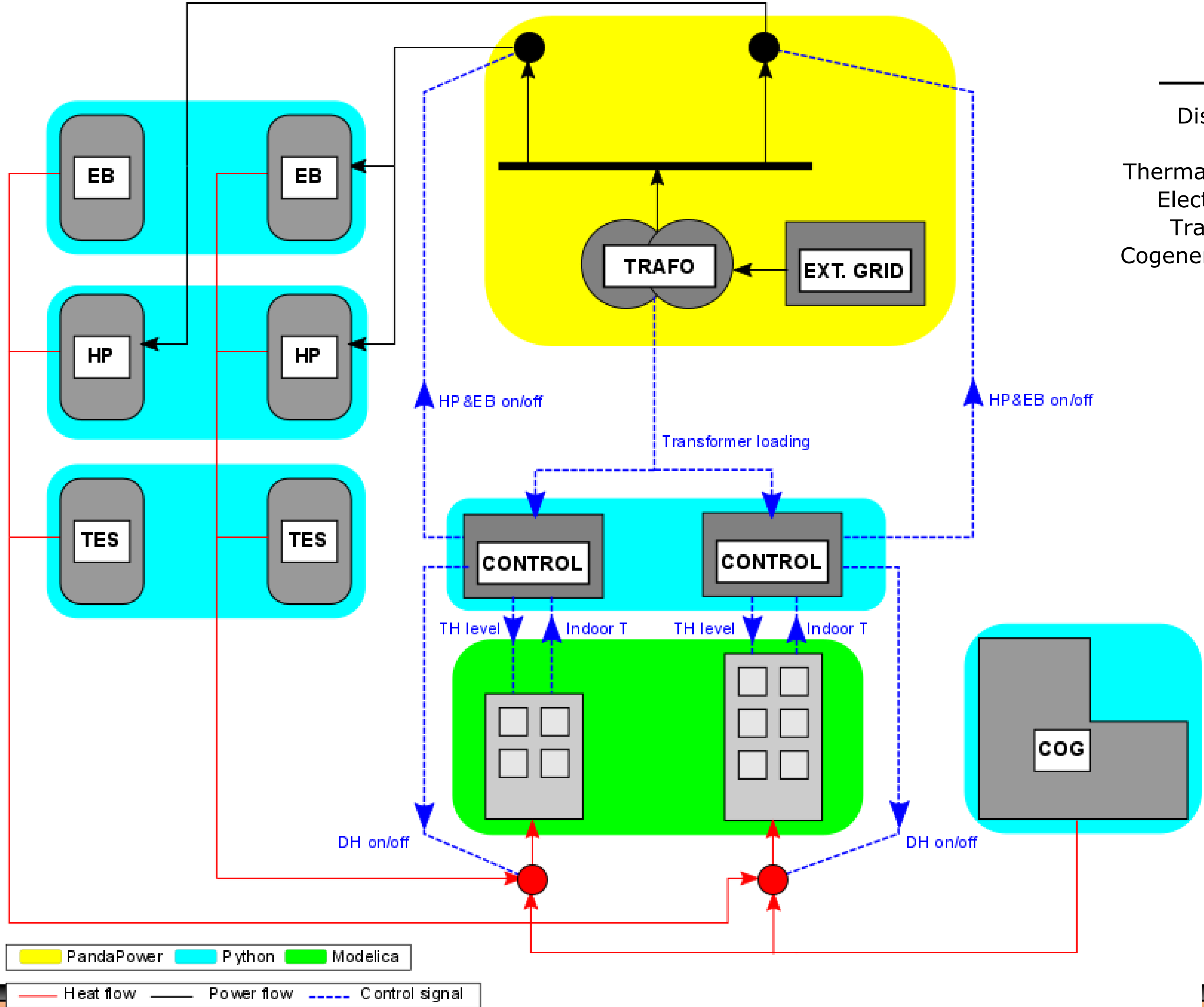
- 22 buildings blocks
- Around 1.2 MW installed heat capacity
- Around 1.6 MW of installed power capacity
- Heat pumps (HP):
  - sized as 55% of the peak load
  - integrated thermal energy storage (TES) and electrical backup (EB)
- Power overloading signal at 80% of the transformer capacity
- District heating (DH) as backup during power grid overloading

How to avoid the electricity distribution grid overloading?

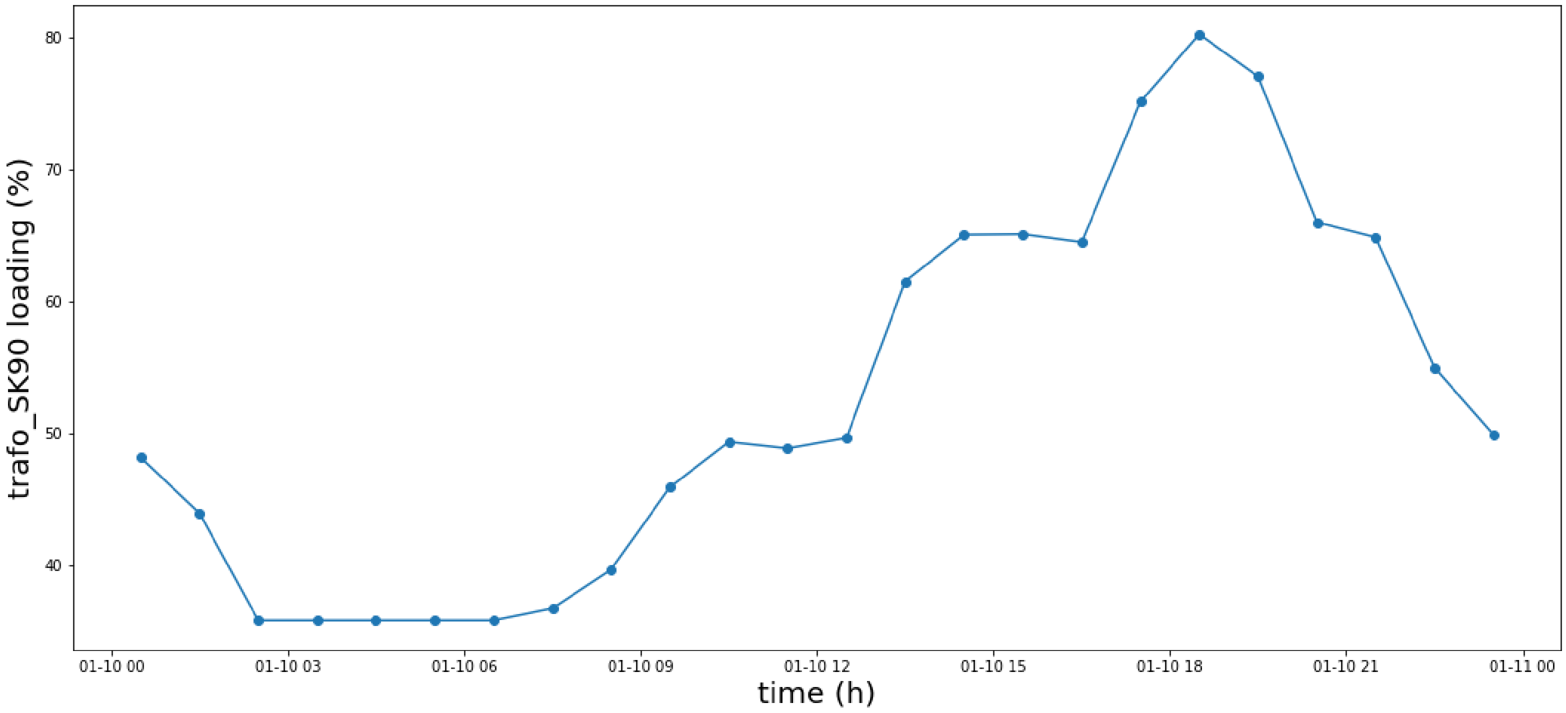
Reference DH	Only DH connection
Scenario TES_1	HP connection, backup DH, 1h TES
Scenario TES_2	HP connection, backup DH, 2h TES
Scenario TES_3	HP connection, backup DH, 3h TES
Scenario TES_4	HP connection, backup DH, 4h TES
ScenarioNumHPTES_1	90% HP connection, backup DH, 1h TES
ScenarioNumHPTES_2	90% HP connection, backup DH, 2h TES
ScenarioNumHPTES_3	90% HP connection, backup DH, 3h TES
ScenarioNumHPTES_4	90% HP connection, backup DH, 4h TES
Electricity price sensitivity	90%, 85% and 80%

Models

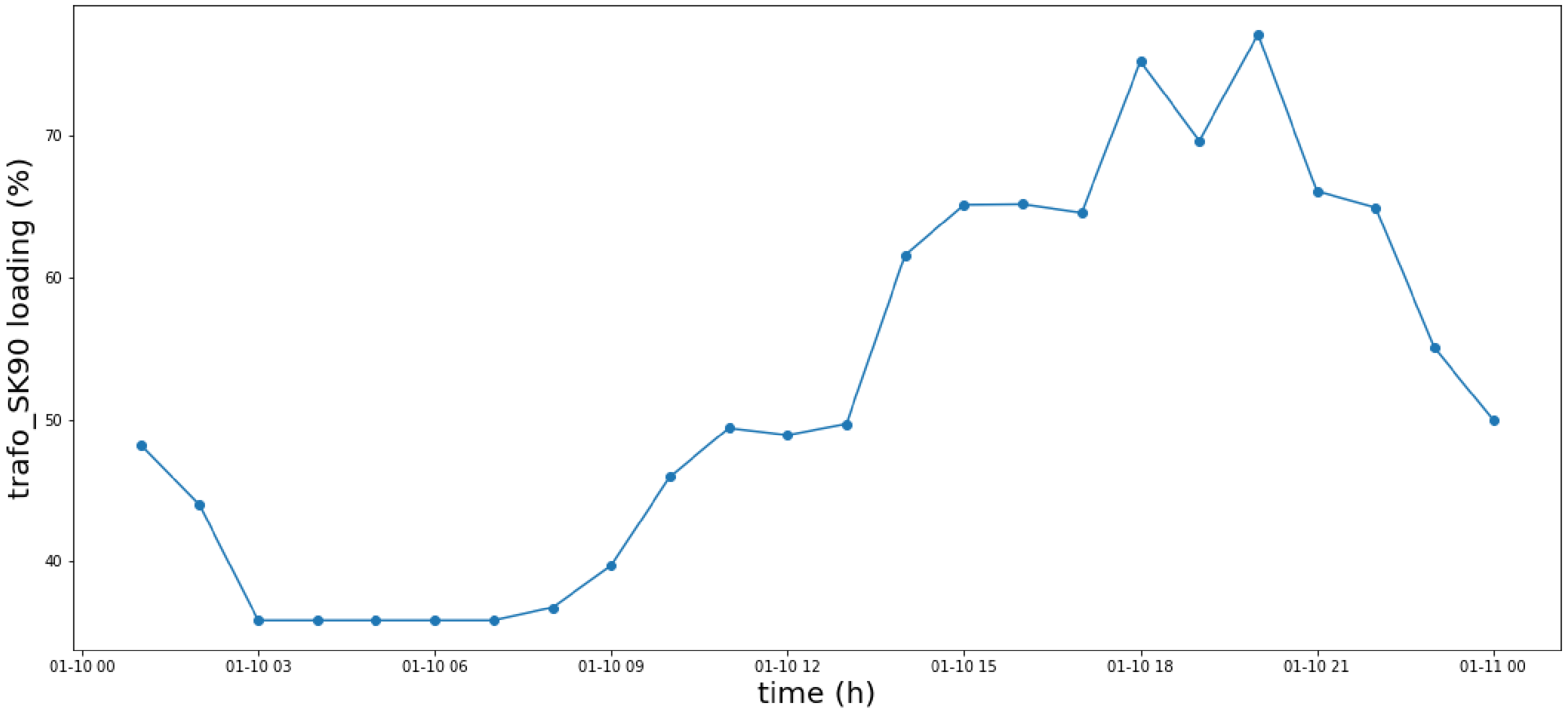
District heating (DH)
Heat Pump (HP)
Thermal E. Storage (TES)
Electrical back up (EB)
Transformer (TRAFO)
Cogeneration plant (COG)
Thermostat (TH)
Temperature (T)



ScenarioTES_2



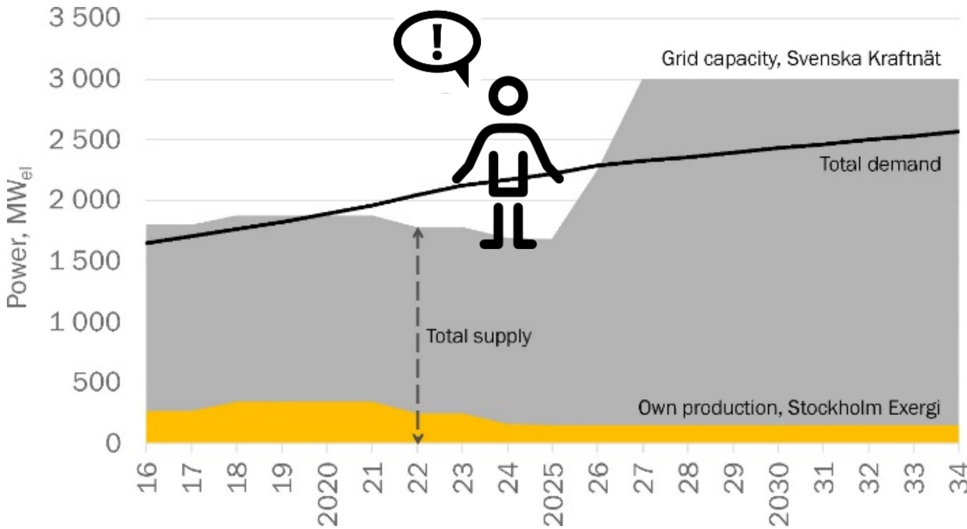
ScenarioTES_2



El. price variation [-]	1	0.9	0.85	0.8
	LCOH [sek/MWh]			
Reference DH	278.93 [4]	-	-	-
Scenario TES_1	302.67	285.44	276.83	268.22
Scenario TES_2	304.73	287.46	278.82	270.18
Scenario TES_3	305.67	288.41	279.78	271.15
Scenario TES_4	307.72	290.41	281.76	273.10
ScenarioNumHPTES_1	302.38	285.15	276.54	267.92
ScenarioNumHPTES_2	305.00	287.69	279.04	270.38
ScenarioNumHPTES_3	305.93	288.63	279.99	271.34
ScenarioNumHPTES_4	307.97	290.63	281.96	273.29

- A simulation approach to capture **interactions among integrated energy systems**
- A techno-economic analysis to **design cost-effective energy infrastructures**
- **TES** can help to alleviate the grid overloading due to HPs installation

  BUT a **full connection** should be avoided
- **Electricity prices** strongly impact the HPs techno-economic competitiveness when compared to DH



Future work:

- **Demand response** to alleviate the grid overloading
- Modelling of DH **heat losses** and mass flow rates

Thank you

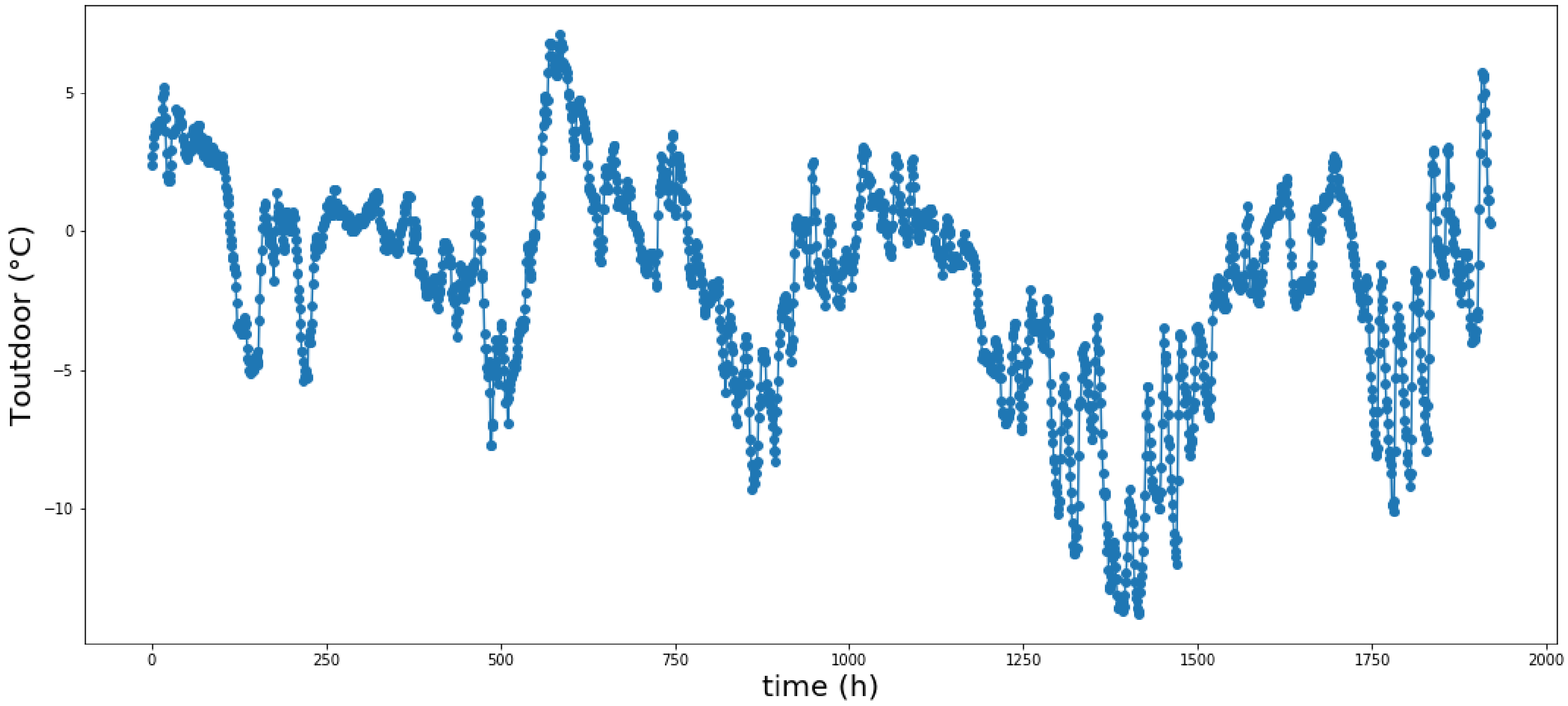
Bibliography

[1] Pasichnyi O, Wallin J, Kordas O. Data-driven building archetypes for urban building energy modelling. Energy 2019;181:360–77. doi:10.1016/j.energy.2019.04.197.

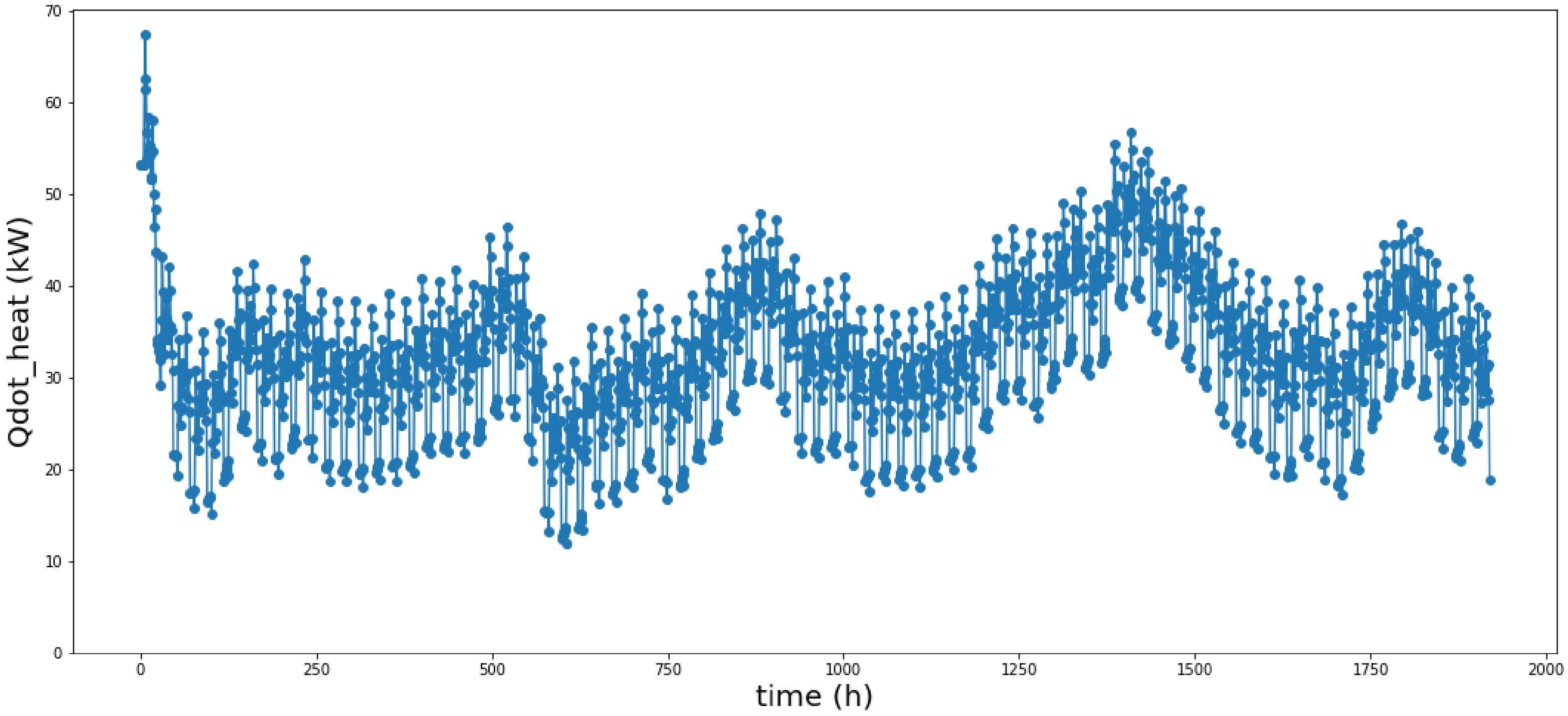
[2] Werner S. District Heating and Cooling in Sweden. Energy 2017;126:419–129.

[3] Puerto P. zerOBNL 2018. https://github.com/IntegrCiTy/zerobnl (accessed October 26, 2018).

[4] Arnaudo M, Topel M, Puerto P, Widl E, Laumert B. Heat demand peak shaving in urban integrated energy systems by demand side management - A techno-economic and environmental approach. Energy 2019;186:115887. doi:10.1016/j.energy.2019.115887.


Toutdoor (°C)
5
0
−5
−10
0
250
500
750
1000
1250
1500
1750
2000
time (h)

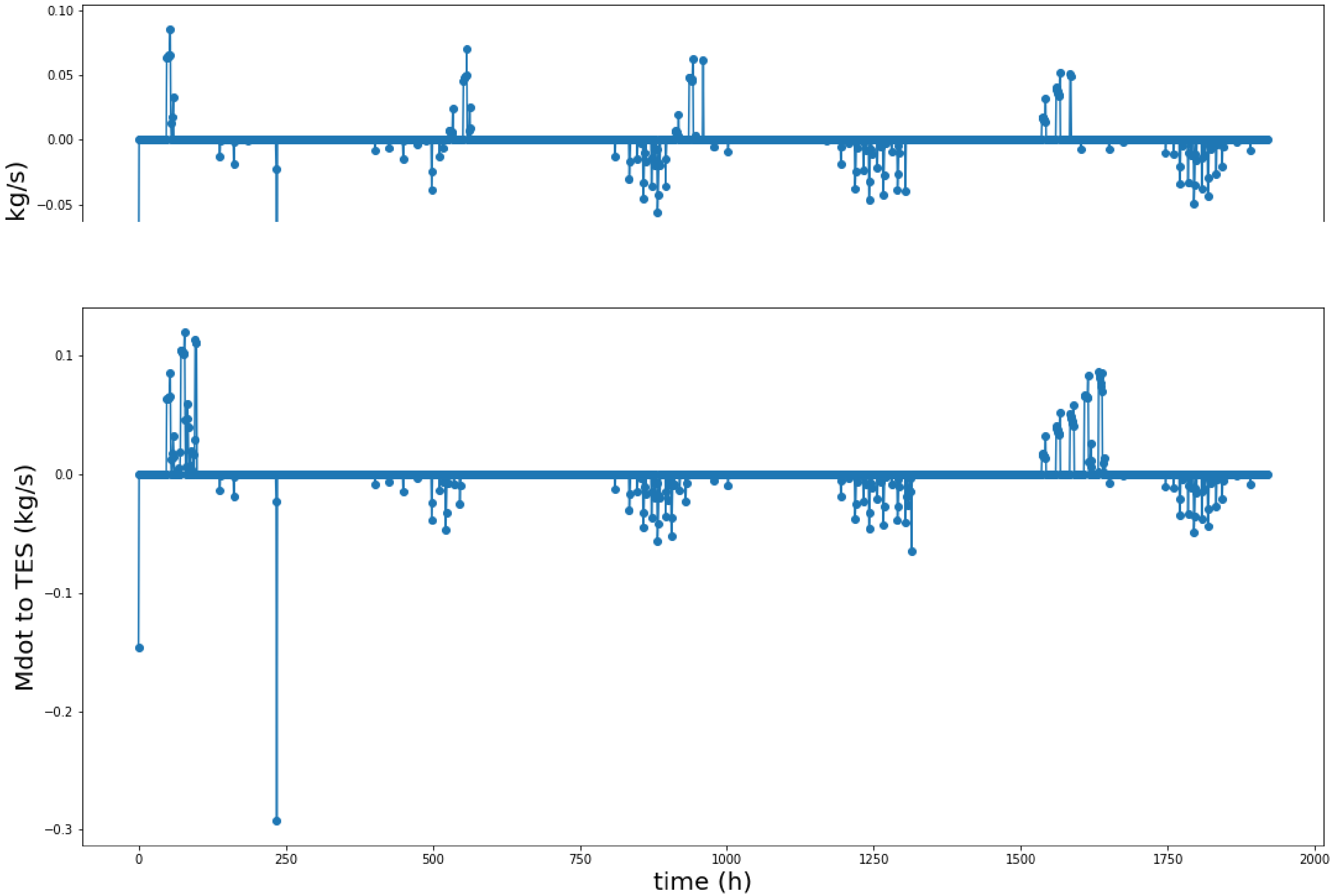
Results



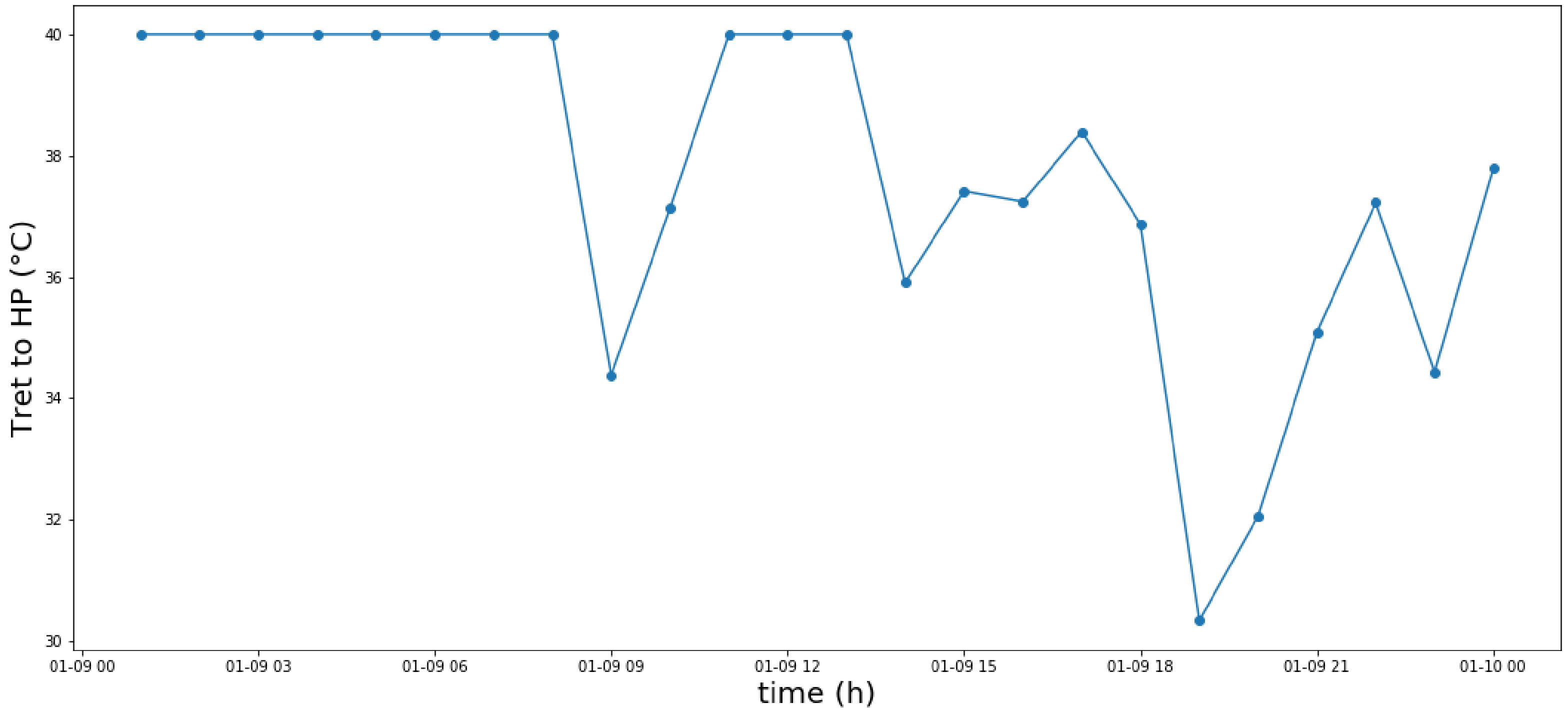
Qdot_heat (kW)
time (h)
0
10
20
30
40
50
60
70
0
250
500
750
1000
1250
1500
1750
2000

Results

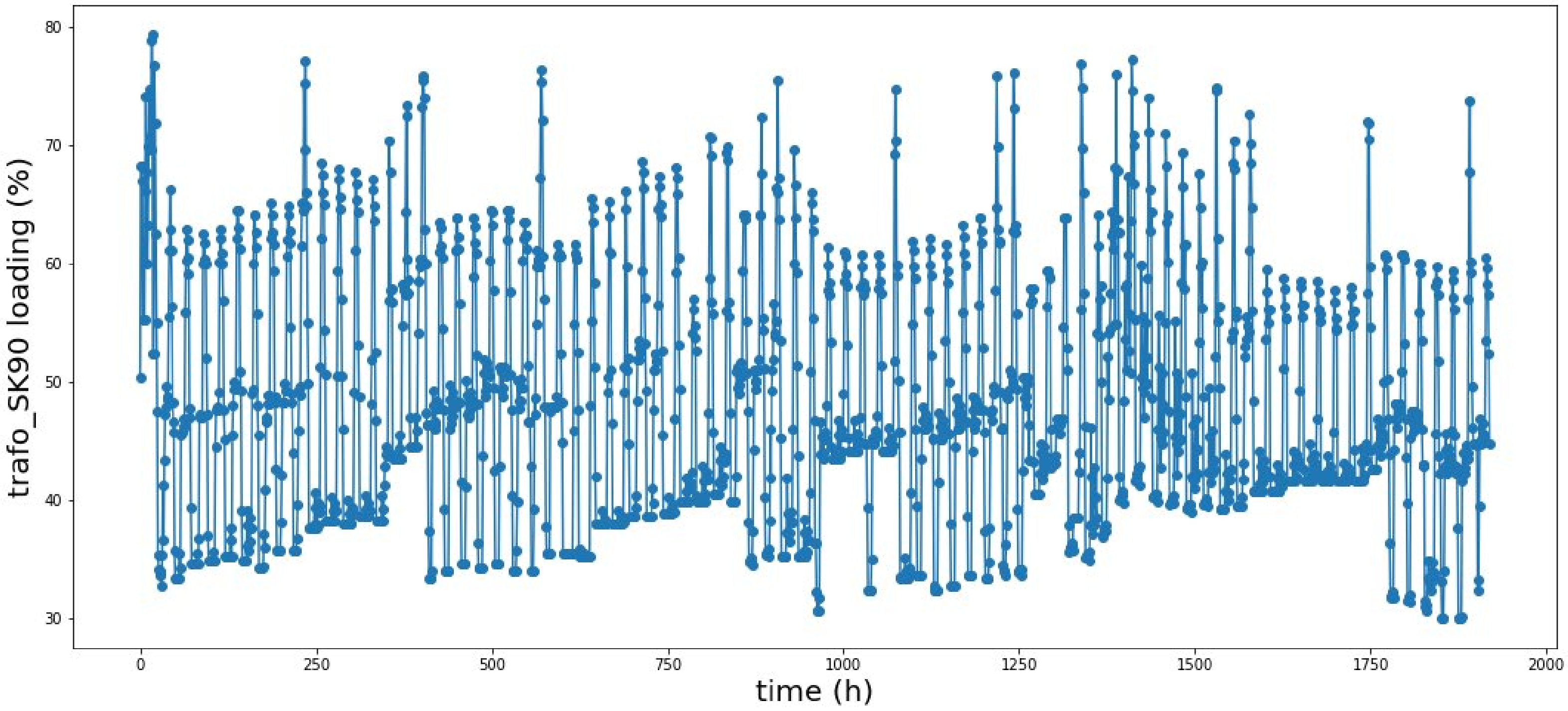
Scenario TES_1 vs. Scenario TES_4



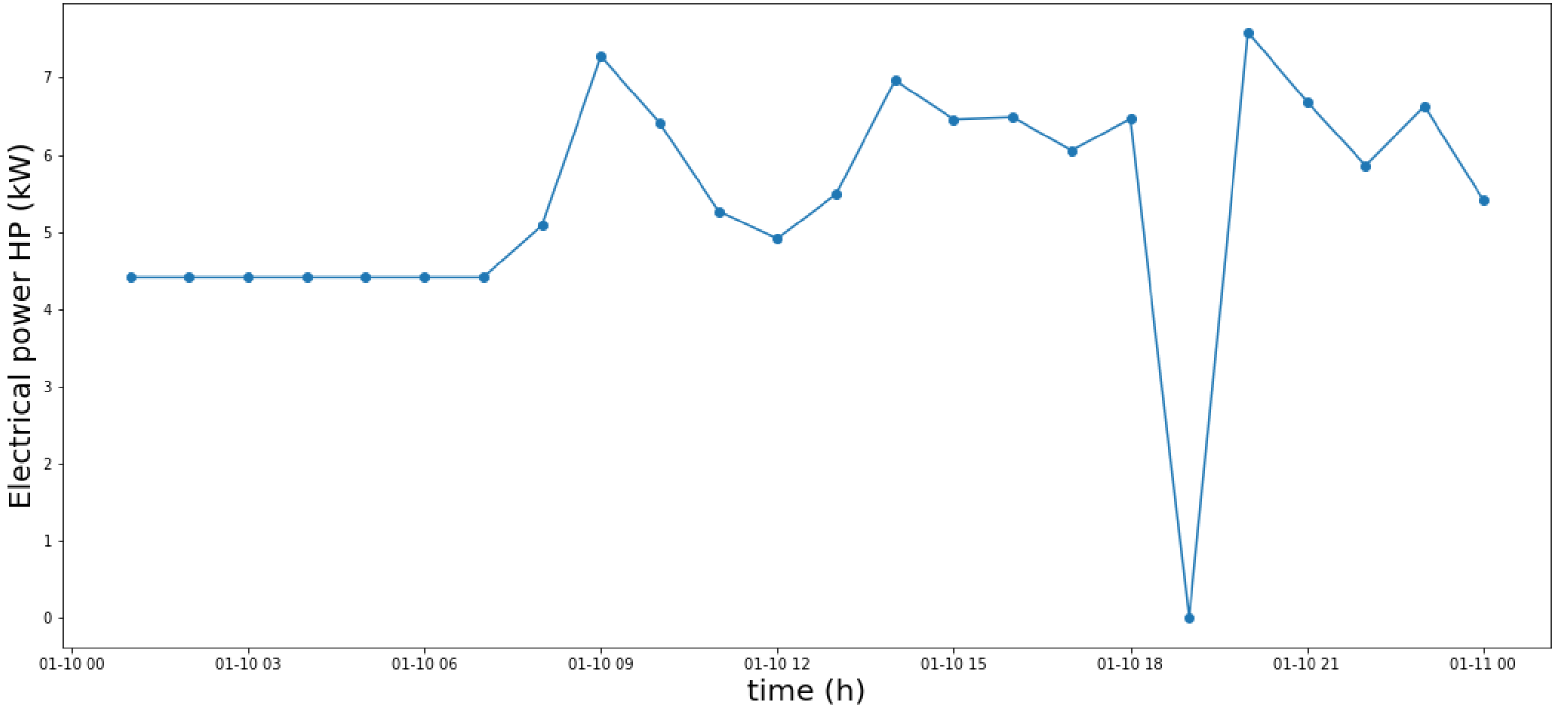
Scenario TES_4



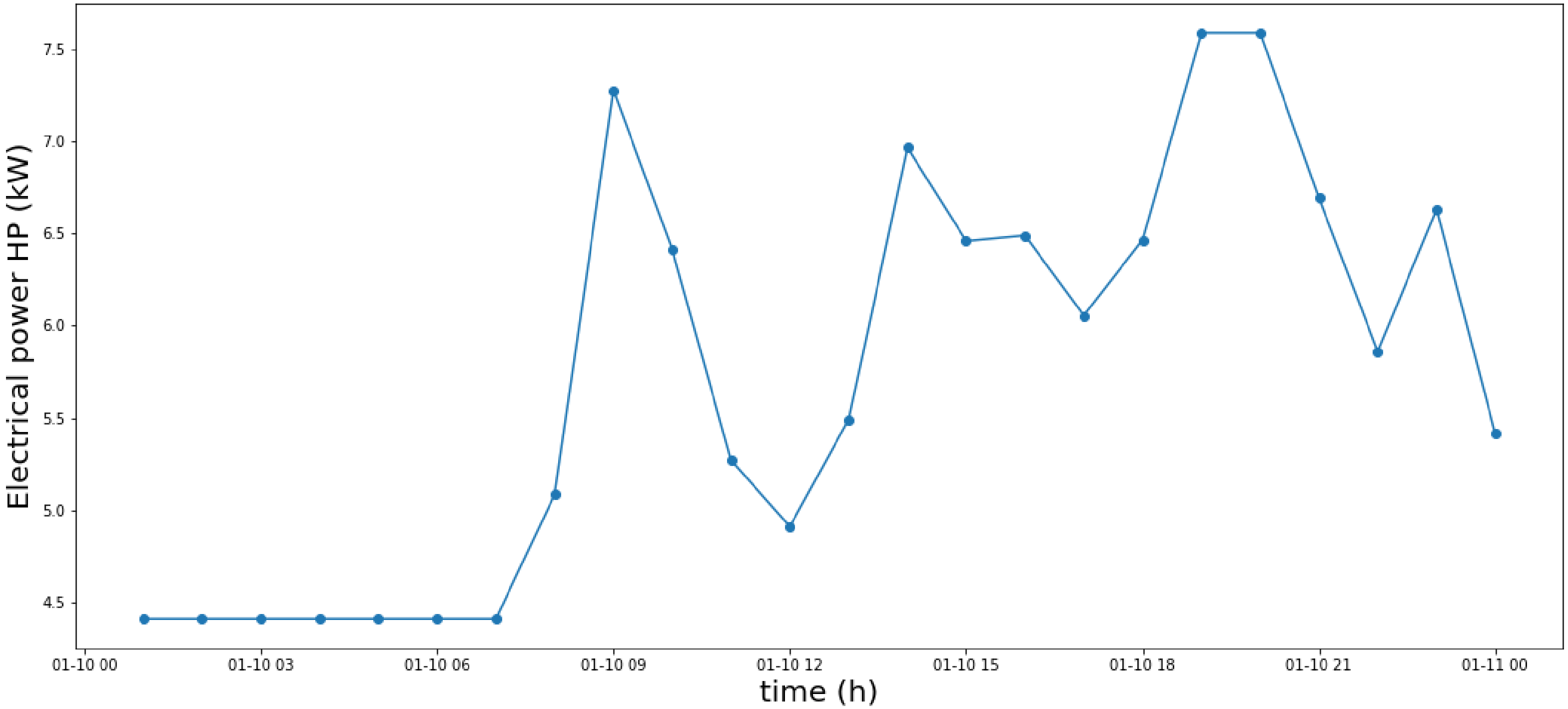
Scenario TES_2



Scenario TES_2 vs. ScenarioNumHPTES_1 for a building block



Scenario TES_2 vs. ScenarioNumHPTES_1 for a building block



Limitations

- One room archetype
- Modelica room model according to German standard
- Cogeneration plant as simplified efficiency
- DH network as simplified mixing of flow rates
- No ramps/delays are considered