Research Centre on ZERO EMISSION NEIGHBOURHOODS IN SMART CITIES

The Research Council of Norway

NTNU

SINTEF

Investment analysis and dynamic simulations of a local energy system with seasonal thermal energy storage

User4GeoEnergy Seminar, Oslo 24.5.2022

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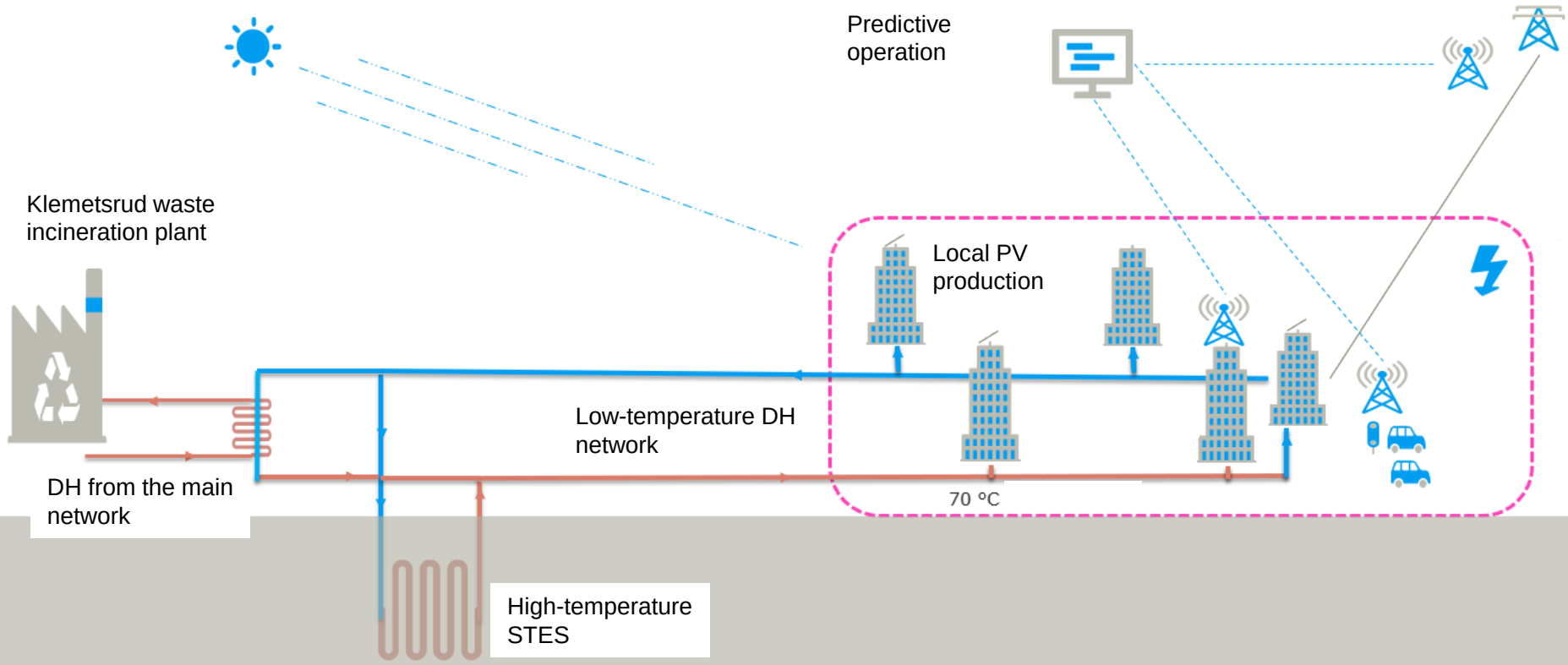
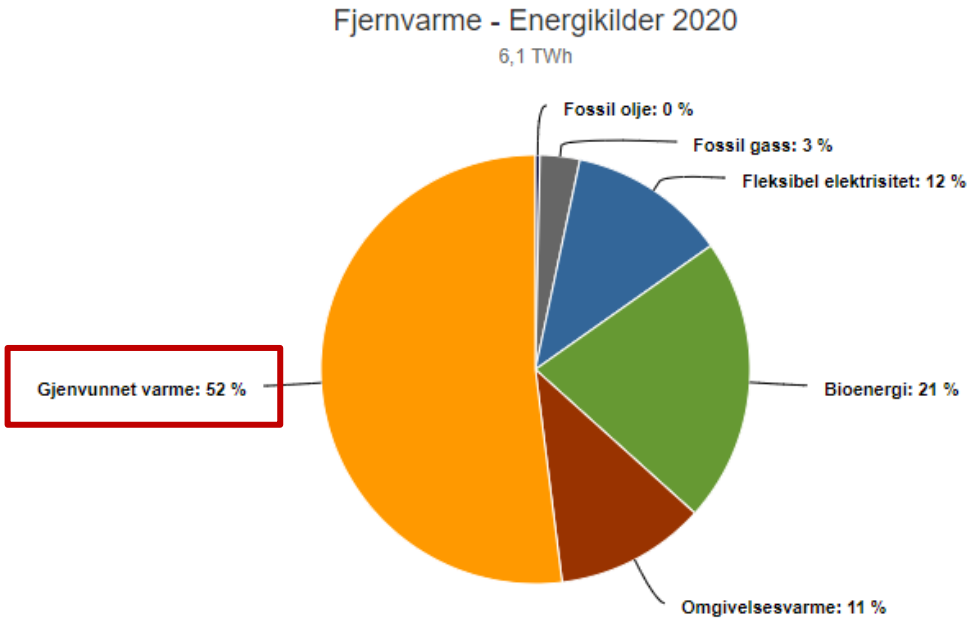
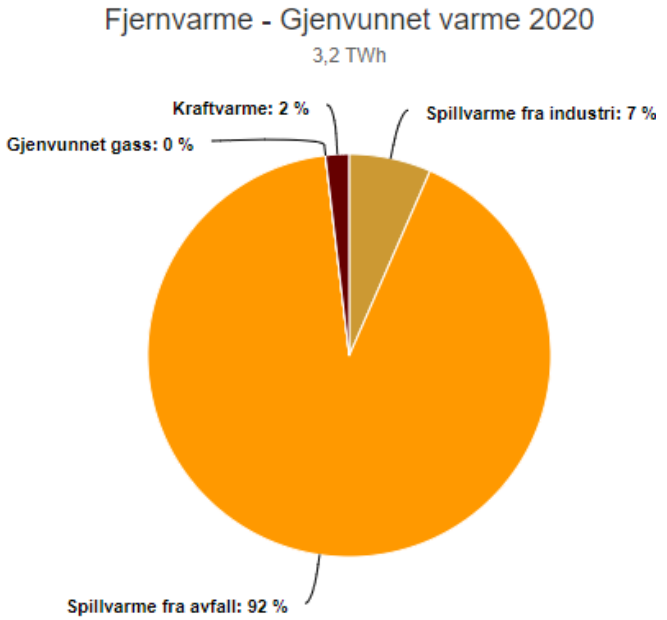
SINTEF Energy Research

The micro energy system of Furuset



Motivation
The demand for seasonal storage in district heating systems





Norsk Fjernvarme - https://www.fjernkontrollen.no/

Goal with the techno-economic analysis

Main objective:
Demonstrate the benefits with district heating and seasonal thermal energy storage.

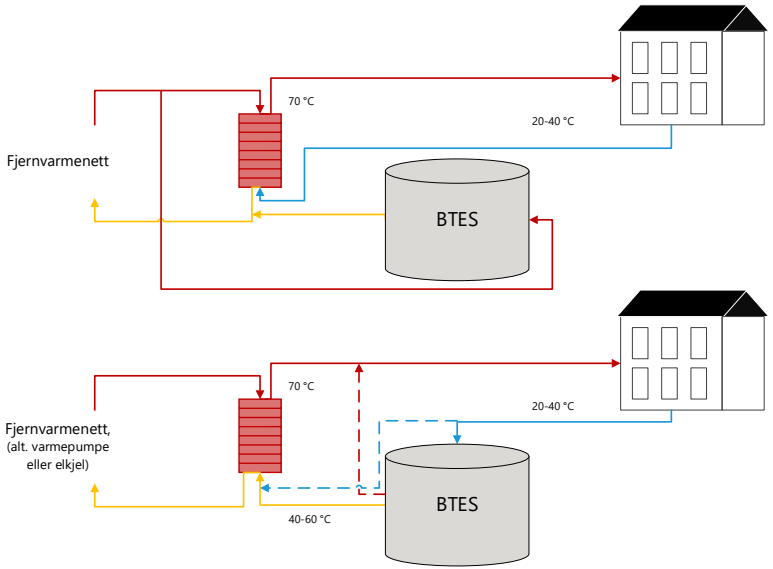
Techno-economic evaluation of three cases:

1. Direct electric heating
2. Conventional high-temperature DH
3. Low-temperature DH with seasonal thermal energy storage (STES)

	Energy demand [GWh/year]
Electricity specific	32.4
Electric vehicles	5.7
Total heating demand	31.9
Heating demand to be covered by DH	15.1
Heating demand to be covered by electricity	16.9

Goal with the dynamic analysis (part of the RockStore project)

- Evaluate the integration of a BTES in a local heating network
- Evaluate different operational strategies with respect to
  - Demand for additional heating from the main DH network
  - Obtained temperatures from the BTES



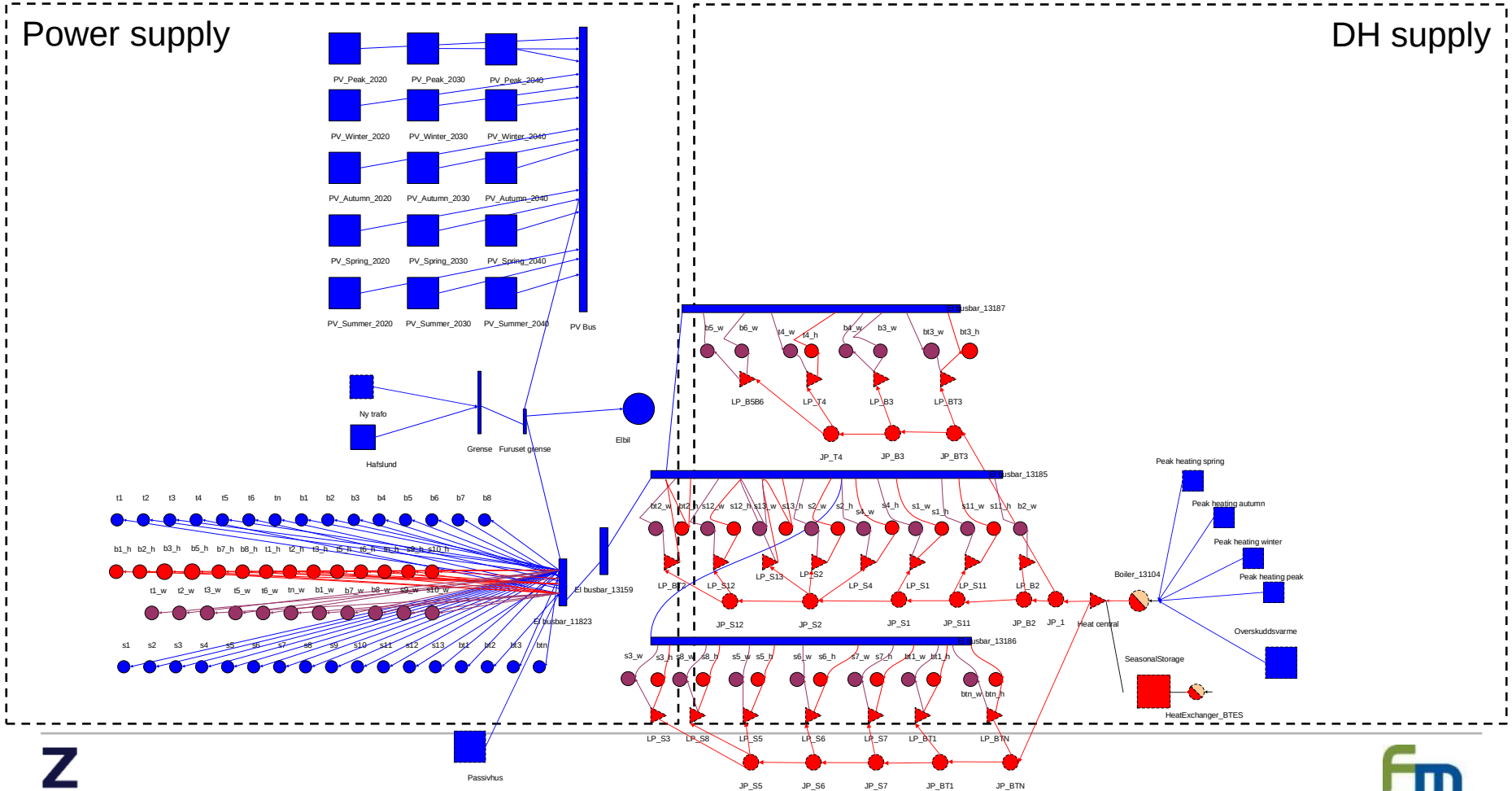
METHODOLOGY

Techno-economic analysis

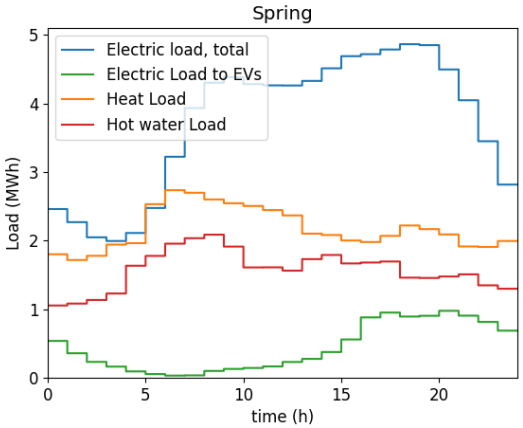
Integrate – optimization of integrated energy systems

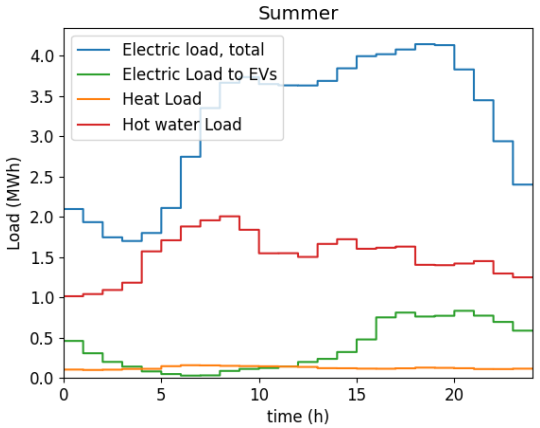
- Software for planning of local energy systems
- Multiple energy carriers: electricity, district heating, hydrogen, ..
- Optimization of
  - **Operation:** within 24 hours for a selected number of representative days
  - **Investments:** over a given planning period (e.g. 30 years)

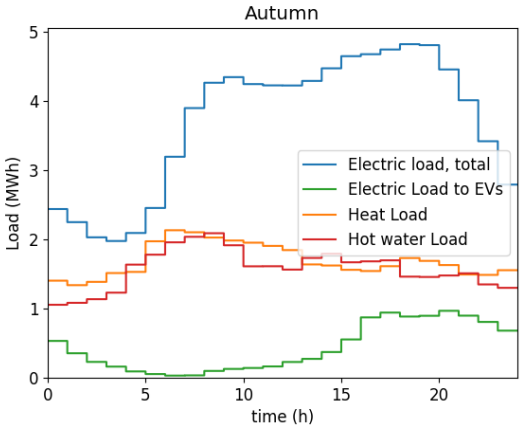
https://www.sintef.no/en/software/integrate/

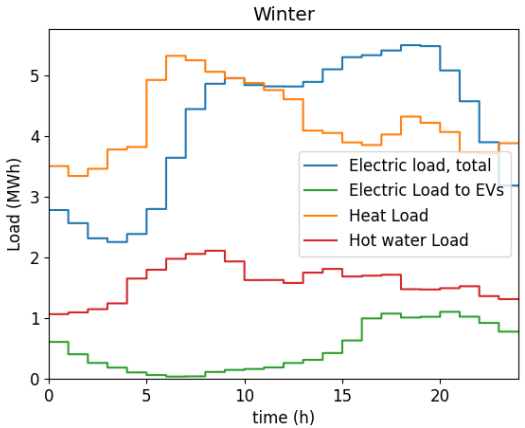

Power supply
DH supply
PV_Peak_2020
PV_Peak_2030
PV_Peak_2040
PV_Winter_2020
PV_Winter_2030
PV_Winter_2040
PV_Autumn_2020
PV_Autumn_2030
PV_Autumn_2040
PV_Spring_2020
PV_Spring_2030
PV_Spring_2040
PV_Summer_2020
PV_Summer_2030
PV_Summer_2040
PV Bus
Ny trafo
Hafslund
Grense
Furuset grense
Elbil
El busbar_13187
LP_B5B6
LP_T4
LP_B3
LP_BT3
JP_T4
JP_B3
JP_BT3
El busbar_13185
LP_BT2
LP_S12
LP_S13
LP_S2
LP_S4
LP_S1
LP_S11
LP_B2
JP_S12
JP_S2
JP_S1
JP_S11
JP_B2
JP_1
El busbar_13186
LP_S3
LP_S8
LP_S5
LP_S6
LP_S7
LP_BT1
LP_BTN
JP_S5
JP_S6
JP_S7
JP_BT1
JP_BTN
El busbar_13159
El busbar_11823
Passivhus
Peak heating spring
Peak heating autumn
Peak heating winter
Peak heating peak
Boiler_13104
Heat central
Overskuddsvarme
SeasonalStorage
HeatExchanger_BTES

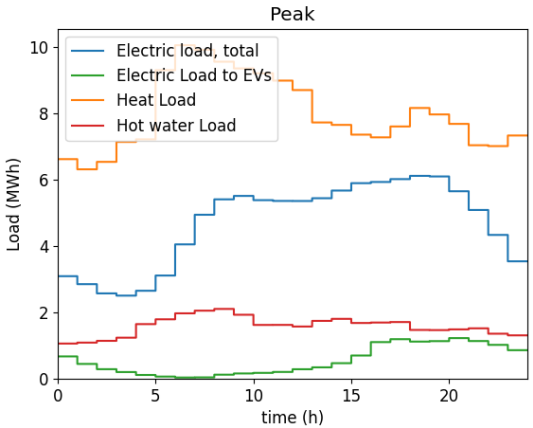
Daily load profiles











Seasonal Thermal Energy Storage – STES

- Capacity: **13 GWh**
- Annual heat loss: **5 GWh (38 %)**
- Max heat flow rate for charging/discharging: **4.27 / 4 MW**

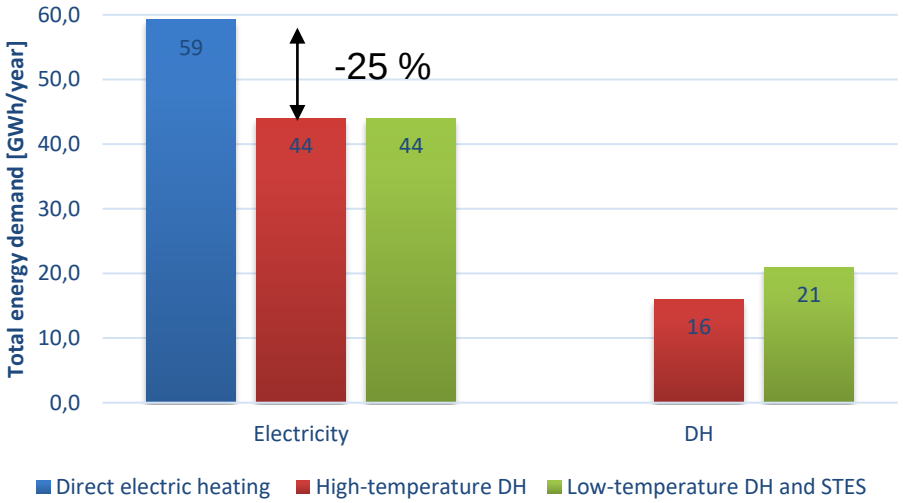
	Number of days	Charge / discharge per season [MWh]
Peak	1	-50
Summer	127	13 000
Winter	123	-6 050
Autumn	62	-1 400
Spring	52	-500
Heat loss		-5 000
SUM	365	0

RESULTS

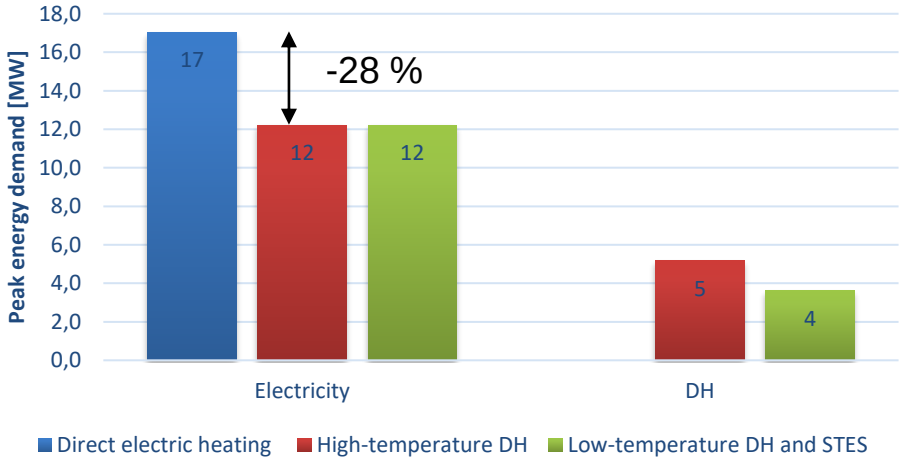
Techno-economic analysis

Annual supplied energy and peak energy demand

Annual demand for electricity and DH

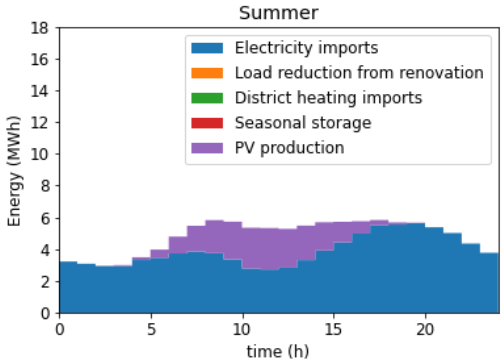


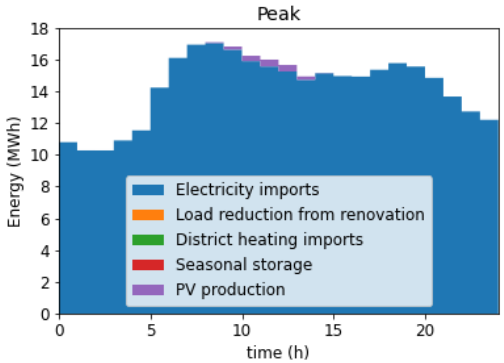
Peak energy demands



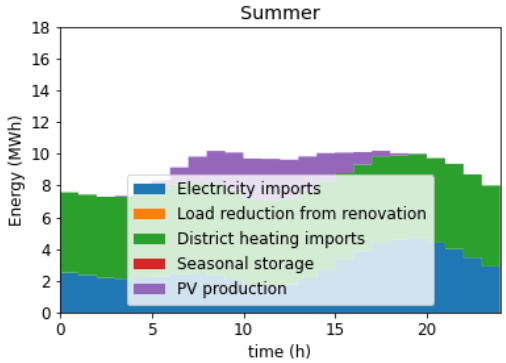
Aggregated energy breakdown – summer and peak

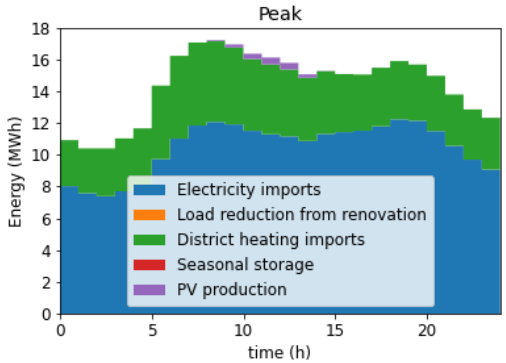
Electric heating



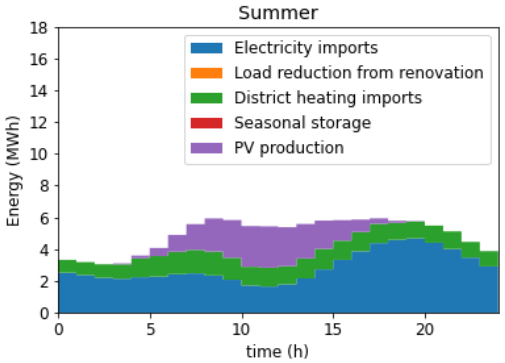


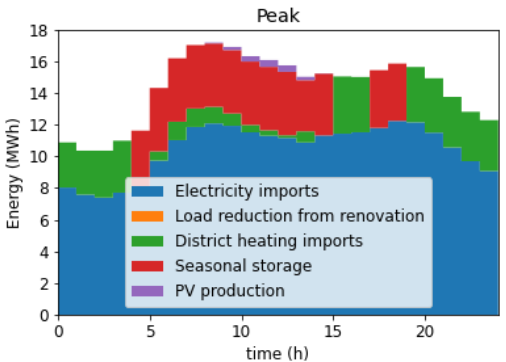
High-temperature DH



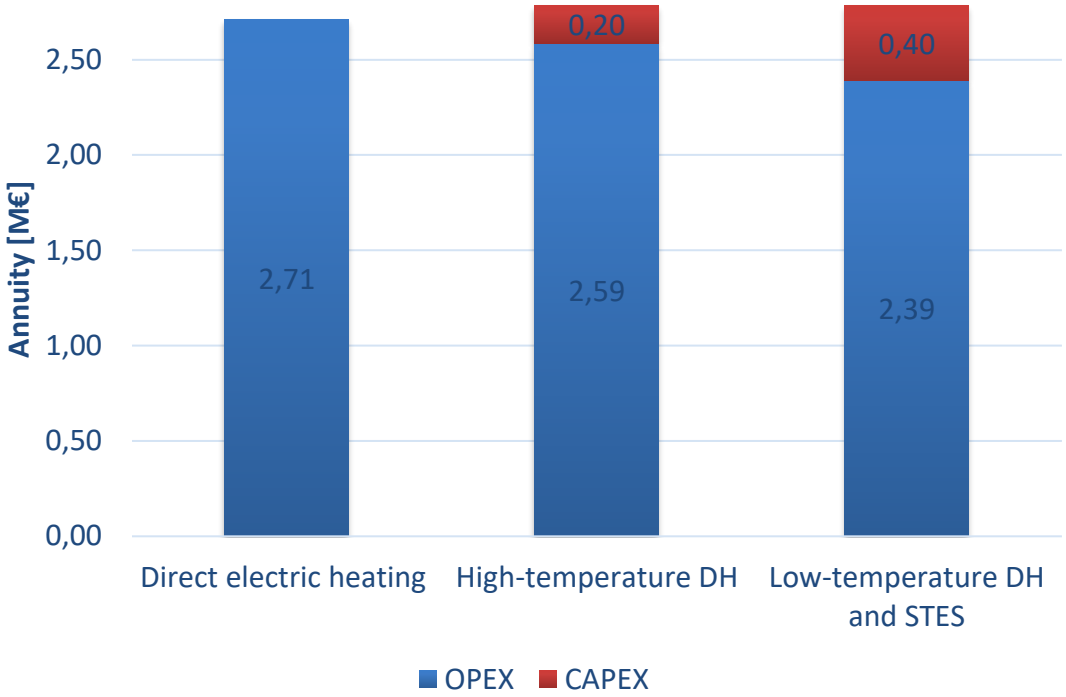


Low-temperature DH+STES





Investment analysis - annuity



NB!

- Results based on historical power prices, for a non-constrained grid.
- Winter power prices similar to those experienced in 21/22 rendered LTDH+STES the least cost solution

Conclusions

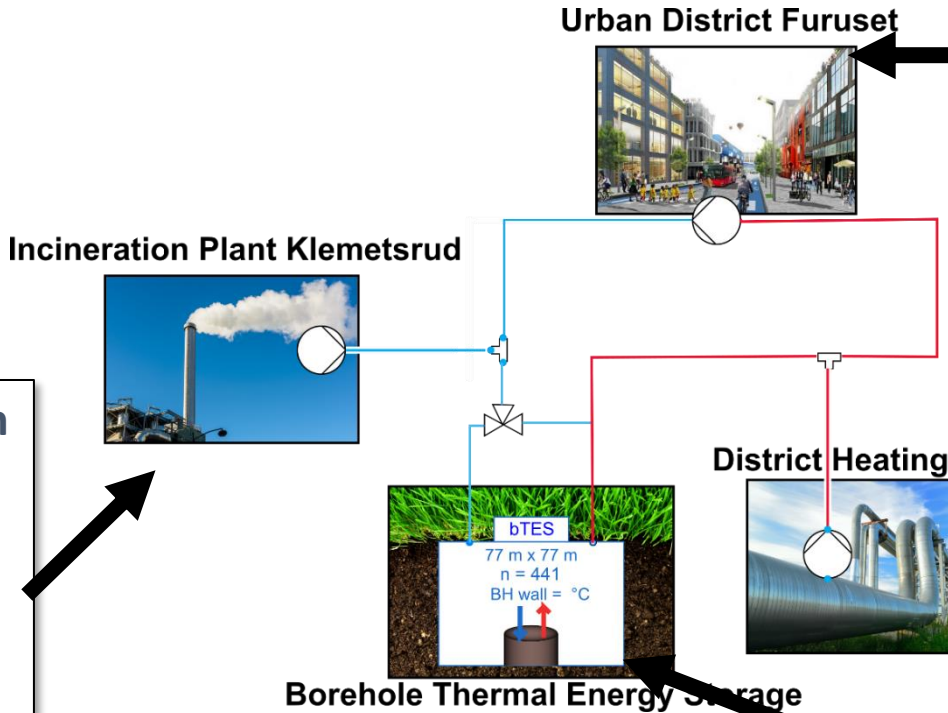
- District heating is effective in lowering the pressure on the power grid
  - Peak power and total yearly power demand reduced by 28 / 25 %, respectively

- Seasonal thermal energy storage is an important technology in enabling increased utilization of excess heat, and reducing the demand for peak heating sources.
  - Temperature not considered in the model
  - The study should be combined with more detaile physical modeling of the STES for more realistic estimation of heat available in different seasons

METHODOLOGY

Dynamic simulations

The model in Dymola



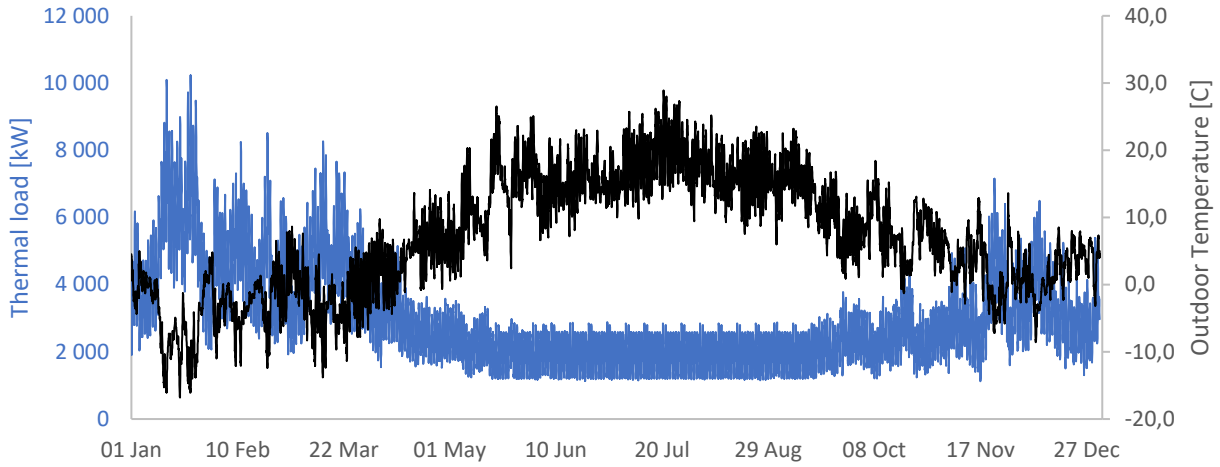
Data import from heat demand profile generator

Incineration Plant: If BTES charging then 360kg/s @85degC

DH import: Simplified heat import with heater

BTES: Dimensioned via SENS report results

Annual heat load at Furuset



- Aggregated load profile – assuming that the entire building mass at Furuset in 2030 will be heated by the local heating grid
- Maximum demand 10.1 MW
- Total annual heat demand 26 GWh

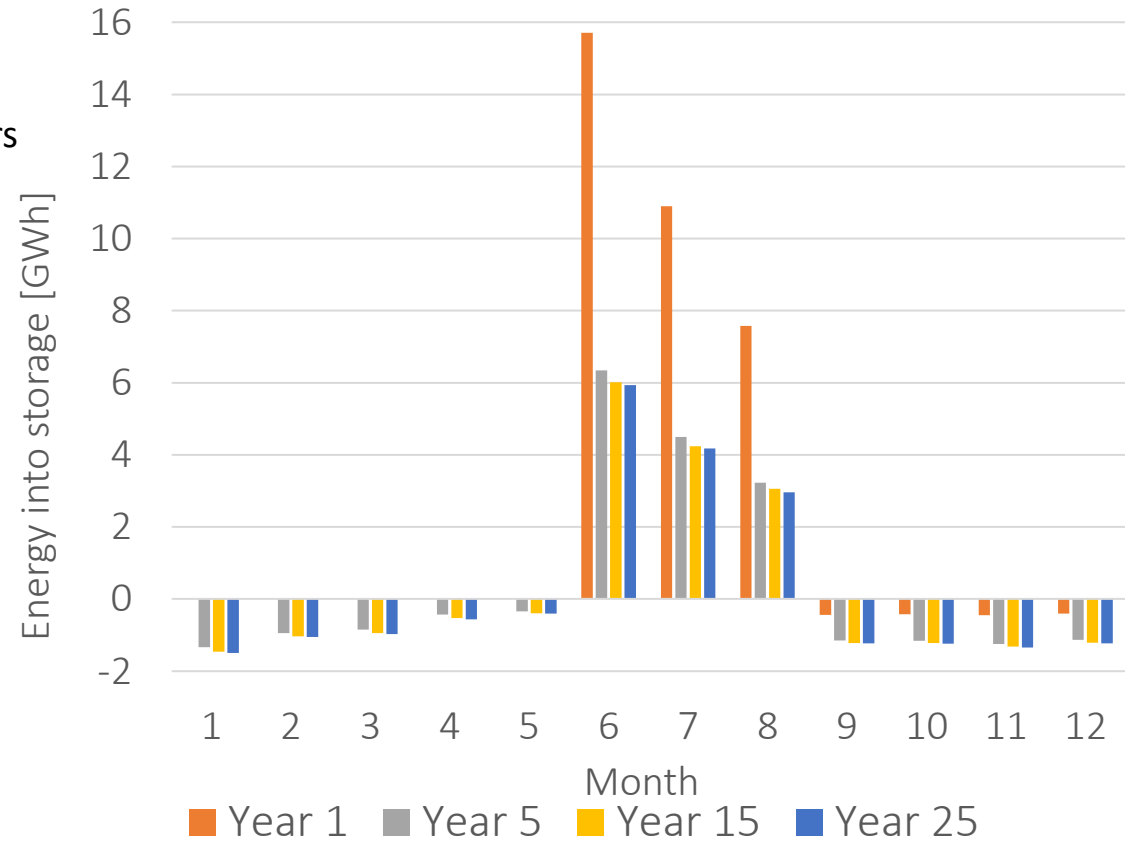
Design of the BTES

Borehole storage parameters

- 440 boreholes, 180 m deep, 6000 m² surface area, charging June-August
- Boreholes are in mixed serial and parallel connection

Steady-state performance parameters

- Charges with 13 GWh/year
- Provides 9.5 GWh/year
- 27 % heat loss



RESULTS

Dynamic simulations

Simulation Results:

When utilizing the stored heat?

- FIVE discharging strategies:

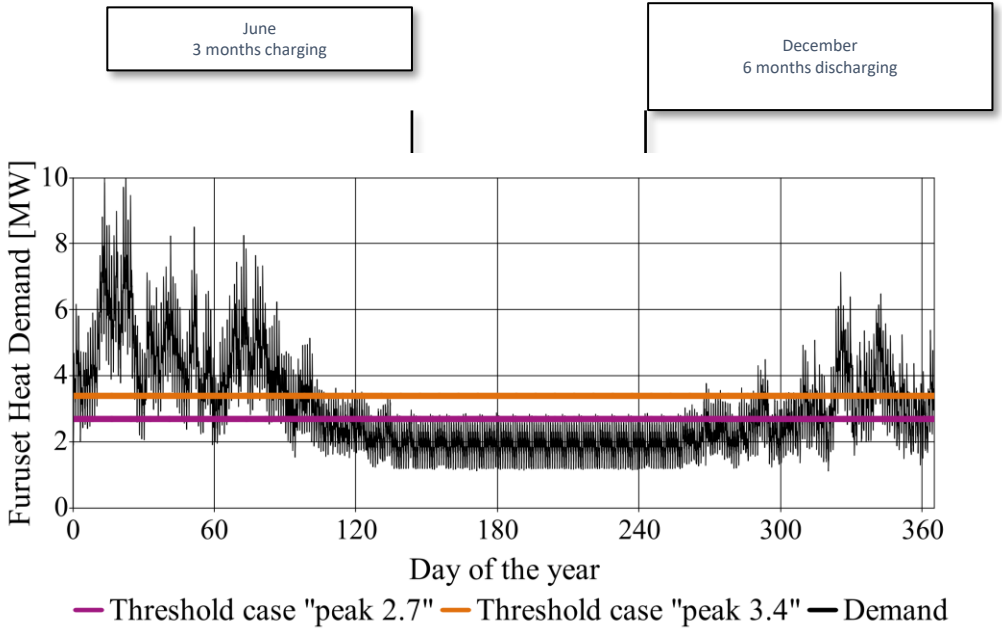
Start discharging in September

Start discharging in December

Start discharging when demand > 2.7 MW

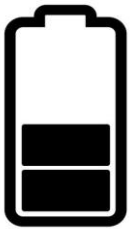
Start discharging when demand > 3.4 MW

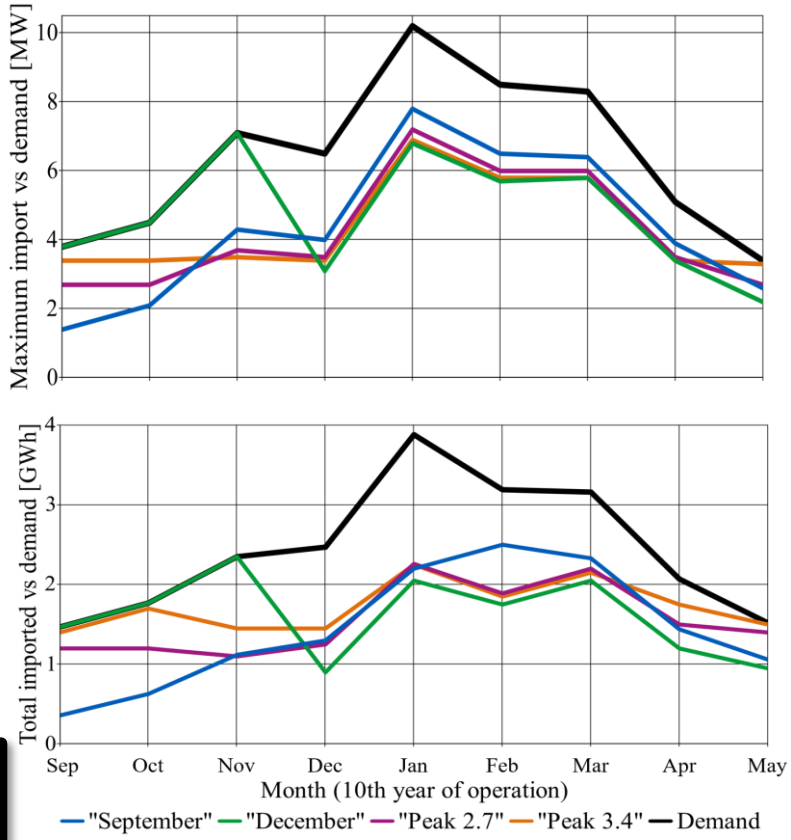
Start discharging in September – and charge also over the weekends



Simulation Results:

When utilizing the stored heat?





Case *September provides most heat* (8.94 GWh),
case *peak 3.4* the least (6.38 GWh)
-> Both *peak* cases provide only slightly increased peak reduction, but at the expense of overall utilization of stored heat

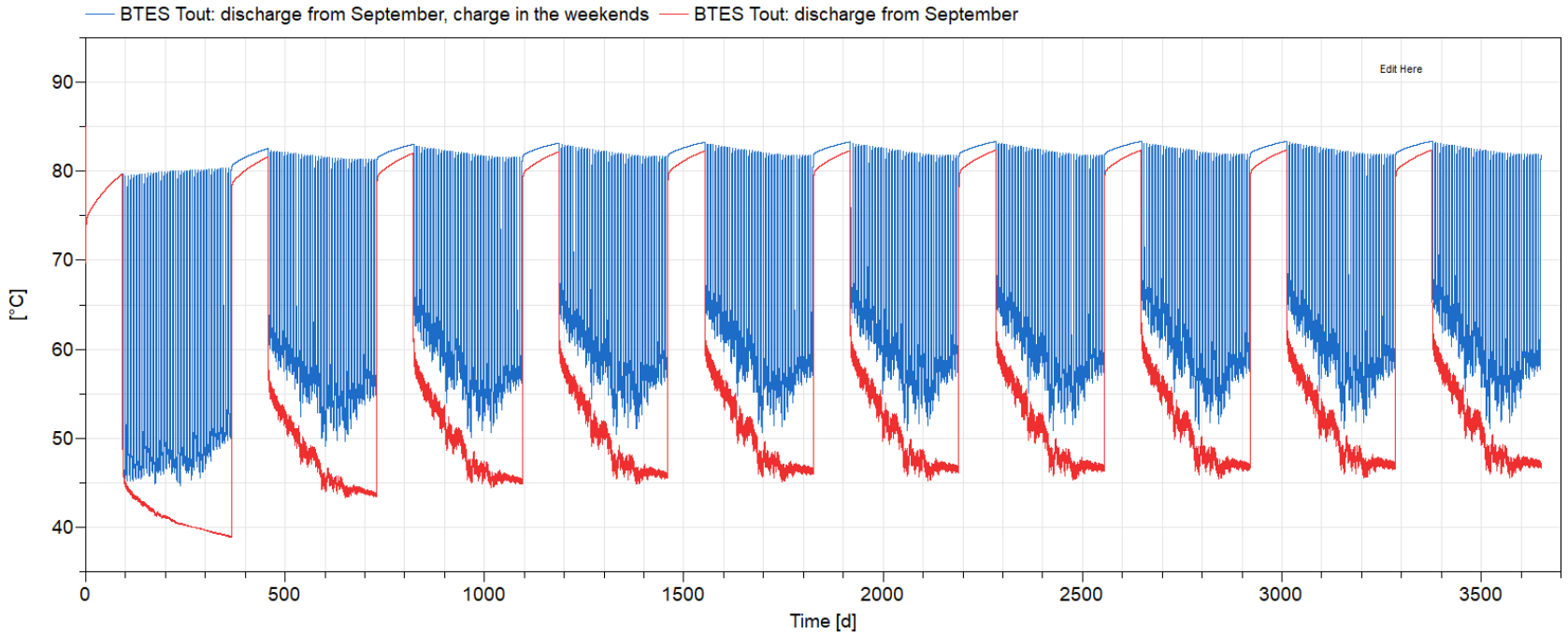
Case	Cost for heat import [MNOK/year]
September	10.04
December	11.16
Peak 2.7	10.48
Peak 3.4	11.26
No heat storage	16.40

Heat import costs are reduced by 31.3 – 38.8 %

Simulation Results:

BTES outlet temperature

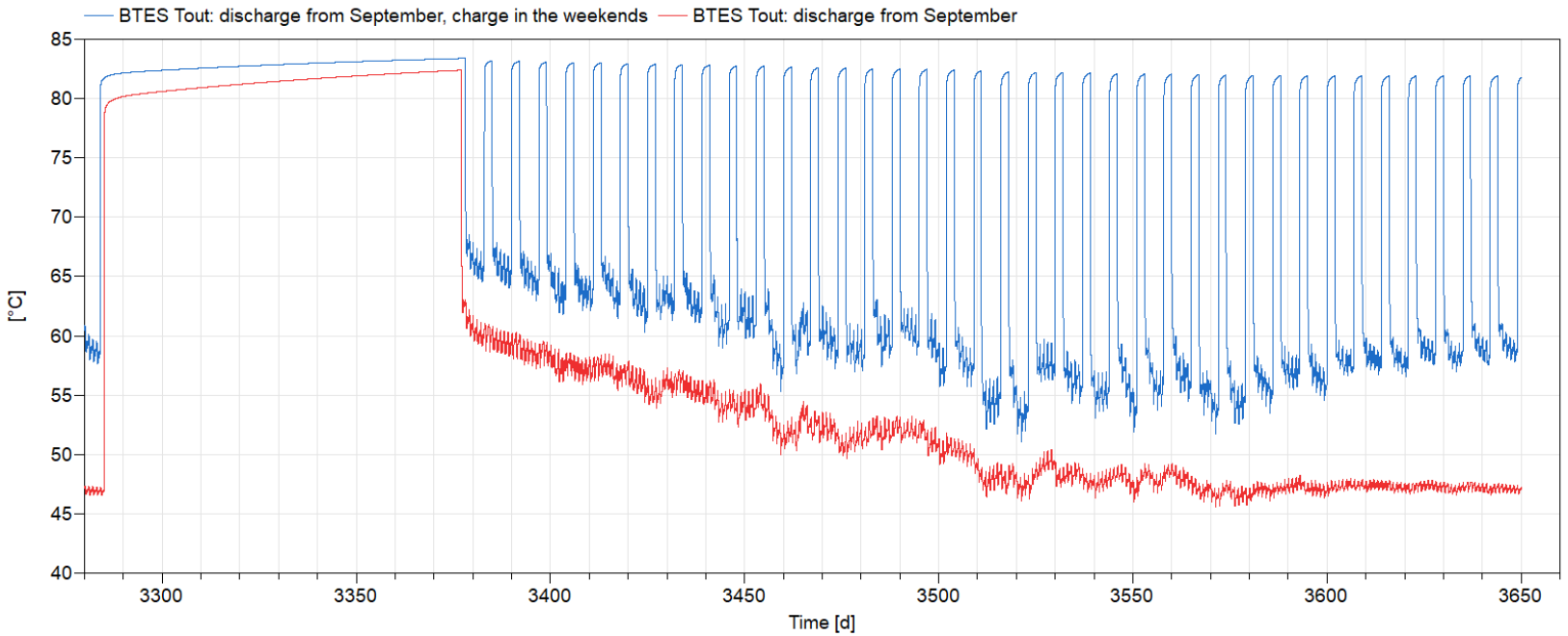
- Discharge from september, with/without charging in the weekends
- Simulation over 10 years



Simulation Results:

Outlet temperature

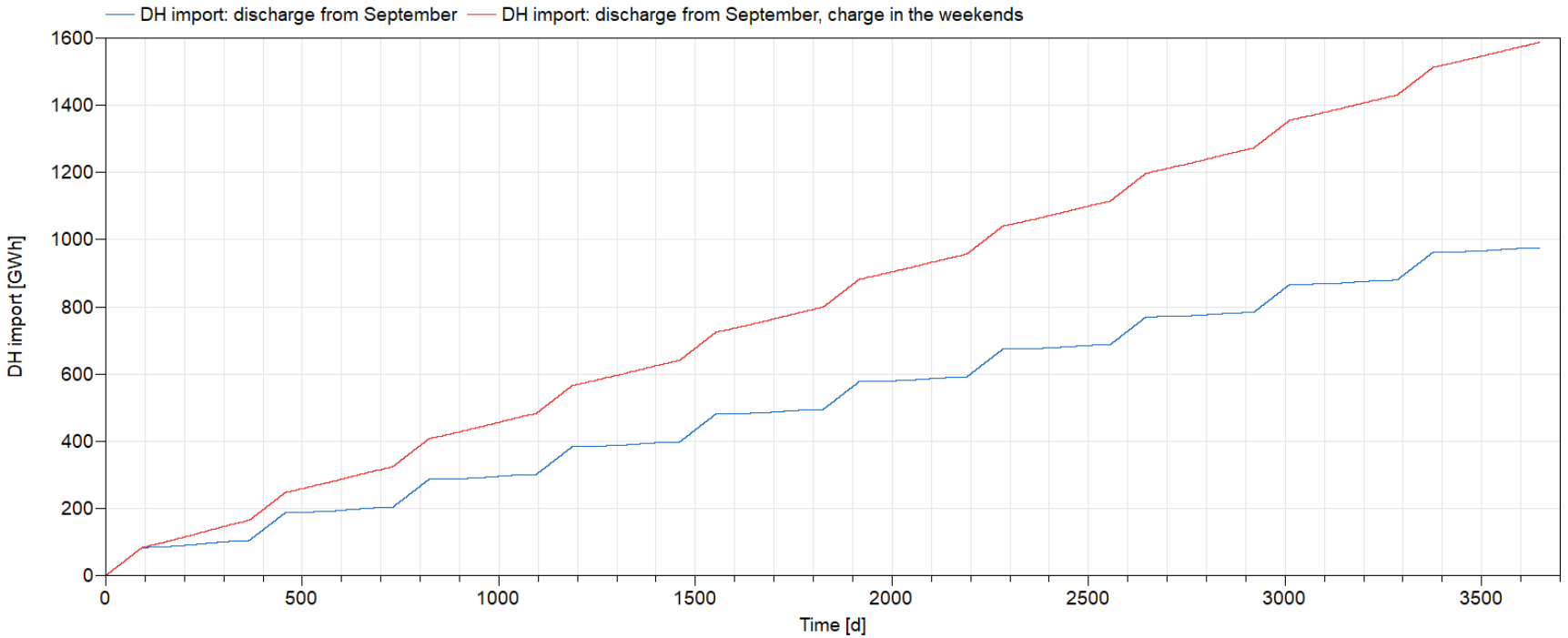
- Discharge from september, with/without charging in the weekends
- The last charging/discharging cycle



Simulation Results:

Imported heat

- Discharge from september, with/without charging in the weekends
- Heat import over 10 years



Conclusions

- A functioning model implemented in Modelica for studying the integration of HT BTES in a district heating systems
- Possibility to evaluate different charging/discharging strategies
- Trade-offs between
  - Outlet temperature from the BTES
  - Return temperature to district heating – *not studied in detail*
  - Amount of imported heat
- More studies needed to find the "optimal" integration and operation of a BTES for a given case

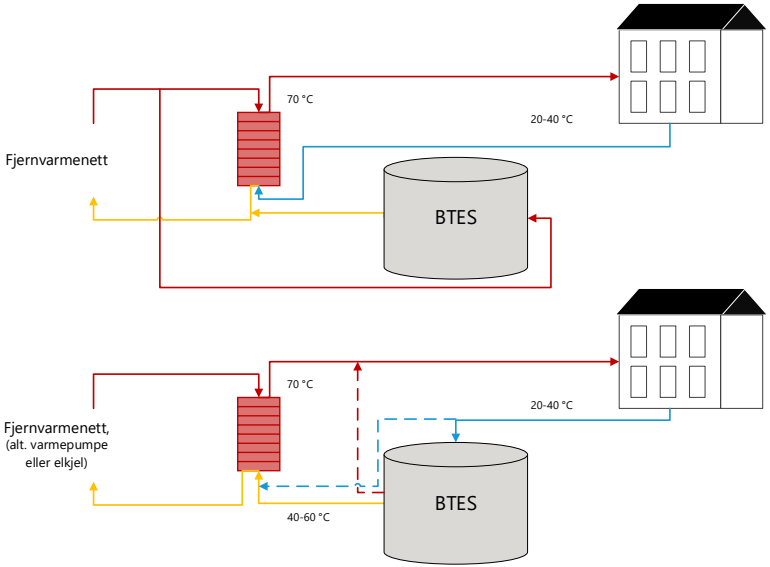
Overall conclusions

Modeling is a key for succesfull planning and design of a seasonal BTES

- Dynamic modeling: details of the operation and outlet temperatures
- Techno-economic modeling: system feasibility and the potential of the tecnology in the context of the green energy shift at large

Techno-economic modeling of seasonal storage is challenging!

- Optimization over a long time horizon required
- Combination with more detailed, dynamic modeling is beneficial



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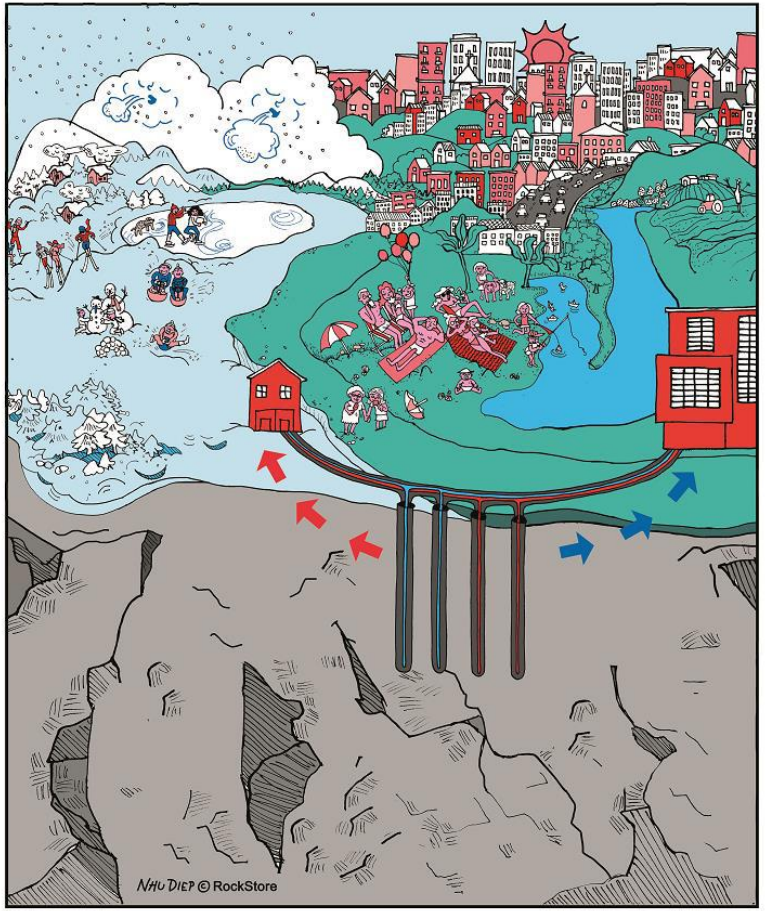
RockStore –
Develop, demonstrate and monitor the next generation BTES systems



Any questions?

hanne.kauko@sintef.no

https://fmezen.no

https://www.norceresearch.no/prosjekter/rockstore-develop-demonstrate-and-monitor-the-next-generation-btes-systems