A novel heat pump-based energy recycling system of an industrial building utilizing waste heat flows and geothermal energy

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Targets of the energy efficiency project utilizing energy recycling heat pumps

- The paper presents a case study, motivated by financial savings and CO_2 emission reductions for an industrial building in Finland based on realized costs and measured energy consumption.
  - The industrial building belongs to the ABB Group with multiple industrial facilities in Finland and around the world.
  - The company lives up to its energy program Mission to Zero, significantly reducing the carbon footprint of its buildings.
- The hybrid heat pump project presented in this case study was a part of an energy efficiency project carried out by Granlund Oy in Finland.
  - ➢ The objective was to design a future proof cost-efficient hybrid heat pump system utilizing all feasible heat sources with a high heating energy coverage rate (at least 95%).
  - ➢ The project focused also on general HVAC improvements in the building reducing the net consumption and on upcoming compulsory HVAC investments in the long-term investment plan.
  - ➢ For the customer paying the investment, a success indicator is that the energy system will receive the available government grants to produce a decent payback time.

Description of the industrial building own by the ABB company

- The investigated industrial building in this study, ABB assembly parts, is in southern Finland near Helsinki.

- Heating consumption is space and ventilation heating divided between the office and manufacturing parts.

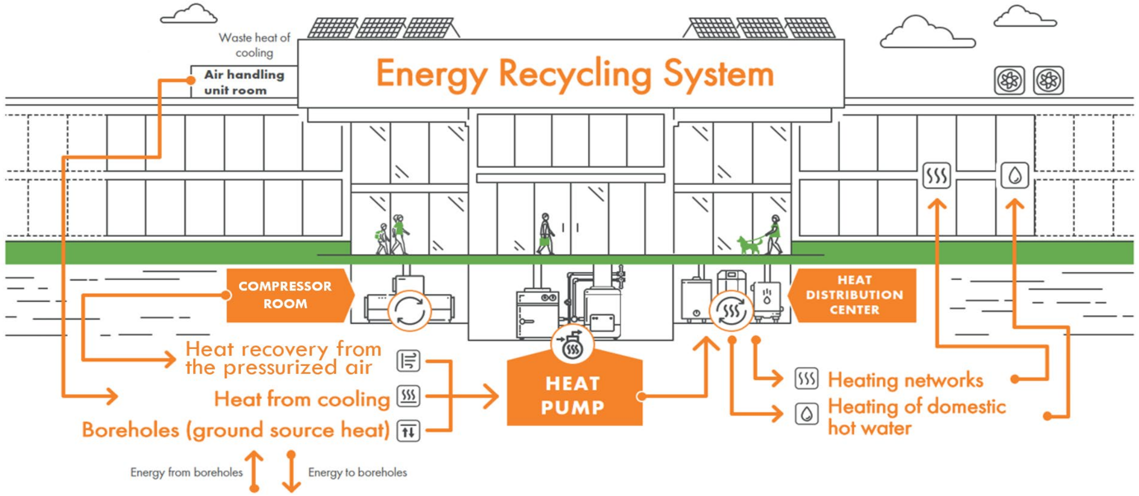
- The industrial building has high energy recycling potential due to the energy intensive plastic manufacturing process:

  - Constant process cooling

  - Waste heat from the pressurized air compressor needed in the manufacturing process

Description of the installed heat pump-based energy recycling system with boreholes

- The installed heat pump system is a hybrid heat pump system consisting of energy recycling and boreholes.
- Boreholes are used to support the energy recycling system:
  - Especially during weekends when no recycling is available
  - Store unused waste heat into the ground
- Heating energy coverage rate > 97 %, energy recycling only 63 %
- The existing chiller is used as backup whenever the heat pumps are not able to recycle heat from the cooling network to the heating networks.



Heat pumps	3x Gebwell Taurus EVI 110, **3 x 104 kW**
Domestic hot water heating	One heat pump in alternating mode
Energy recycling: cooling network	Heating capacity 100 kW at 10 / 5 °C
Energy recycling: pressurized air	Heating capacity 60 kW at 20 / 5 °C
Borehole field	**18 pcs of boreholes and depth 250 m**

Case study: Investigated heat pump systems

- The objective of the presented study was to:

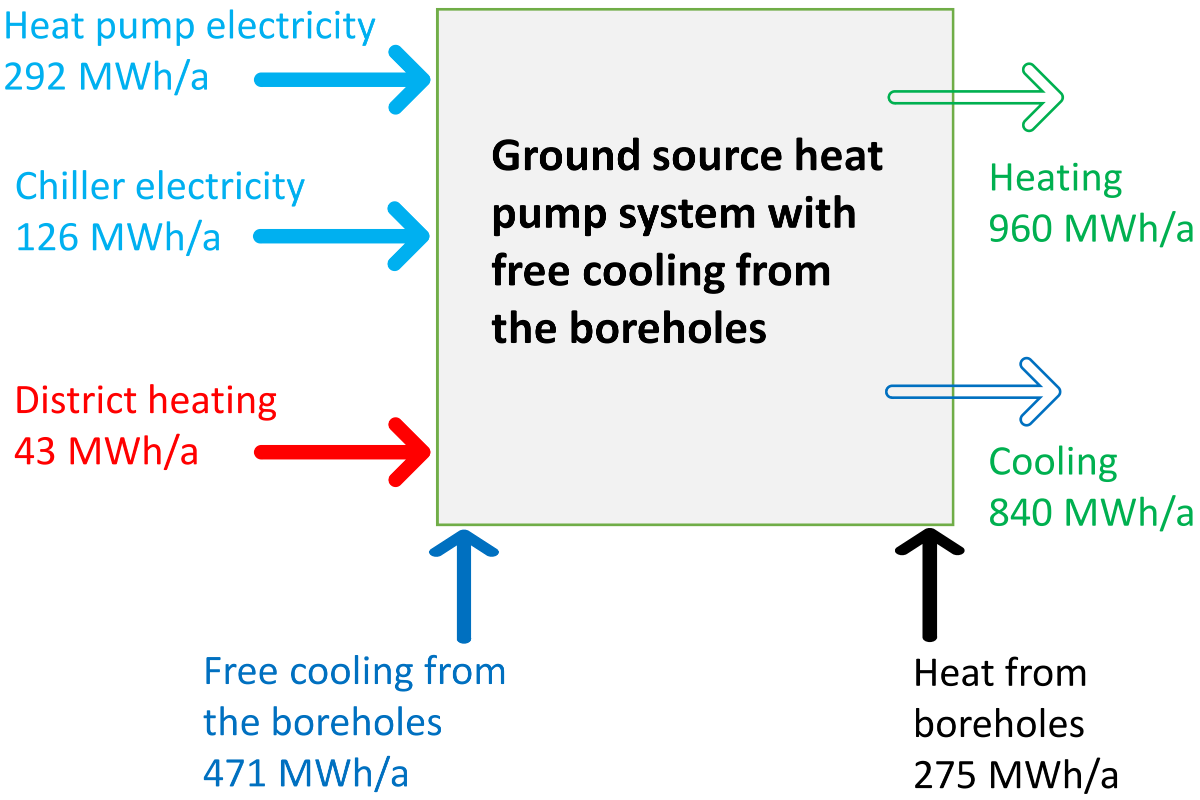
  - ➢ Compare the installed hybrid heat pump system to a conventional ground source heat pump system utilizing free cooling as concerns the energy performance of the system and financial viability.

- Energy recycling from the cooling networks and free cooling from the ground is the conventional approach in the Nordic countries.

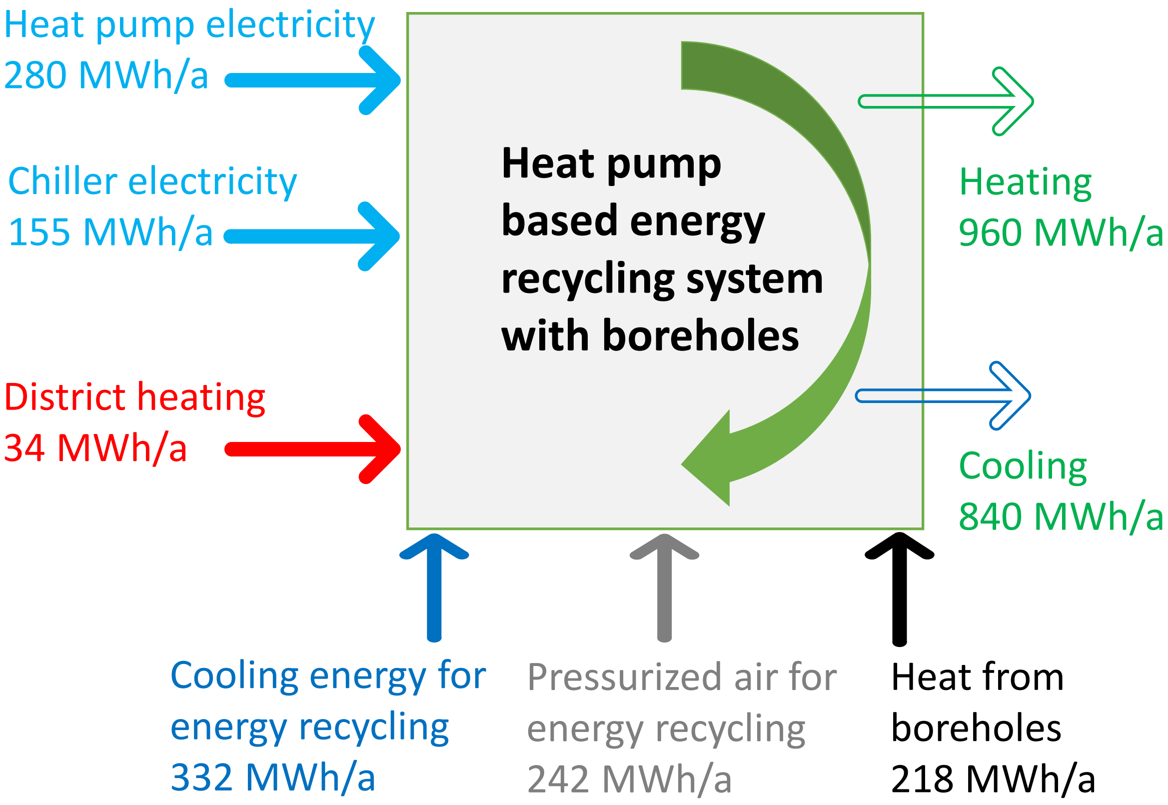
- The target was to achieve a high heating energy coverage rate using the heat pump system, at least 95% in accordance with the ABB's energy program "Mission to Zero".

- Energy system simulations were performed to compare the two heat pump systems:
  - Energy simulation tool IDA ICE 4.8.2 (Indoor Climate and Energy) with its ESBO plant interface (Early Stage Building Optimization) for simulation of energy systems

Energy balances of the compared heat pump systems



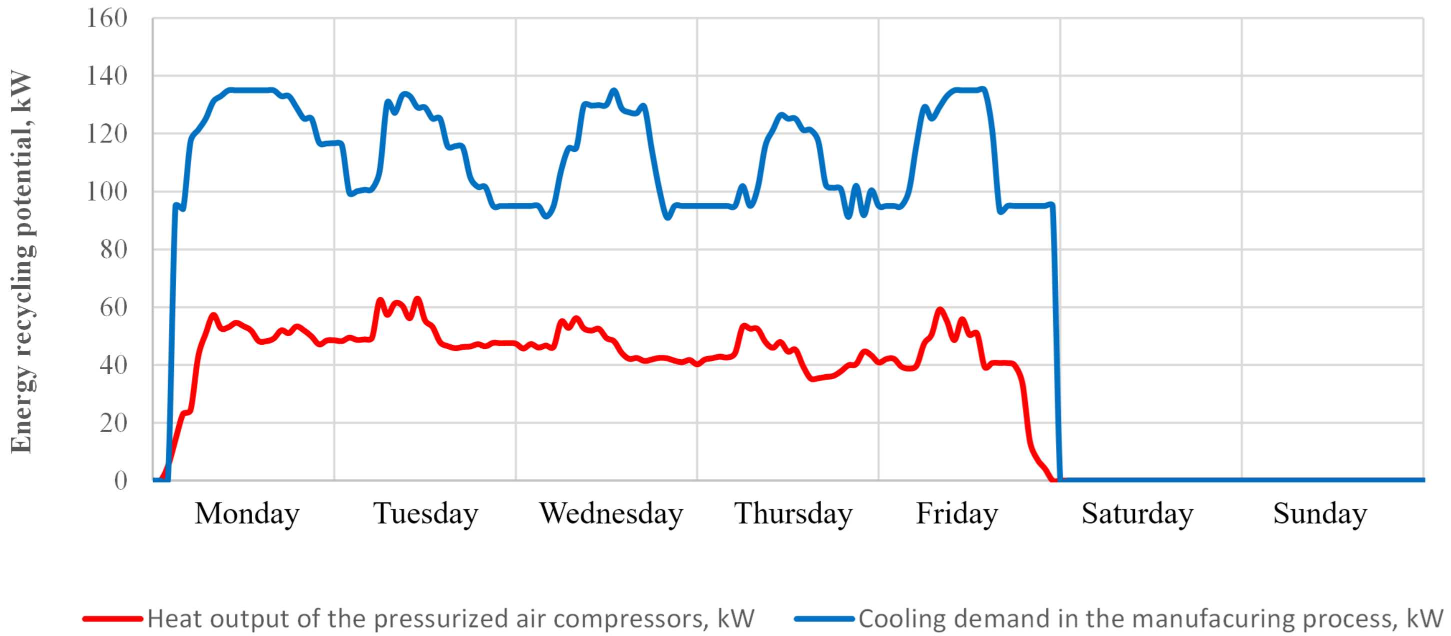
Heat into the boreholes 124 MWh/a



Heat into the boreholes 170 MWh/a

Consumption profiles in the energy system simulation

- Energy simulations were performed according to measured data from the old air 75 kW compressor (new 90 kW).
- The manufacturing line is closed from Friday evening to Monday morning: During weekends, the system is currently working as a normal ground source heat pump system.



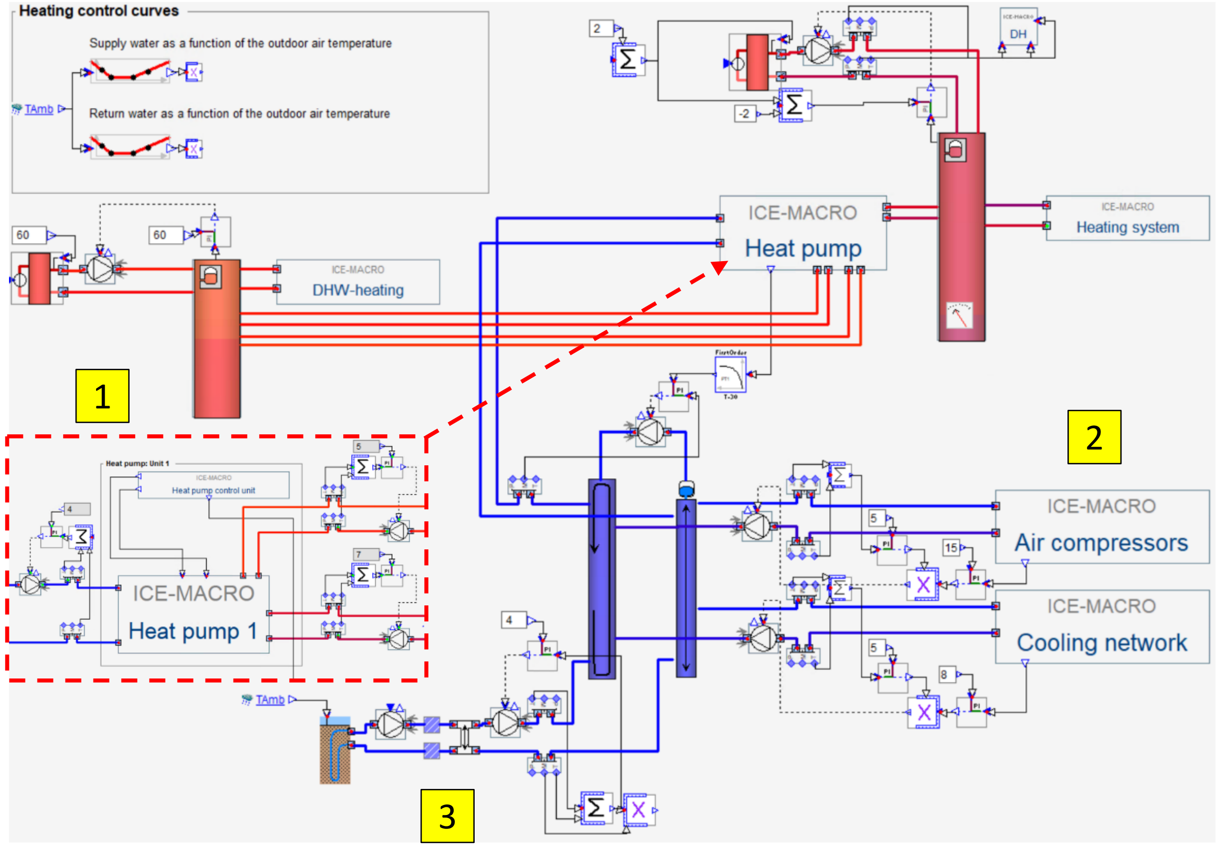
Simulation model for the hybrid heat pump system in IDA ICE

Energy simulation tool IDA ICE 4.8.2 (Indoor Climate and Energy) with ESBO plant interface (Early Stage Building Optimization)

1. Parametric heat pumps (macro model) using measured performance data

2. Energy recycling:
    - Heat recovery from the pressurized air compressors
    - Cooling network

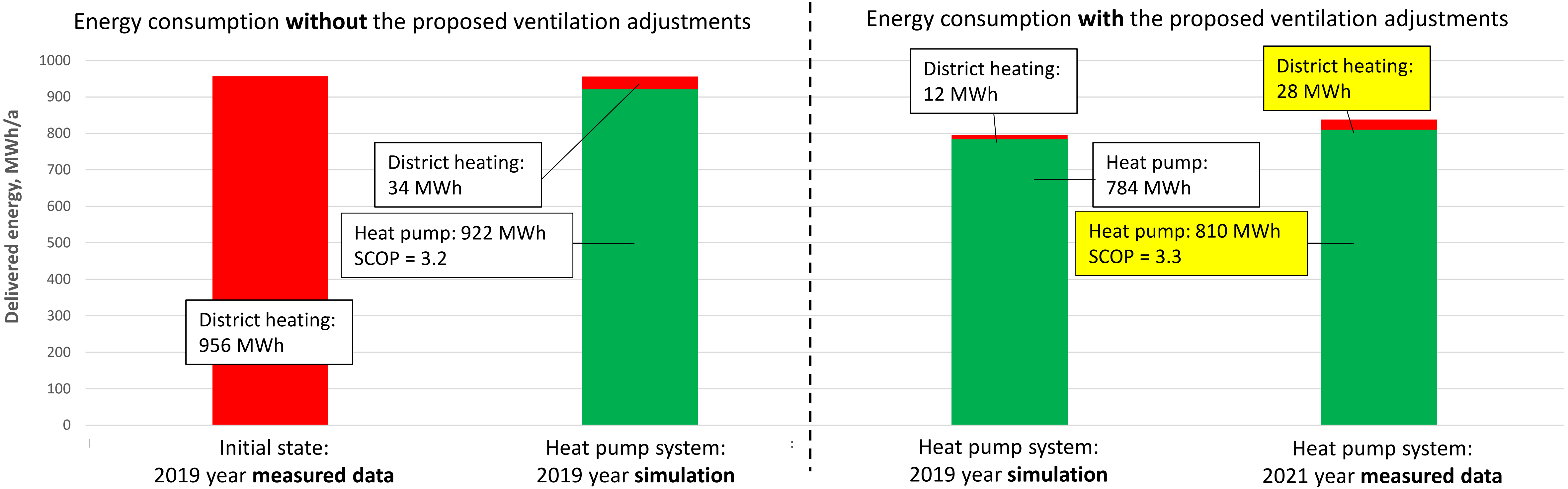
3. Borehole field



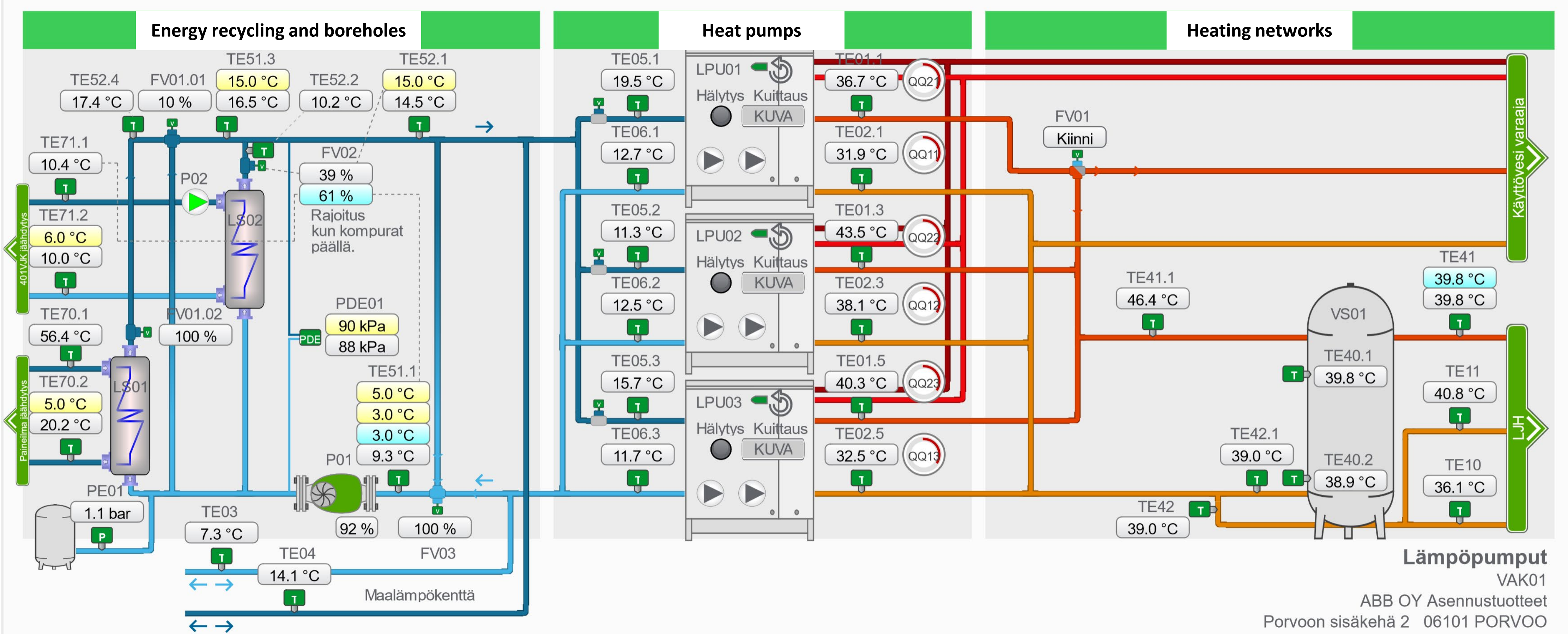
Energy monitoring of the hybrid heat pump system

The installed heat pump system has been operational since November 2021 and its performance is monitored through a new building automation system interface provided by Schneider Electric

Energy consumption



Energy monitoring of the hybrid heat pump system



Life cycle cost analysis

Energy tariffs:

- Electricity including distribution and taxes 85 €/MWh + power fee
- District heating 68 €/MWh + capacity fee

	Installed heat pump system		Conventional heat pump system with free cooling
Investment cost	447 k€		442 k€
District heating consumption	34 MWh		43 MWh
Seasonal COP	3.3		3.1
Life cycle cost savings during a life span of 20 years with energy grants (-20% of the investment cost)	661 k€		663 k€
Payback time without energy grants	9.1 years	Payback time almost identical	8.8 years
Payback time with energy grants (-20% of the investment cost)	7.3 years		7.1 years

Conclusions

- The installed hybrid heat pump system was dimensioned as a future proof solution and on the safe side:
  - A future proof dimensioning with extensive energy recycling was chosen because in the future manufacturing will most likely be active also during the weekends.
  - A safe side approach was chosen because it was unclear if the proposed changes to the ventilation system would be implemented due to high quality requirements of contaminant removal.
  - The extended operational hours of the manufacturing line in the future and the pressurized air compressor to be renewed soon are the main motivating factors for the chosen dimensioning.

- Financially the installed system is on par with the conventional heat pump system (payback time without energy grants about 9 years) with the present heating demand.
  - With the extended operational hours of the manufacturing line the differences will increase: More boreholes would be needed in the conventional system and the SCOP difference would increase.

- Monitoring revealed that there is room for improvement considering the supply water temperature curve: The COP value could be better with small optimizations.