Electrification of District Heating

FUTURE ENERGY SOLUTIONS
Lappeenranta, September 9 – 10

Pauli Hiltunen, pauli.hiltunen@vtt.fi

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Share of different energy sources in district heating

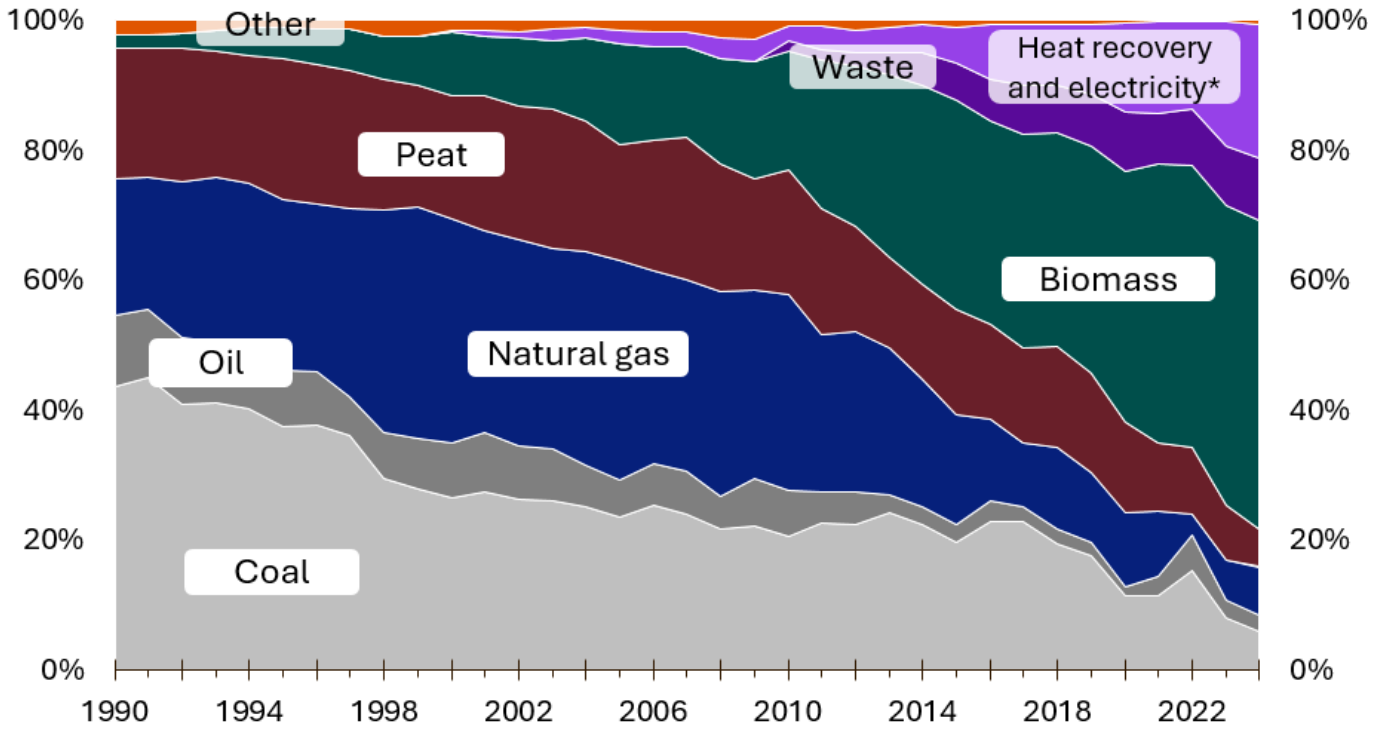

Figure from source: Finnish Energy. District heating statistics – District heating 2024 preliminary graphs. 2025. URL: https://energia.fi/en/statistics/district-heating-statistics/

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Heat pumps and electric boilers

- Heat pumps can utilize waste heat sources and ambient heat in district heat production
  - E.g. Waste heat from data centers, sewage water and outdoor air
  - The coefficient of performance (COP) is usually between 3 and 5
- Electric boilers convert electricity directly into heat (COP≈1)
  - The advantage is cheaper investment and more flexible production

Heat produced by electric boilers (GWh)

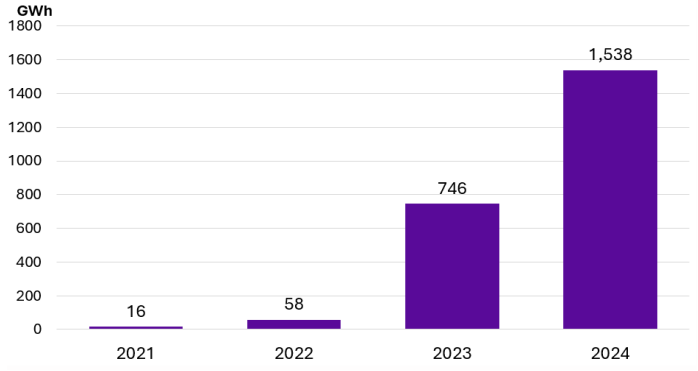

Figure from source: Finnish Energy. District heating statistics – District heating 2024 preliminary graphs. 2025.
URL: https://energia.fi/en/statistics/district-heating-statistics/

Decided electric boiler investments in Finland's district heating networks

Helsinki	540 MW
Espoo	150 MW
Vantaa	180 MW
Tampere	150 MW
Jyväskylä	120 MW
Rest of Finland	1 230 MW
Altogether	**2 370 MW**

Source: Confederation of Finnish Industries. Green investments in Finland.
URL: https://ek.fi/tutkittua-tietoa/vihreat-investoinnit/

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Benefits of electrification of district heating

- Electrification can reduce the consumption of fossil fuels and biomass in district heat production
- Emissions caused by district heat production can be reduced through electrification
  - Although emission factor of district heating has decreased, it is still higher than electricity's in Finland

Emission factor of district heating 2023[1]	85 kg_{CO2}/MWh
Electricity emission factor 2023[2]	36 kg_{CO2}/MWh

- Electric boilers and heat pumps can be run when electricity is cheap and there is a lot of renewable power (wind and solar) available
  - Electric boilers are usually placed in connection with heat storages, which increases flexibility
- Heat pumps are usually used for base load and have a long annual operation time
- The annual operation time of electric boilers is shorter

Sources: 1. Finnish Energy. District heating statistics. https://energia.fi/tilastot/kaukolampotilasto/
2. Fingrid. Sähköntuotannon ja –kulutksen CO2-päästöarviot. https://www.fingrid.fi/sahkomarkkinainformaatio/co2

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Backbone modelling framework

- Developed by VTT
- Open access: https://gitlab.vtt.fi/backbone/backbone/
- North European energy system model (https://github.com/vttresearch/north_european_model)
  - Power systems of 14 Northern and Western European countries
  - District heating systems in eight countries and the seven largest cities in Finland
  - Industrial sector and hydrogen
  - Electricity transfers between countries and regions
- Helsinki region DHC model (https://gitlab.vtt.fi/backbone/models/helsinki-dhc-model)
  - The District heating system of the Helsinki Metropolitan Area (Helsinki, Espoo, Vantaa)
- The models minimize the total costs of the modelled systems

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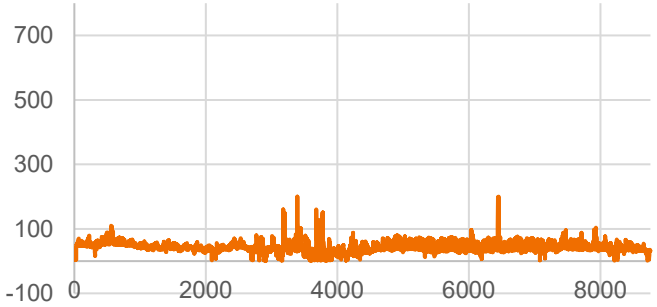
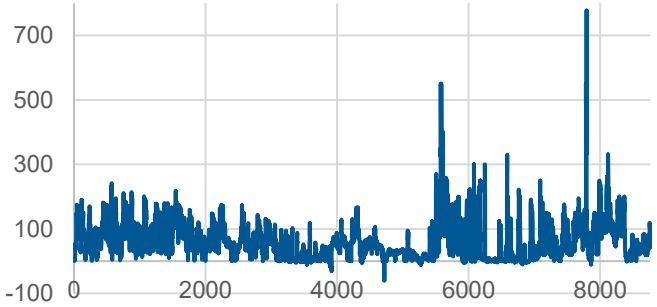
Electrified district heating as part of the electricity markets

- The increasing capacity of wind and solar power has increased the volatility of electricity prices
- Electrified district heating can balance fluctuations in electricity prices by consuming excess renewable electricity
- District heating networks and heat storages can be used as energy storage for fluctuating renewable power

Electricity price 2019 (€/MWh)



Electricity price 2023 (€/MWh)



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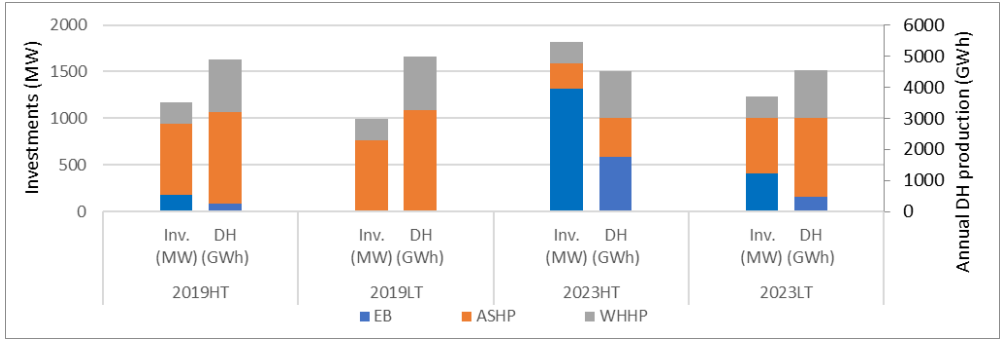
Helsinki region DHC model

(Electrification of district heating: The impact of electricity price volatility and distribution temperatures on the optimal capacity mix)

- Optimal investments of electric boilers (EB), air source heat pumps (ASHP), and waste heat heat pumps (WHHP) were studied in four scenarios:
  - Two different scenarios of electricity price
    - High volatility (2023) and low volatility (2019)
    - The annual average was equal
  - Scenarios of high network temperature (HT) and low network temperature (LT)



- Volatile electricity price favored the electric boilers
- Lower distribution temperatures increased the profitability of heat pumps over the electric boilers

Ref.: Hiltunen, P.; Lindroos, T.J.; Rämä, M. Electrification of District Heating: The Impact of Electricity Price Volatility and Distribution Temperatures on the Optimal Capacity Mix. 2025 (In review)

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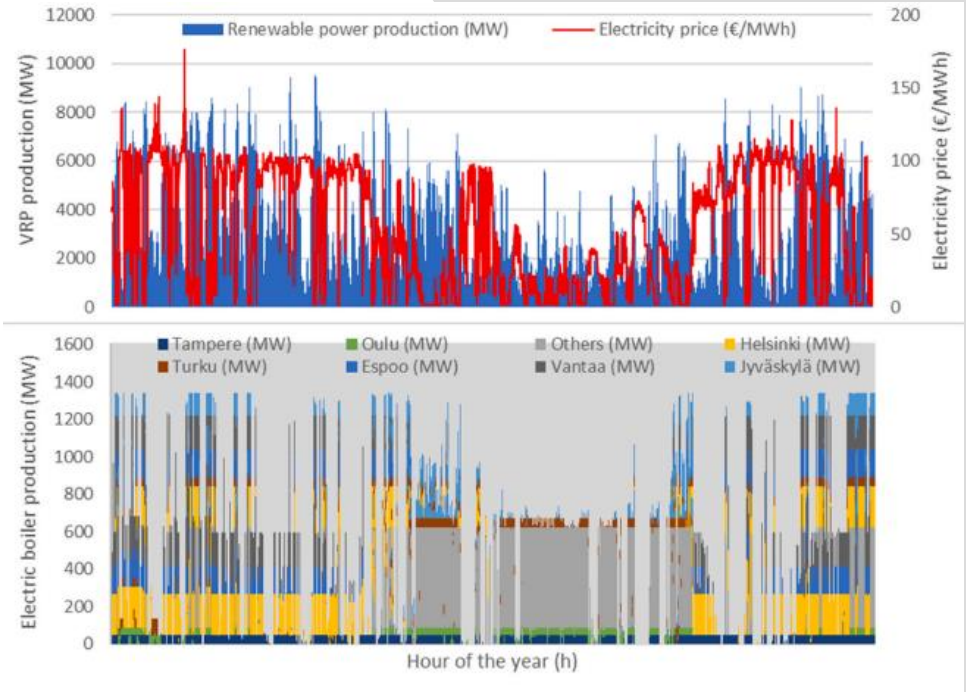
North European energy system model

(The impact of electric boilers and heat storages in the Nordic power markets and district heating systems)

- North European energy system was modelled in three scenarios:
  - 0 GW of electricity boilers (EB)
  - 1.34 GW of EBs in Finland
  - 2.68 GW of EBs in Finland
- The EBs increased the average Finnish electricity price by and 6.7% and 9.4%
  - The EBs in Finland had an impact on the electricity price in the neighboring countries as well
- DH production costs decreased



Ref.: Hiltunen, P.; Lindroos, T.J.; Rämä, M. The impact of electric boilers and heat storages in the Nordic power markets and district heating systems. Cleaner Engineering and Technology. 2025. Vol. 27, 101028. https://doi.org/10.1016/j.clet.2025.101028

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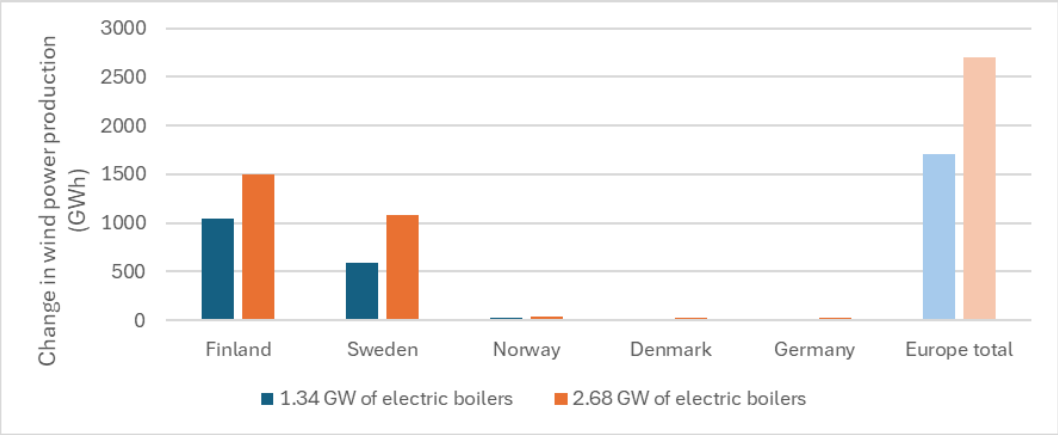
Impact of electric boilers on wind power production

- The electric boilers produced 3.3 TWh (1.34 GW of EBs) and 4.8 TWh (2.68 GW of EBs) => 9% and 13% of the Finnish DH production
- Wind power production increased by 1.7 – 2.7 TWh in the modelled area
  - In Finland the increase was 1.1 and 1.5 TWh (4.7% and 6.8%)
  - In Sweden 0.6 and 1.1 TWh (1.2% and 2.2%)



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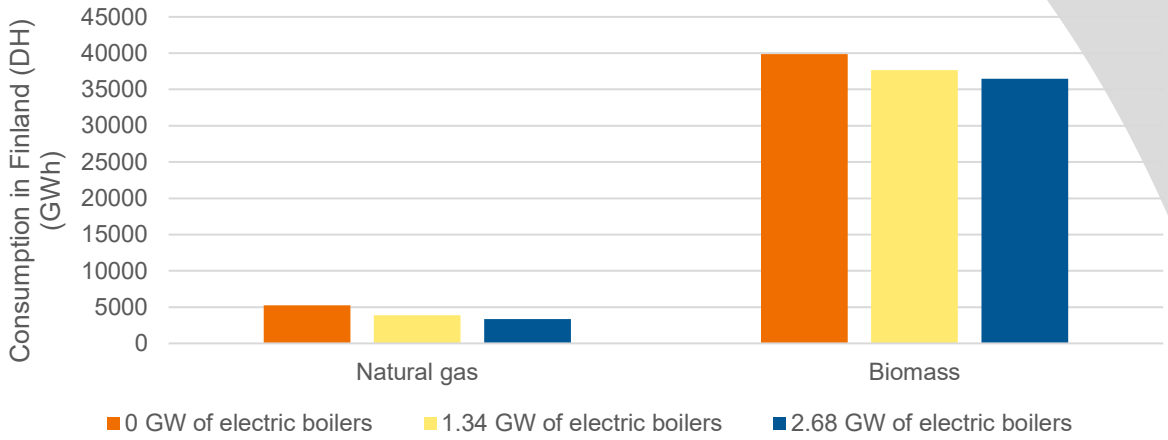
Impact of electric boilers on fuel consumption



- Electric boilers reduced the consumption of both natural gas (-26.2% and -36.2%) and biomass (-5.5% and -8.5%) in Finland
- On the other hand, the production of CHP electricity from biomass increased slightly

Ref.: Hiltunen, P.; Lindroos, T.J.; Rämä, M. The impact of electric boilers and heat storages in the Nordic power markets and district heating systems. Cleaner Engineering and Technology. 2025. Vol. 27, 101028. https://doi.org/10.1016/j.clet.2025.101028

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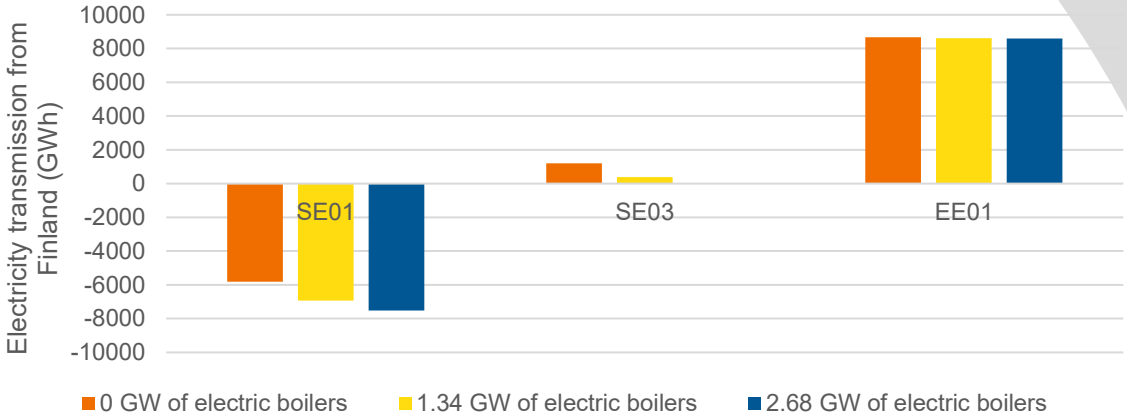
Power transmission



- Electric boilers also had an impact on the export and import of electricity
  - Electricity exports decreased and imports increased
- Changes in electricity exports and imports increased the consumption of fossil fuels and biomass in the neighboring countries
  ⇒Total emissions did not decrease

Ref.: Hiltunen, P.; Lindroos, T.J.; Rämä, M. The impact of electric boilers and heat storages in the Nordic power markets and district heating systems. Cleaner Engineering and Technology. 2025. Vol. 27, 101028. https://doi.org/10.1016/j.clet.2025.101028

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Combined heat and power plants and electrified district heating

- CHP together with electrified district heating can balance the district heating production costs

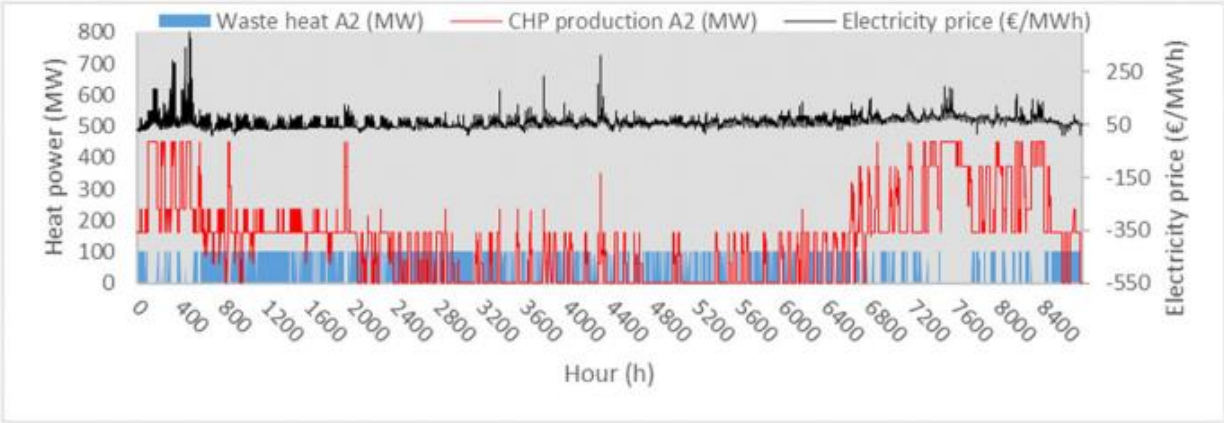

Figure from: Hiltunen, P.; Syri, S. Low-temperature waste heat enabling abandoning coal in Espoo district heating system. 2021. Energy. Vol. 231. 120916. DOI: https://doi.org/10.1016/j.energy.2021.120916

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Cities' electricity balance

- Combined heat and power plants have been an important source of electricity in Finland
- Due to rising fuel prices, low electricity prices, Finland's climate targets, and alternative production methods, the role of CHP in the electricity markets has decreased
- District heating systems are changing from electricity producers to consumers of electricity

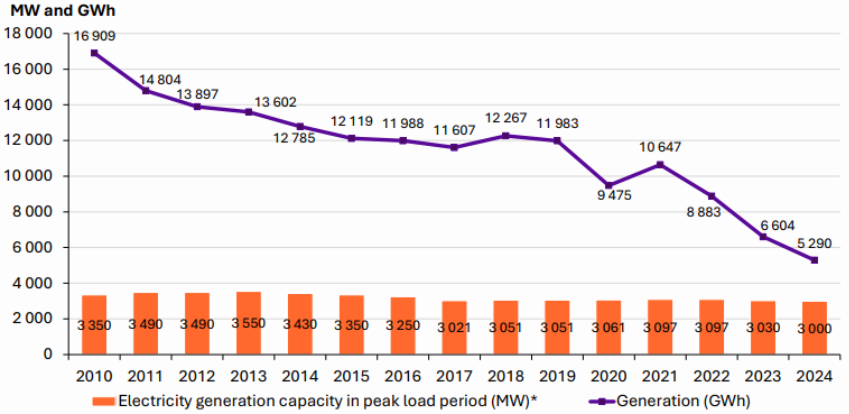

Figure from: Finnish Energy. Statistics on electricity. Energy Year 2024 - Electricity. 15.1.2025. URL: https://energia.fi/en/statistics/statistics-on-electricity/

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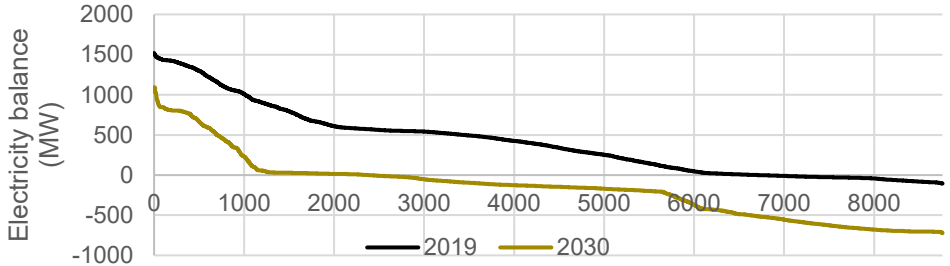
Modelling of the Helsinki region district heating system: Stability curve of electricity balance 2019 vs 2030



Electricity balance = electricity production – electricity consumption

"The connection of electricity consumption facilities to the main grid is temporarily tight in southern Finland"
- Fingrid 21.1.2025
URL: https://www.fingrid.fi/en/news/news/2025/the-connection-of-electricity-consumption-to-the-main-grid-is-temporarily-tight-in-southern-finland/

Retirement of the CHP capacity together with increasing electrification of the district heating systems may increase the risk of power deficit during the periods of extreme cold and low wind (Koivunen et al.).

Koivunen, T.; Syri, S.; Mikola, I. The impact of district heat electrification on electricity market scarcity situations in Finland. IEEE. 2025 21st International Conference on the European Energy Market (EEM). DOI: 10.1109/EEM64765.2025.11050307

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