WHAT ROLE DO CHP PLANTS AND ELECTRIC HEAT GENERATORS PLAY IN DECARBONISED DISTRICT HEATING NETWORKS?

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ENSURE
*Neue **E**nergie**N**etz**S**trukt**UR**en für die **E**nergiewende*

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Agenda

- Motivation and research question
- Step 1: Definition of scenarios and typified heating networks
- Step 2: Model based scenario analysis with the PowerFlex electricity market model
- Step 3: Sensitivity analysis
- Conclusion and next steps

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Motivation and research question

- Motivation:
  - The generation of district heating in Germany is based on fossil fuels and CHP plants.
  - To decarbonise district heating generation, fossil fuels must be replaced by renewable energies.
  - Need for new technologies (e.g. large scale heat pumps) and new energy carriers (e.g. electricity, hydrogen, geothermal energy, waste heat and solar thermal energy).

- Research question:
  - What role can CHP plants and electrical heat generators play in decarbonised district heating networks (e.g. as a flexibility option)?
  - How do they interact with the electricity system (e.g. load peaks and residual load)?

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Step 1: Definition of scenarios and typified heating networks

- Scenarios defined in the Kopernikus project ENSURE (Phase II, 2020 – 2022):
  - ENSURE scenario A (missed target scenario with regard to climate neutrality)
  - ENSURE scenario B (focus on Paris-compatible reduction path)
  - ENSURE scenario C (focus on European integration)
  - ENSURE scenario D (focus on decentralized energy transition)
- <u>Scenario update:</u> **ENSURE scenario B 2045** (with Wind & PV from NEP scenario B 2045)
- Six typified district heating networks were defined for Germany:
  - One local district heating network with 20% of total building heat covered by district heating
  - Four metropolitan networks, each with a share of 20% of total building heat and 5% of total process heat covered by district heating
  - One industrial network with 80% of total process heat covered by district heating

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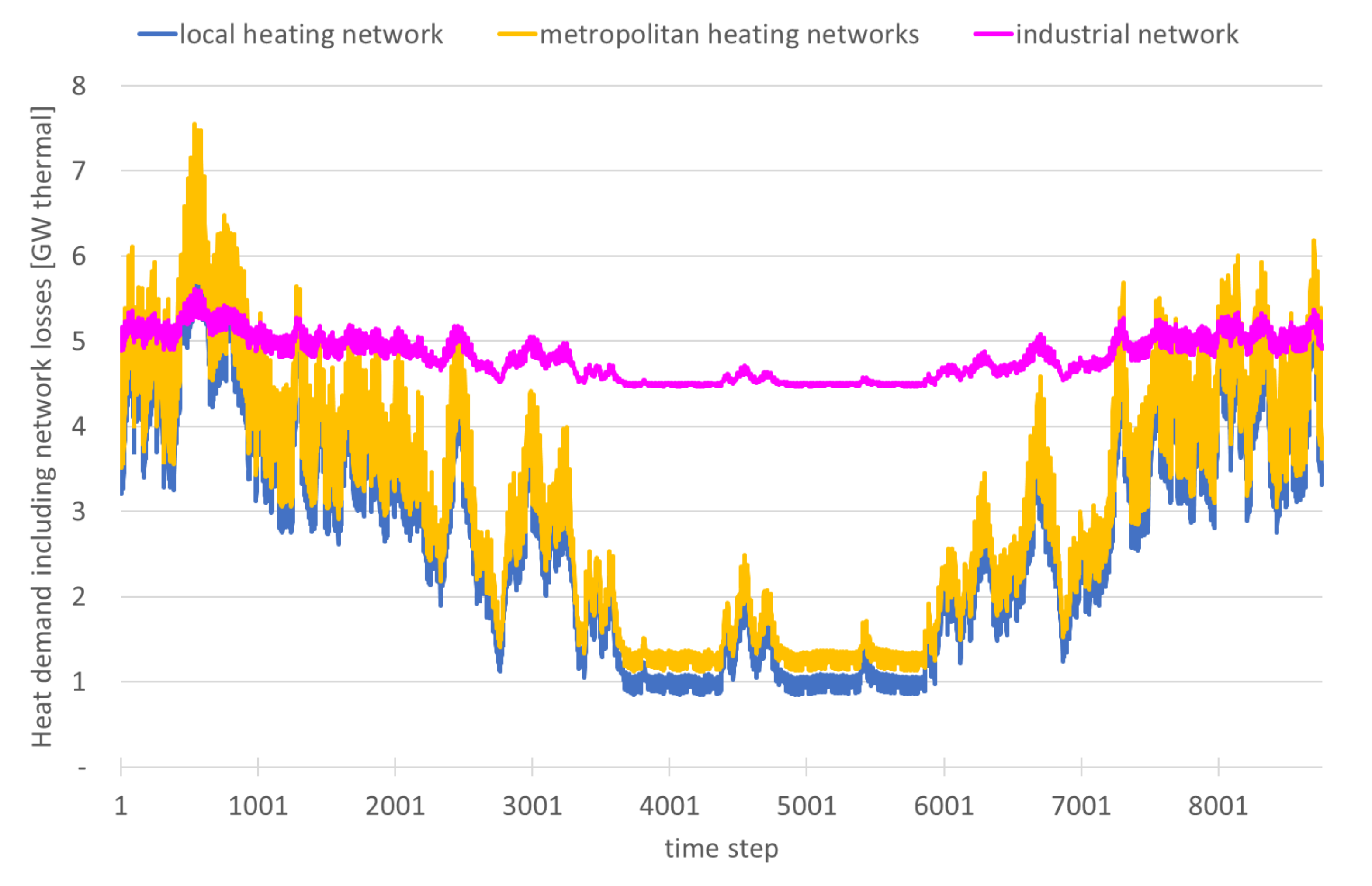
Six typified district heating networks: hourly profiles for ENSURE Scenario B 2045

- Total annual heat demand covered by district heating networks (including network losses): 170 TWh
- Seasonal heat demand for local and metropolitan heating networks
  - Local: 24 TWh
  - Metropolitan: 26 TWh
- Nearly uniform heat demand for industrial heating network of about 42 TWh



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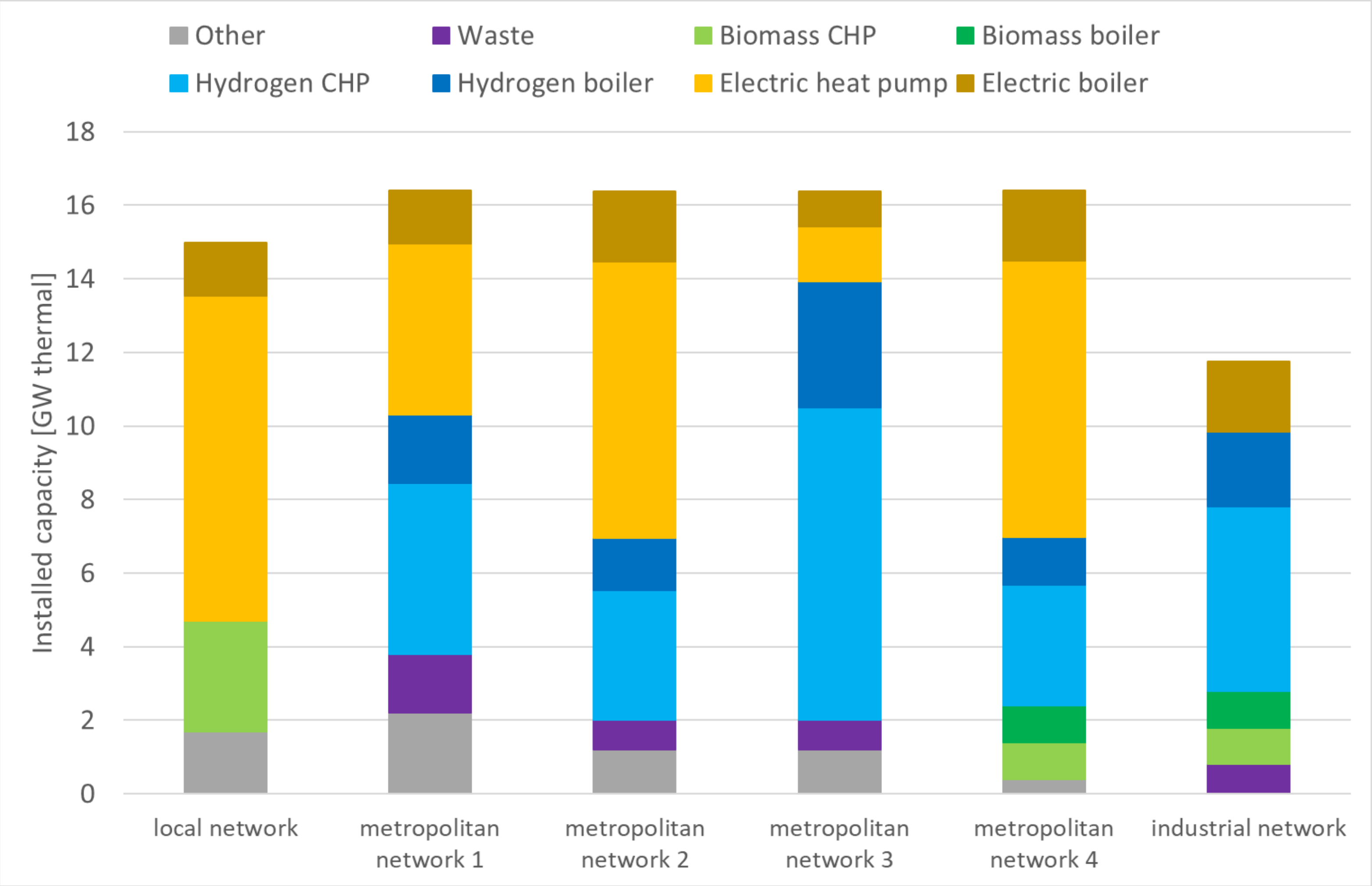
Six typified district heating networks: installed capacity of energy carrier specific plant fleet for ENSURE Scenario B 2045

- **Criteria to distinguish metropolitan networks**
  - Continuous heat supply
  - 2: focus on electricity
  - 3: focus on hydrogen
  - 4: no waste, but biomass
- **Merit order of heating technologies:**
  - Cheapest options: other (geothermal energy, waste heat and solar thermal energy) and waste
  - Expensive option: hydrogen boiler



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Step 2: Model based scenario analysis with the PowerFlex electricity market model

- **Regional scope:**
  - 27 ENTSO-E countries
  - NTC limit cross-border flows (transport model)

- **Dispatch optimization:**
  - Minimization of total marginal costs from generation plants, storage facilities and demand-side flexibility options.
  - Marginal costs of heat generation from electrical heat generators as well as CHP plants arise during the simultaneous dispatch decision and vary as a result per hour and district heating network.

- **Typical results:** generation mix, application profiles, full load hours, marginal prices of electrical and thermal load constraints

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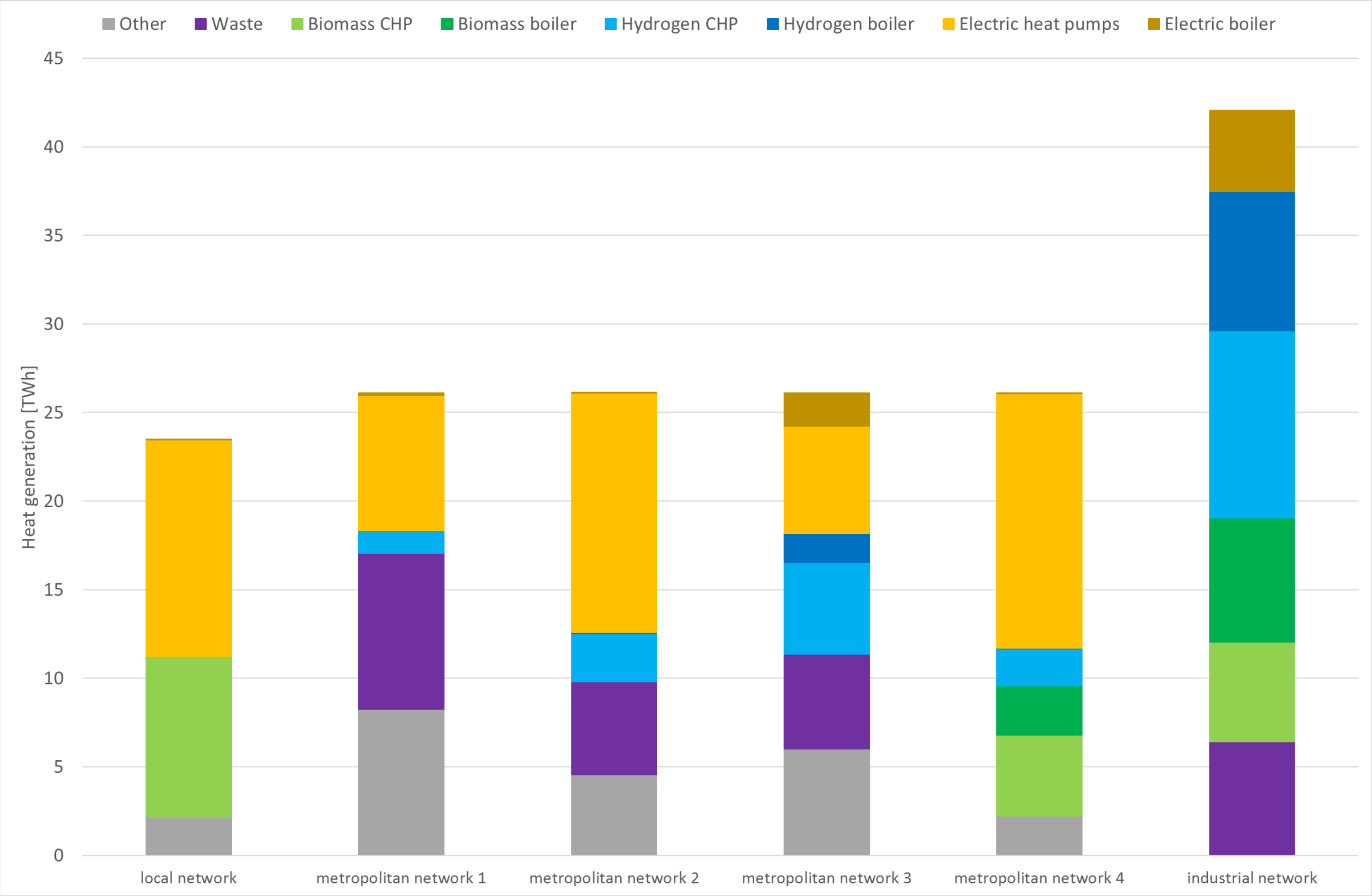
Preliminary results: energy carrier specific mix and full load hours for district heat generation in updated ENSURE Scenario B 2045

- **Energy carrier specific mix (average over all networks)**
  - Electricity: 23%
  - Hydrogen: 23%
  - Biomass: 22%
  - Other: 17%
  - Waste: 15%
- **Full load hours (average)**
  - Waste & other: 5.000 – 6.500 h
  - Biomass: 4.000 – 5.000 h
  - Heat pumps: 1.800 h
  - Hydrogen: 1.000 h



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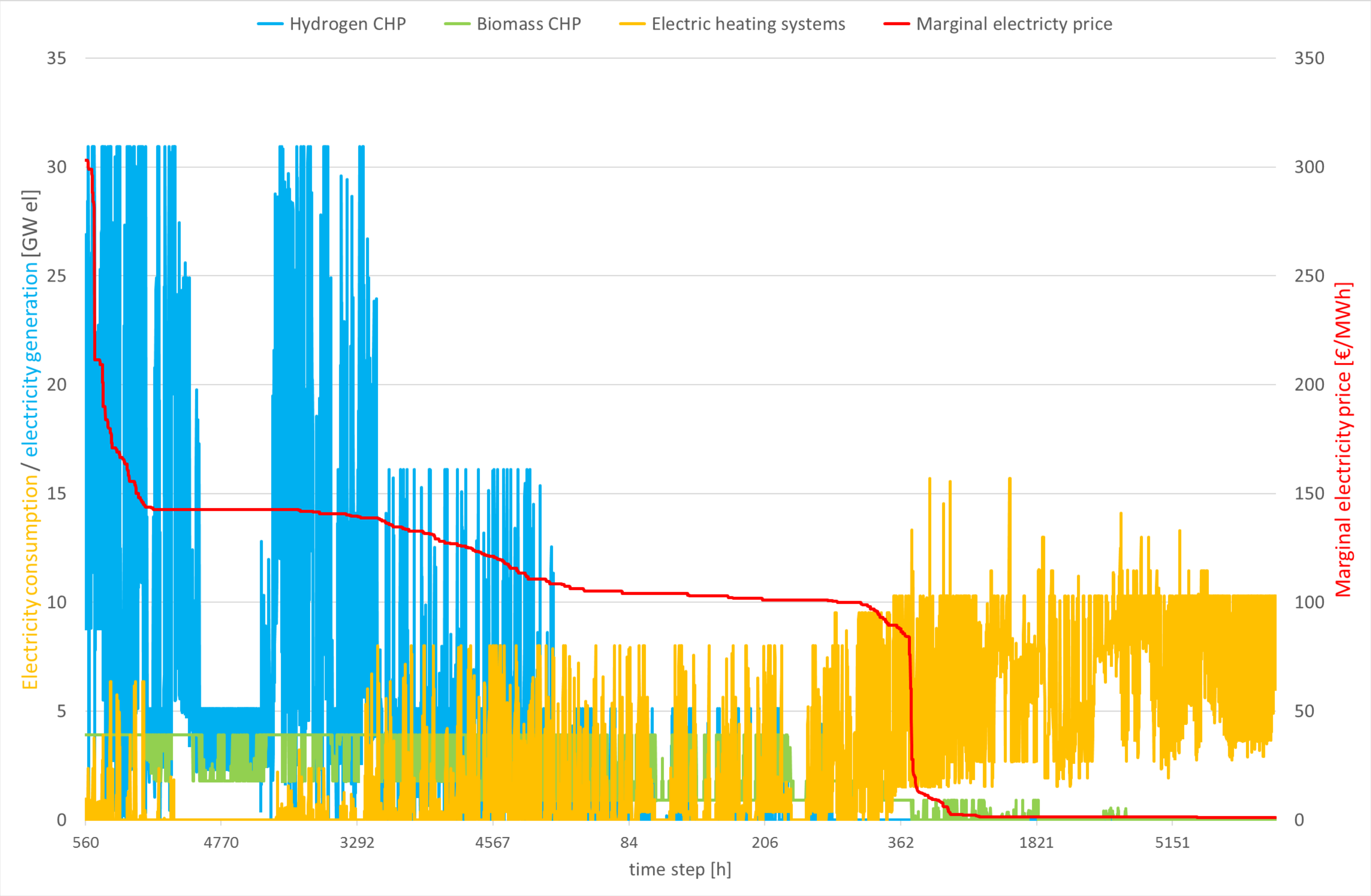
Preliminary results: application profiles depending on electricity prices in updated ENSURE Scenario B 2045

- **Marginal electricity price:**
  - Average: 87 €/MWh
  - 2.700 h: < 20 €/MWh
  - 430 h: > 145 €/MWh
  - 5.100 h: 100 – 145 €/MWh
- **Hydrogen CHP:**
  - generation > 100 €/MWh
  - High production in industrial heating network
- **Electric heating systems:**
  - Max load: 16 GW
  - Demand: 25 TWh



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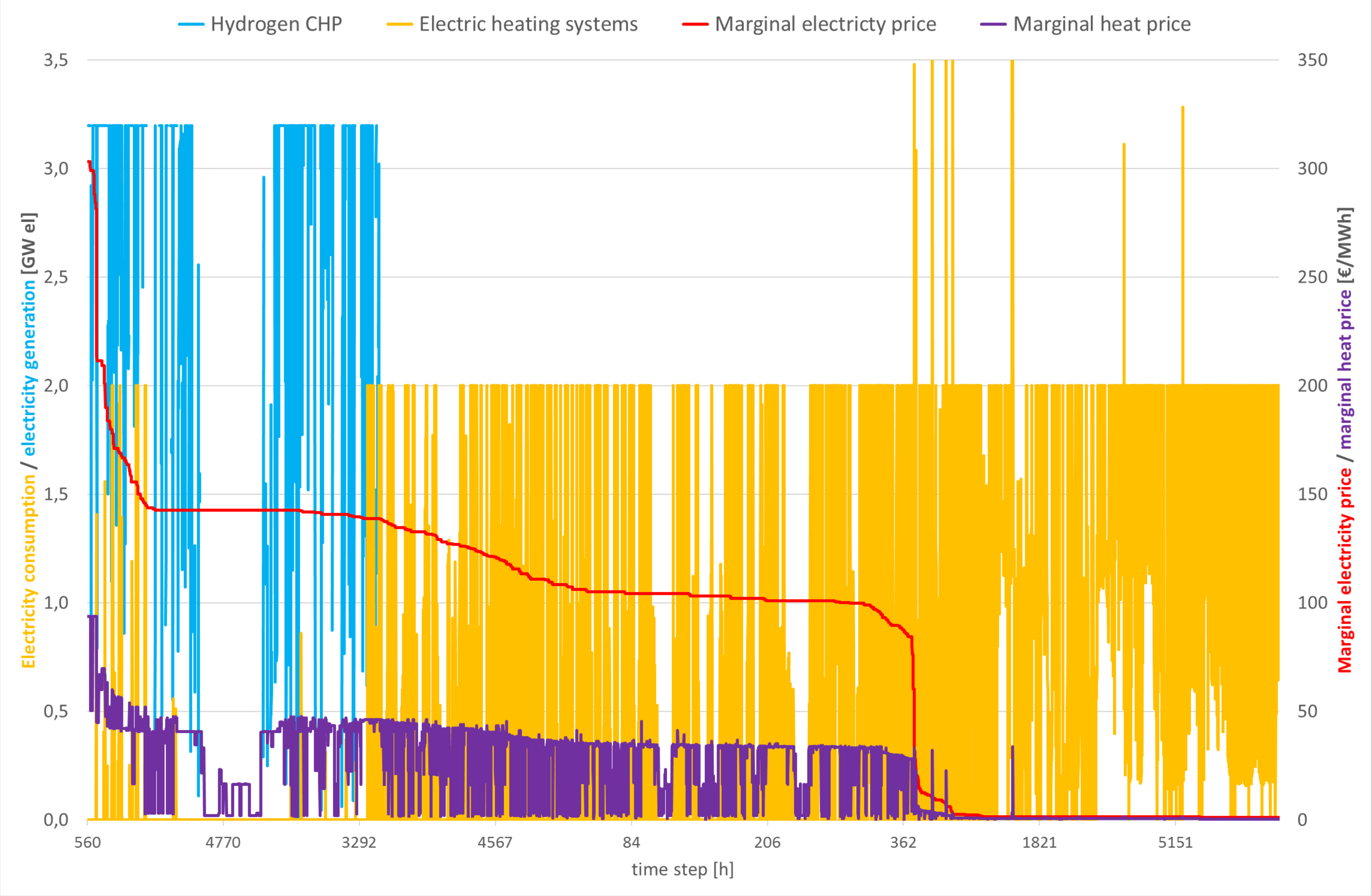
Preliminary results: application profiles depending on electricity prices in metropolitan network 2 (updated ENSURE Scenario B 2045)

- **Tipping point:**
  - 138,7 €/MWh electricity price
- **Electric heat pump**
  - 46,2 €/MWh heat generation
- **Hydrogen CHP plant**
  - Marginal costs: 171 €/MWh electricity
  - 171 – 138,7 €/MWh el = 32,3 €/MWh el
  - 32,3 €/MWh el * 1,43 = 46,2 €/MWh heat



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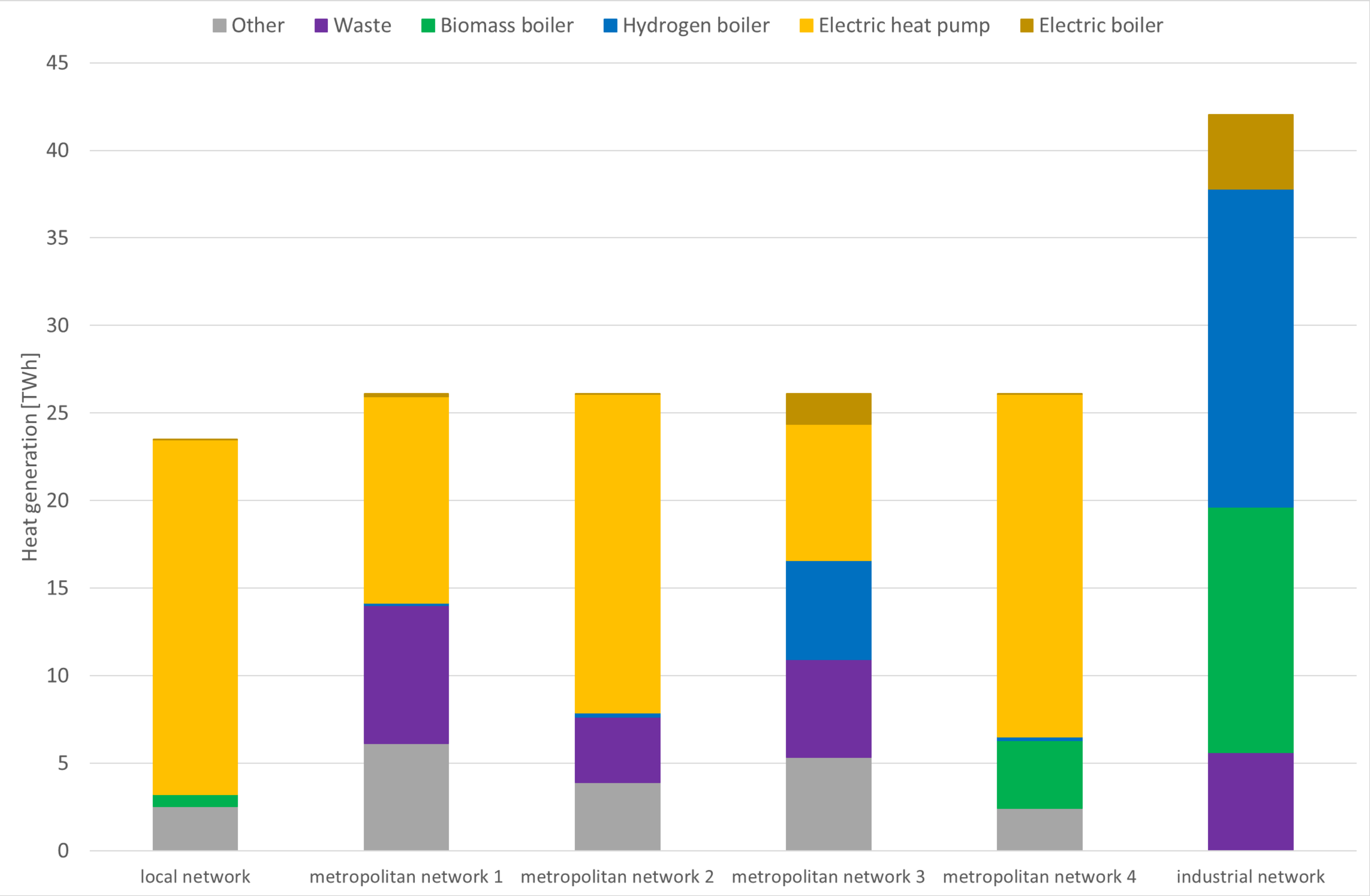
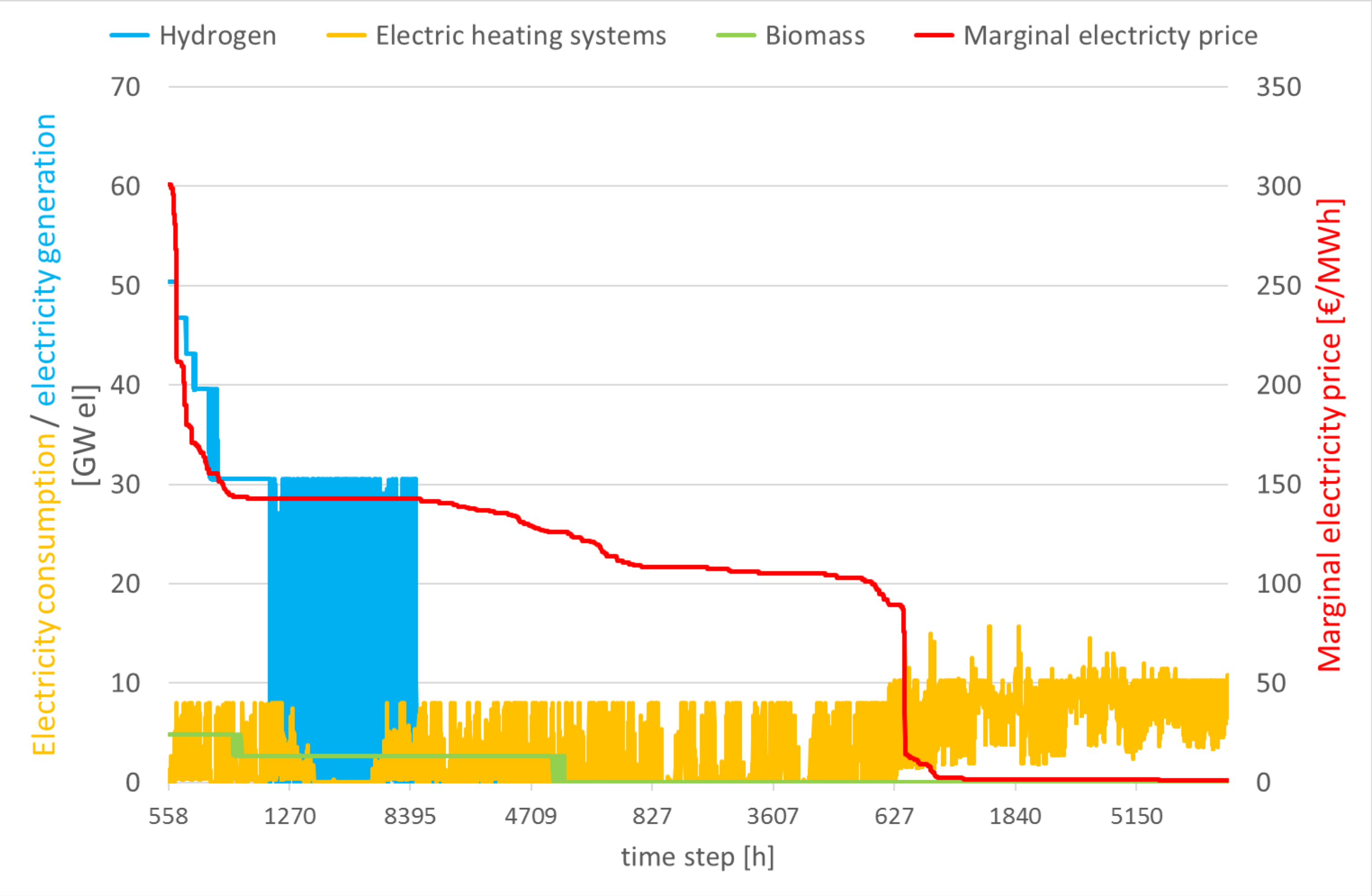
Preliminary results: energy carrier specific generation mix for district heat in updated ENSURE Scenario B 2045 **(without CHP plants)**

- **Energy carrier specific mix (average over all networks)**
  - Electricity: 49%
  - Hydrogen: 18%
  - Biomass: 11%
  - Other: 12%
  - Waste: 13%
- **Full load hours (average)**
  - Waste & other: 4.000 – 5.500 h
  - Heat pump: 2.600 h
  - E- & H-boiler: 650 – 700 h
  - High boiler use in the industrial network



Preliminary results: application profiles depending on electricity prices in updated ENSURE Scenario B 2045 **(without CHP plants)**

- **Marginal electricity price:**
  - Average: 90 €/MWh
  - 2.700 h: < 20 €/MWh
  - 500 h: > 145 €/MWh
  - 5.300 h: 100 – 145 €/MWh
- **Hydrogen:** > 142 €/MWh
- **Biomass:** > 125 €/MWh
- **Electric heating systems:**
  - Max load: 16 GW
  - Demand: 32 TWh



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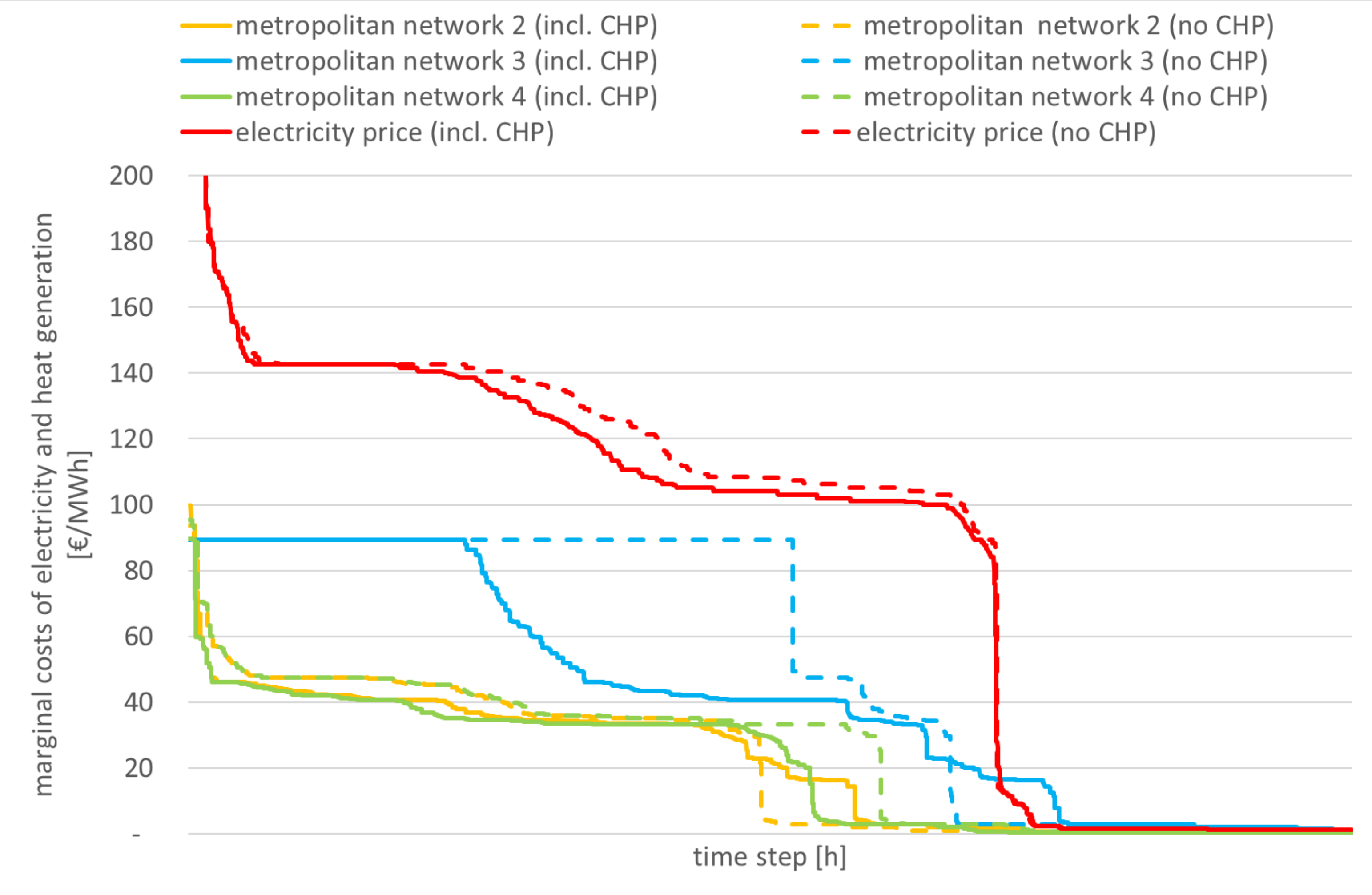
Preliminary results: marginal costs of electricity and heat generation in updated ENSURE Scenario B 2045 (with and without CHP plants)

- Sensitivity “no CHP plants”
  - Increase of marginal costs of electricity generation
- Sensitivity “focus electricity” vs. “focus hydrogen” in metropolitan networks 2/4 & 3
  - Hydrogen increases marginal costs of heat generation
  - Hydrogen boiler are an expensive technology
- Further evaluation is needed for average costs of heat generation



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Conclusion

- The integration of geothermal energy, waste heat and solar thermal energy in heating networks should be used wherever possible.
- Hydrogen CHP and electric heat pumps are in the midfield of the merit order and change places depending on the electricity price (tipping point).
- Electric heat pumps profit from low electricity prices and CHP plants from high electricity prices.
- The expected development of electricity prices is a key parameter for the choice and dimensioning of heat generation plants.
- Heating technologies based on hydrogen (as an expensive energy carrier) increase marginal costs of heat generation.
- Electric peak loads of up to 15 GW from heat pumps and electric boilers occur in the scenario.

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Next steps

- Further sensitivity analysis on fuel prices, CHP parameters, availability of plants, biomass cap (e.g. 4.000 and 2.500 full load hours) and thermal storage capacities
- Implementation of “average costs of heat generation” as an additional result indicator.
- Consideration of high temperature heat pumps for industrial heating networks.
- Evaluation of additional scenarios and scenario years (2030 and 2045)
- Deep dive into the different heating networks
  - Further evaluation of PowerFlex modelling results
  - Additional modelling with a district heating network specific PyPSA application

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Contact and acknowledgement

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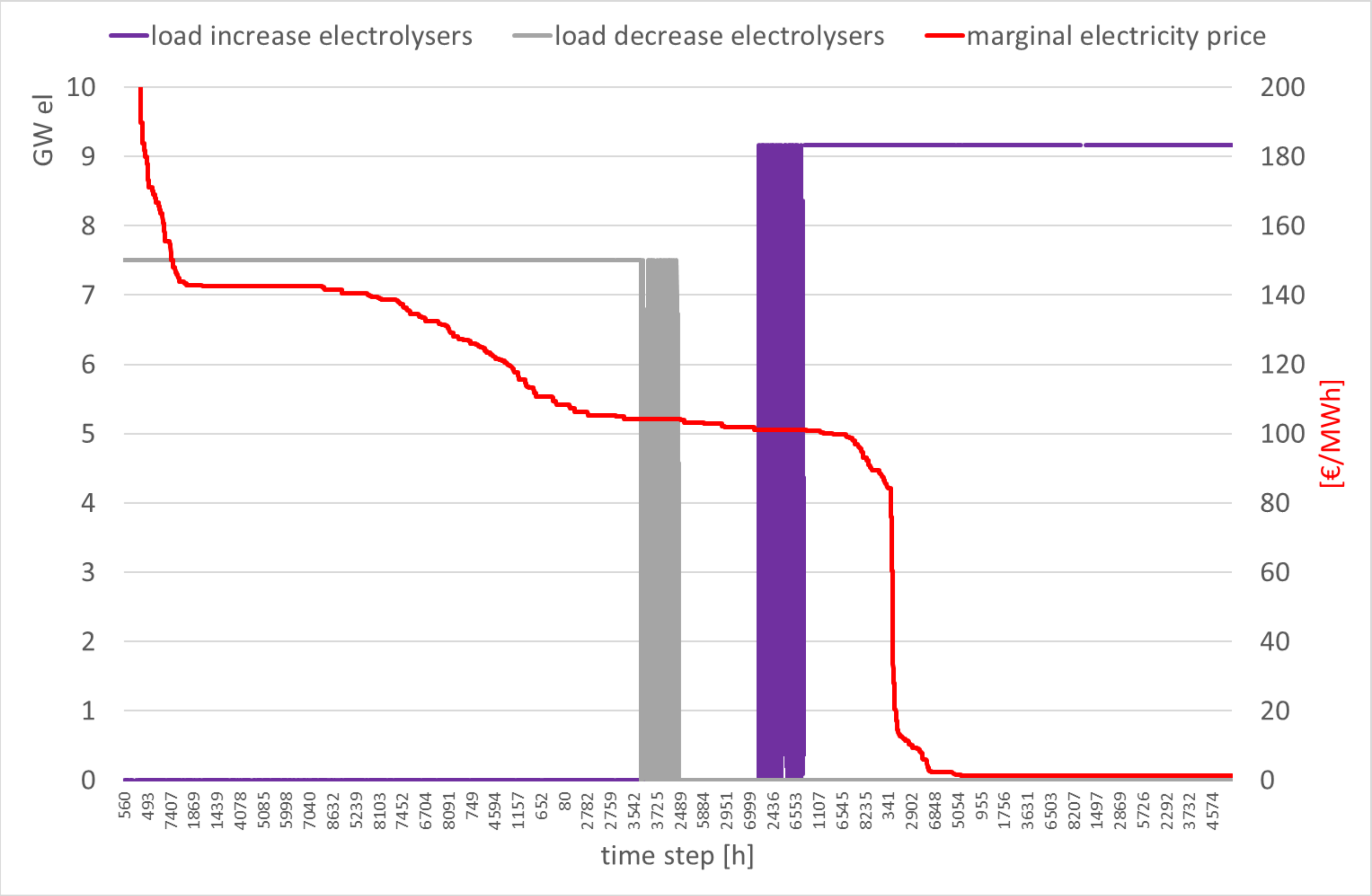
Preliminary results: application profiles depending on electricity prices in updated ENSURE Scenario B 2045

- Flexibility flattens the electricity price curve
- Load increase: < 100 €/MWh
- Load decrease: > 105 €/MWh



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