Modelling full-scale implementation of CCUS at large wood chip fuelled CHP plant in Denmark

Ea Energy Analyses

IEA Task 32 workshop on BECCUS – 21 September 2023

Presentation of preliminary results from case study

CCS tenders and the new Danish CCS strategy

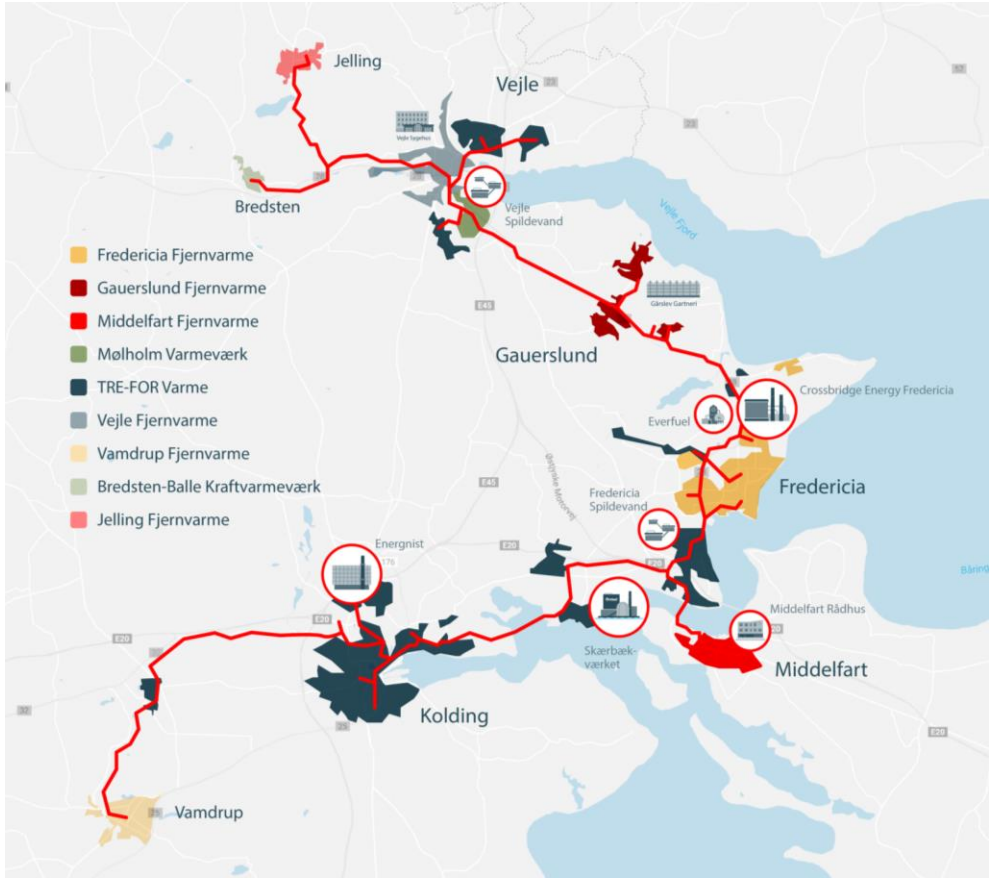
- According to Danish climate legislation, "Klimalov", CO_{2e} emissions must be reduced with 70% in 2030 compared to 1990 and Denmark must be climate neutral in 2050.
  - In May 2023, Ørsted won the first CCS tender: 430,000 tonnes CO_2/year in 20 years from 2 biomass-fired power plants. Must be in operation by 2026.
  - In August 2023, new tender for negative emissions was published (NECCS). Expected 500,000 tonnes year from 2026.
- A broad majority in Parliament agreed yesterday (September 20th) on a CCS strategy going forward:
  - Total budget of 3.6 bio. € for two new tenders aiming for at least 2.3 mill. tonnes of captured and sequestered emissions/year (15 years) from 2029 (at least 3.2 mill. tonnes/year including first tenders).
  - New clear legislation regarding ownership and operation of CO_2 infrastructure will be put forward. Both public and private can own and operate – framework for 3rd party access.
  - Public co-ownership in carbon storage facilities

The Skærbæk CHP plant

- The Skærbæk CHP plants is located in the Western part of Denmark between Fredericia and Kolding
- Owned and operated by Ørsted
- The first production was established in 1951 and was based on coal
- Today the plant's production consists of:
  - A natural gas CHP plant from 1997 with an electrical capacity of 392 MW.
  - Two wood chip fired boilers with flue gas condensation from 2017. Provides steam for the same turbine as the natural gas boiler.
  - Heat storage tank – 25,000 m3
- The plant uses app. 550,000 tonnes of biomass per year

The TVIS district heating system

- The district heating system of TVIS is one of the largest in Denmark and delivers heat to Kolding, Vejle, Middelfart and Frederica and smaller towns
- The main production units are
  - The Skærbæk CHP plant – biomass and natural gas
  - Surplus heat from the Crossbridge refinery
  - The waste combustion plant in Kolding (two separate units)
  - Some smaller local production units
  - Gas and oil boilers for peak load and reserve
- Yearly heat production is 6.6 PJ (2022)
  - 50% biomass, 25% waste, 25% surplus heat



Why CC(U)S on Skærbæk?

- The CHP plant provides green CO_2 that can be utilised to deliver negative emissions (CCS) or input for green fuel (CCU)
- As base load in the district heating system the biomass boiler has a high number of operating hours that can improve the economy of carbon capture and storage and/or usage
- The plant is close to possible off takers and infrastructure: possible hydrogen backbone, local industry and port facilities for shipping of CO_2 or green fuels
- There is a large district heating network that can utilise surplus heat from the plant, carbon capture and fuel production

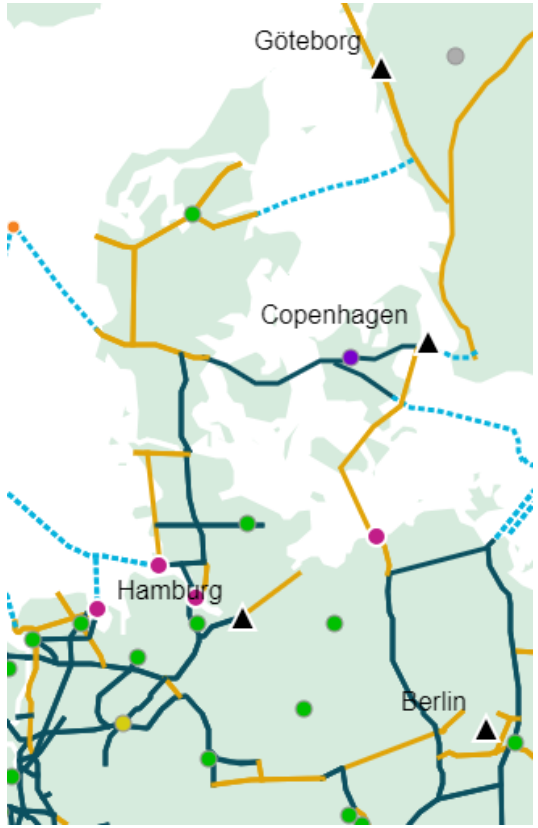
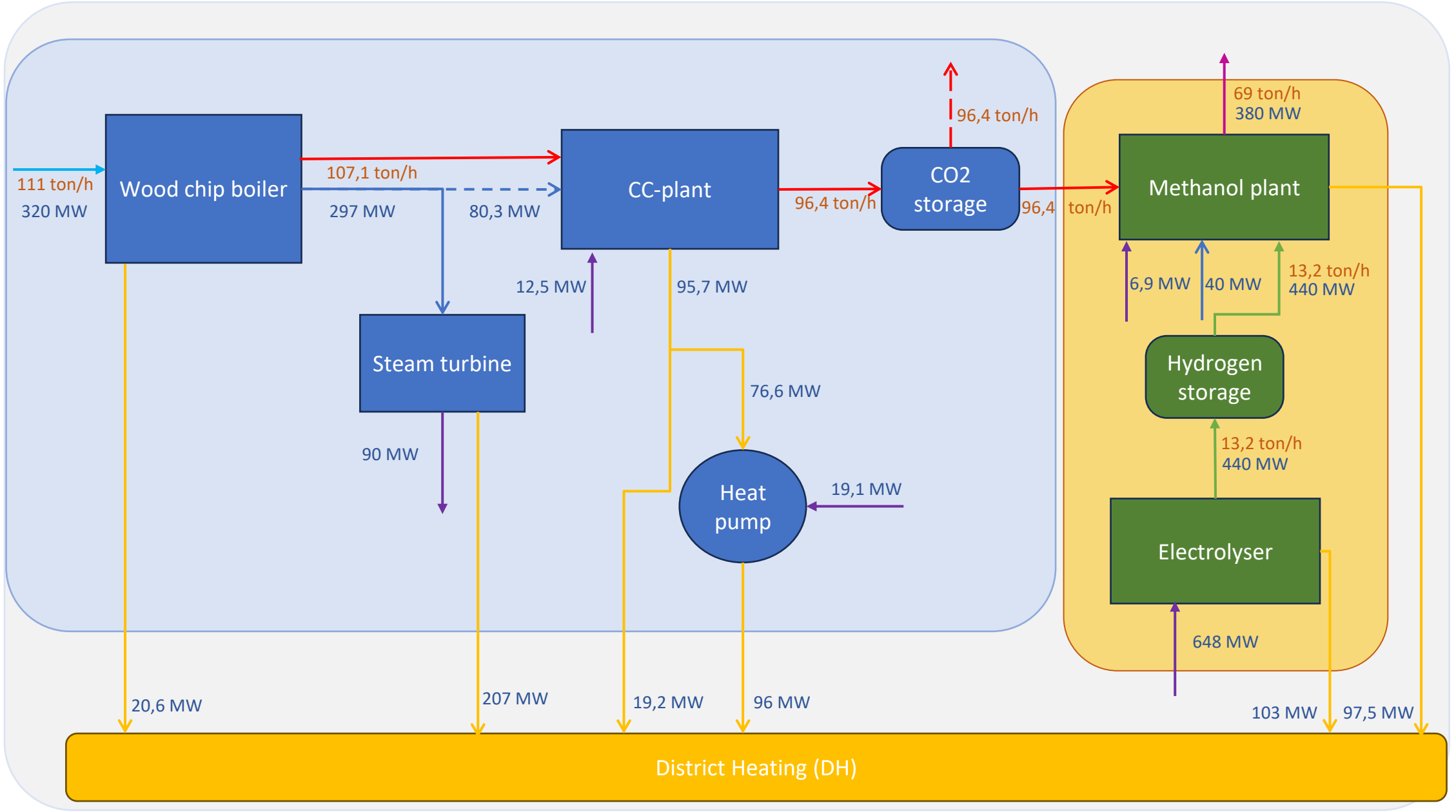


Illustration from European Hydrogen Backbone of possible hydrogen infrastructure.

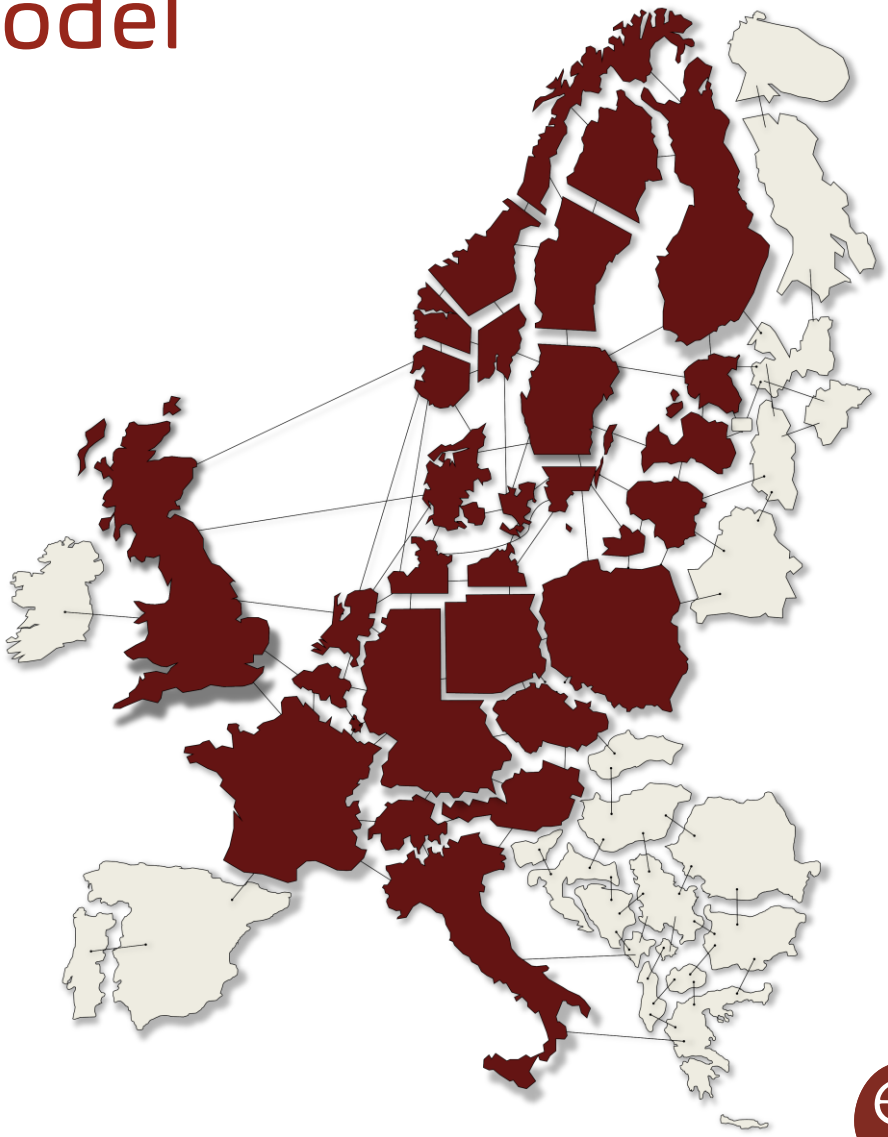
Technical model of CCUS at Skærbæk



NB: A dashed arrow means the mass flow can have a double choice. Data on publicly available data for Skærbæk CHP and the Danish Technology Catalogue.

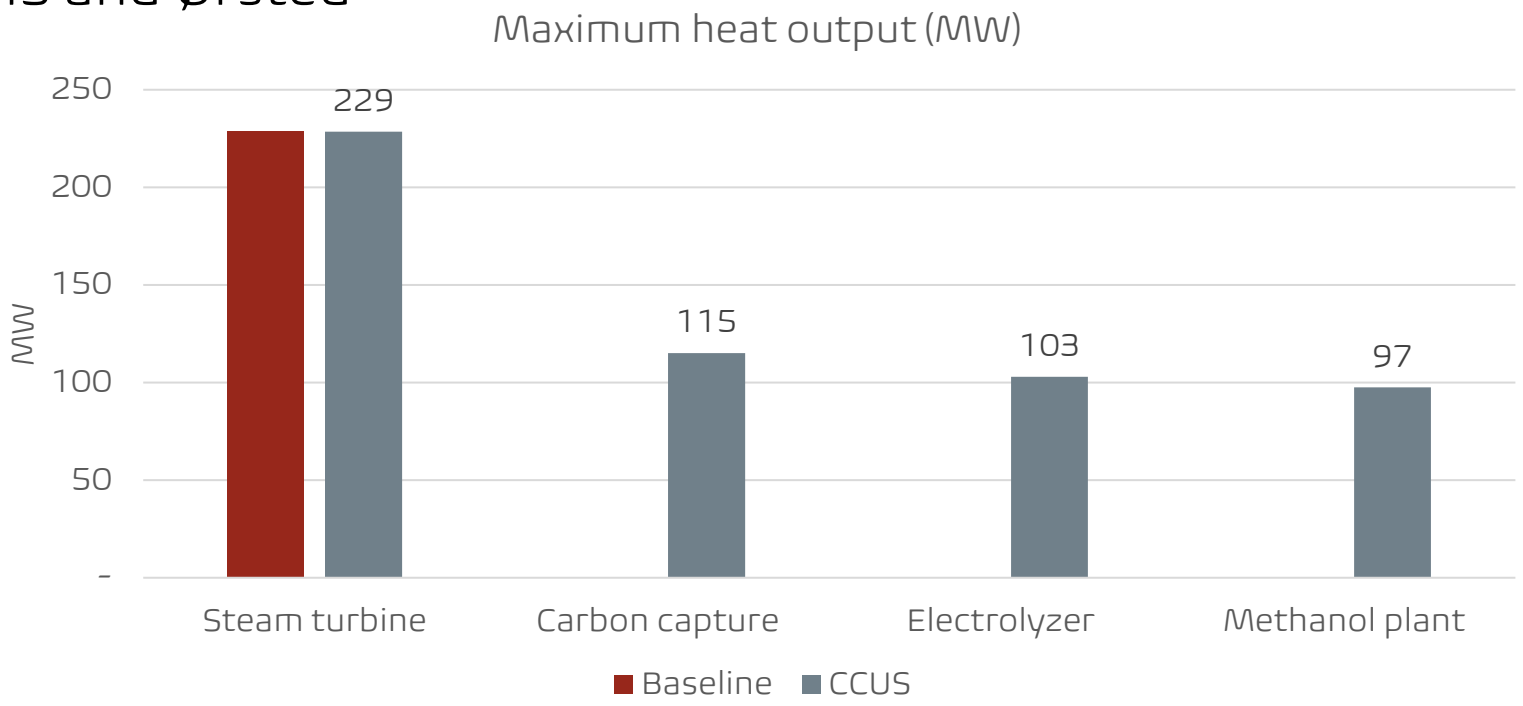
The CHP plant, the district heating system and the power system are all combined in one energy system model

- The energy system model Balmorel is applied
- The North European power system is modelled to provide the power price as an important input to optimising the CHP plant including CCUS
- Heat consumption, production units and network constraints in the TVIS district heating system are modelled in detail including off take of heat production from the plant
- Details of the CHP plants and the CCUS-process are modelled in a special extension to Balmorel, the OptiFlow module, that also allows for modelling of mass balances and more detailed energy conversion processes



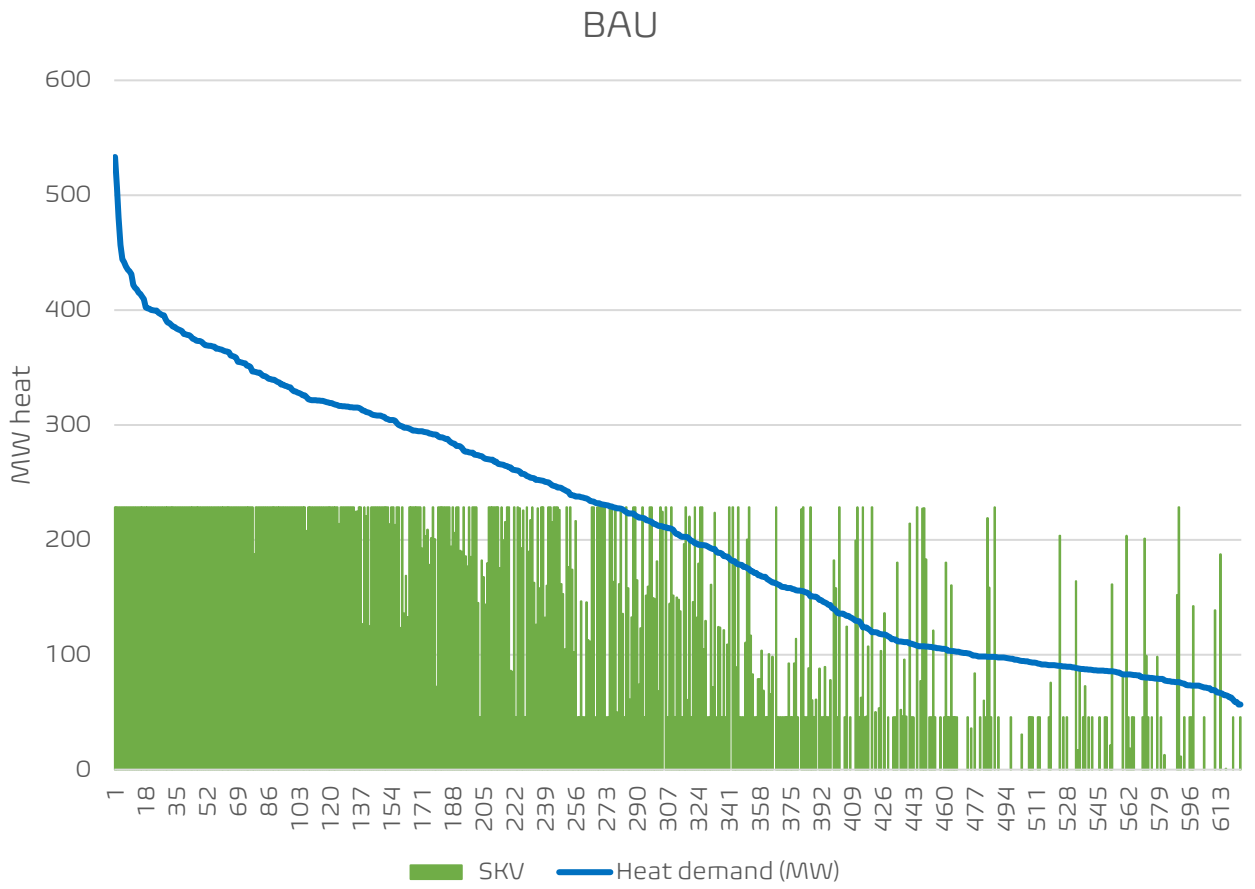
Scenarios

- Two scenarios simulated in the year 2035
  1. **Baseline** without CCUS
  2. **CCUS**-scenario
     - Assumed 4,500 full load hours for methanol plant with 380 MW fuel output capacity
- Scenarios and input data have been set up by Ea Energy Analyses – in dialogue with TVIS and Ørsted



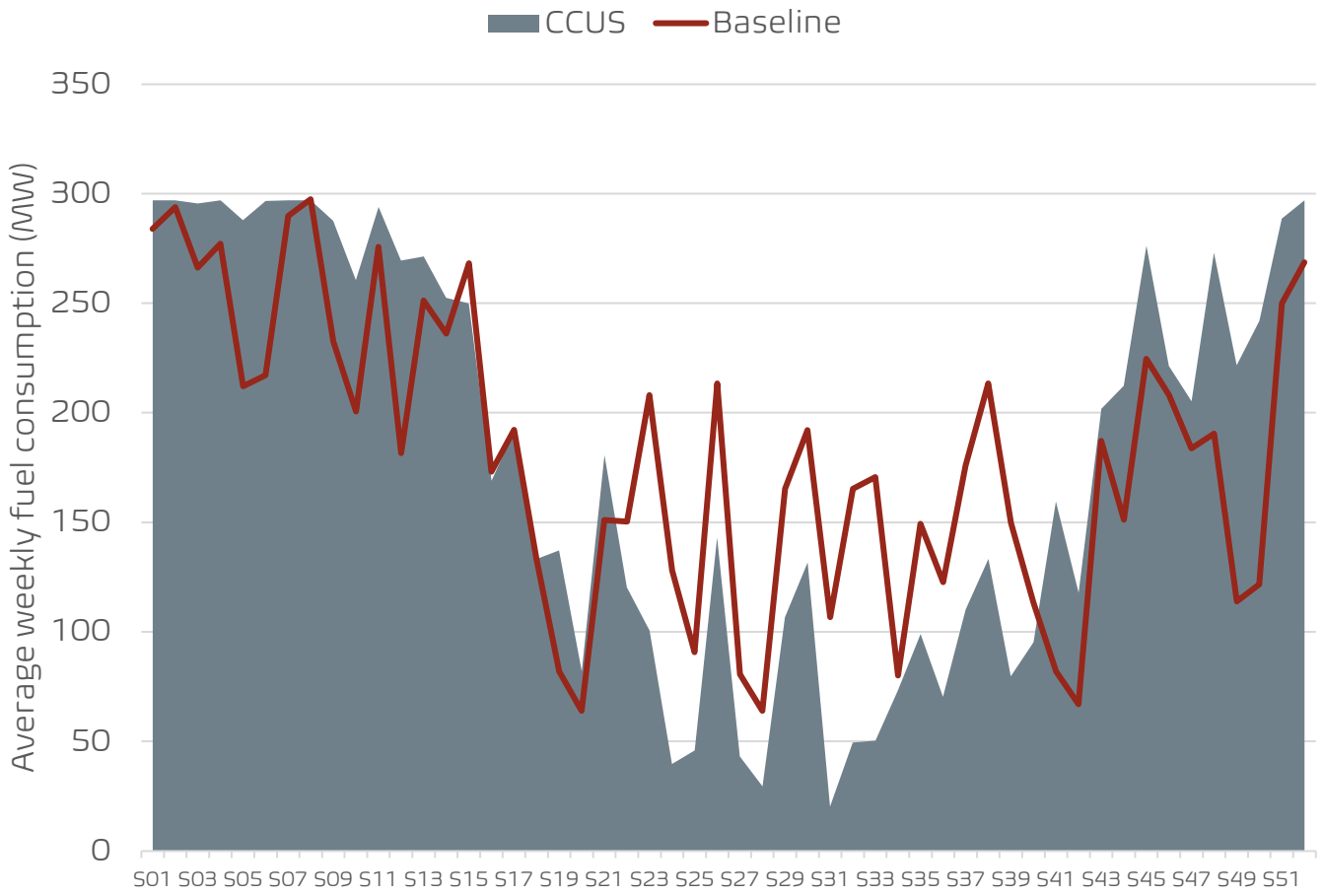
Operation of Skærbæk CHP in the baseline scenario

- Skærbæk CHP delivers about **4.000 TJ** heat, which equals about **65%** of total district heating supply
  - Remaining heat covered by surplus heat and waste incineration
- The total fuel use on Skærbæk CHP is 5.550 TJ of wood chips
  - This corresponds to app. **4.800 FLH** operation of the boilers
- Most of the heat is delivered during winter and spring/autumn with some generation during summer when electricity prices are high



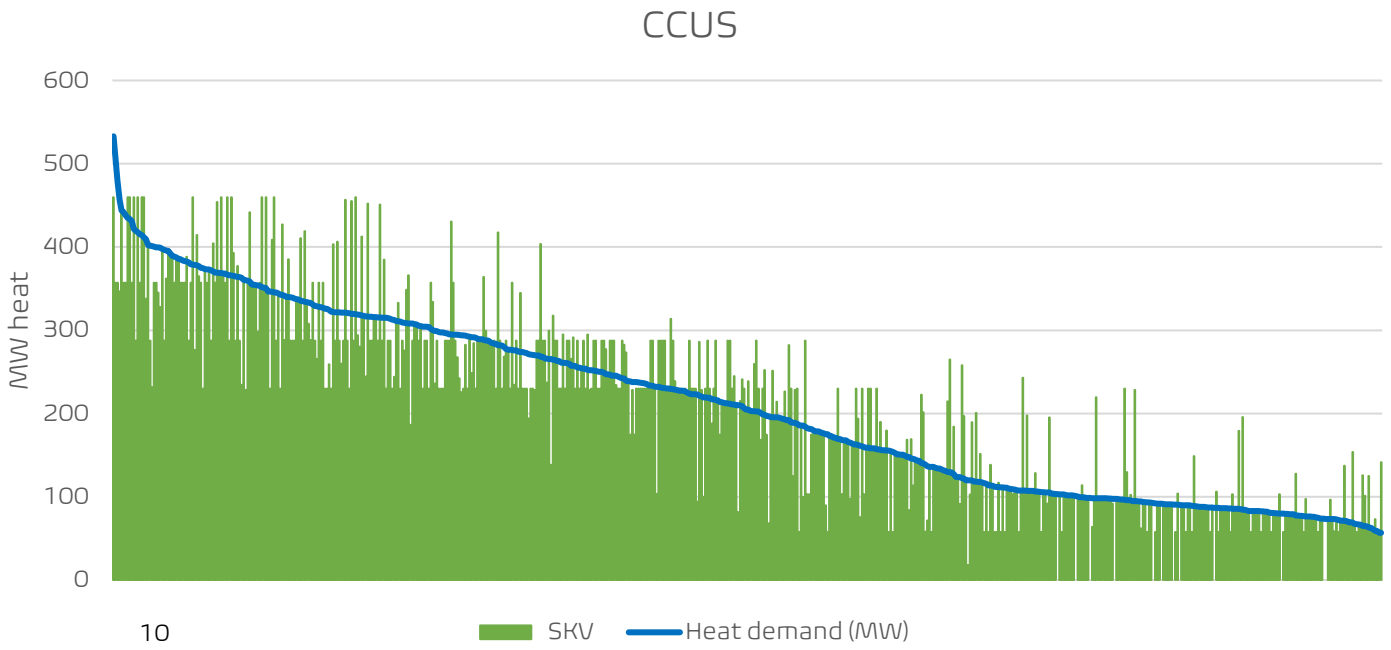
Impact of CCUS on the operation of Skærbæk CHP

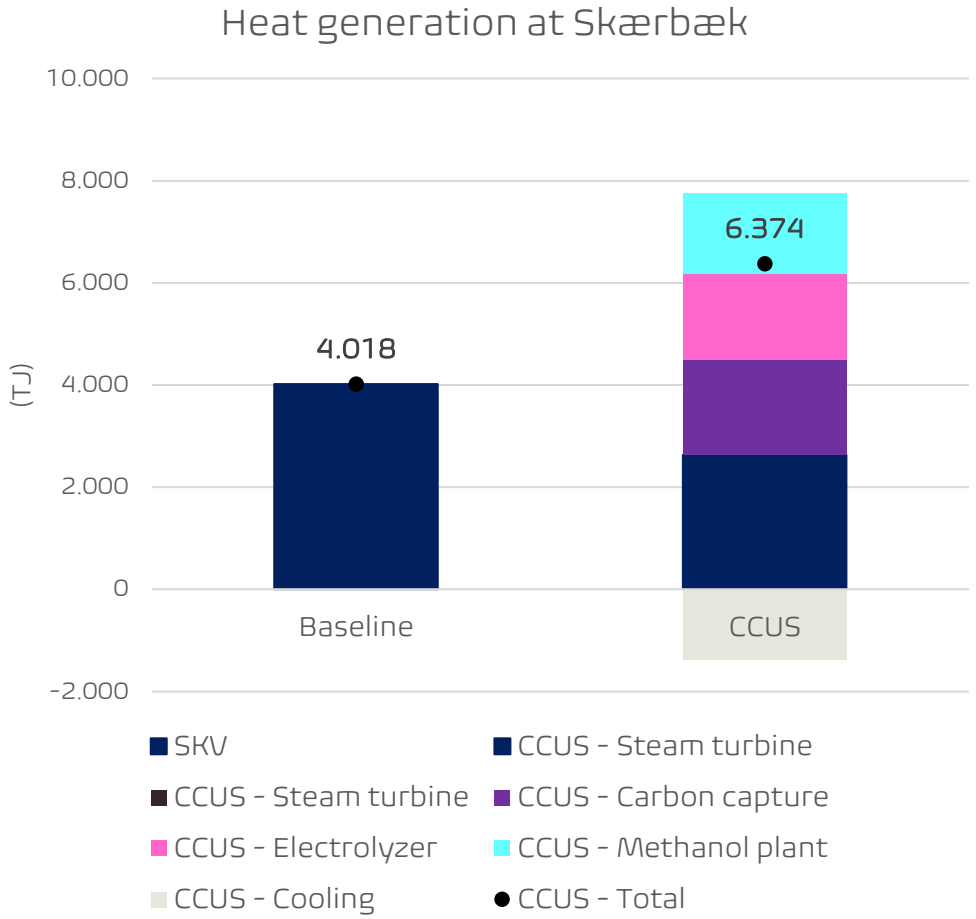
- With the addition of CCUS, the Skærbæk plant increases heat generation to **6,400 TJ** to cover almost the **entire district heating demand**
- However, the total fuel use is almost the same, 5.550 TJ in the Baseline increasing to 5,600 TJ or **4,900 FLH**
  - 10% of CO2-emissions are captured and exported (not used for methanol production)
- Net Electricity generation decreases from 295 GWh in the Baseline to -2,800 GWh with CCUS. The total power use for the CCUS process is 3.1 TWh.
- With CCUS, the biomass boilers run less in wintertime and more in the summer compared to the Baseline



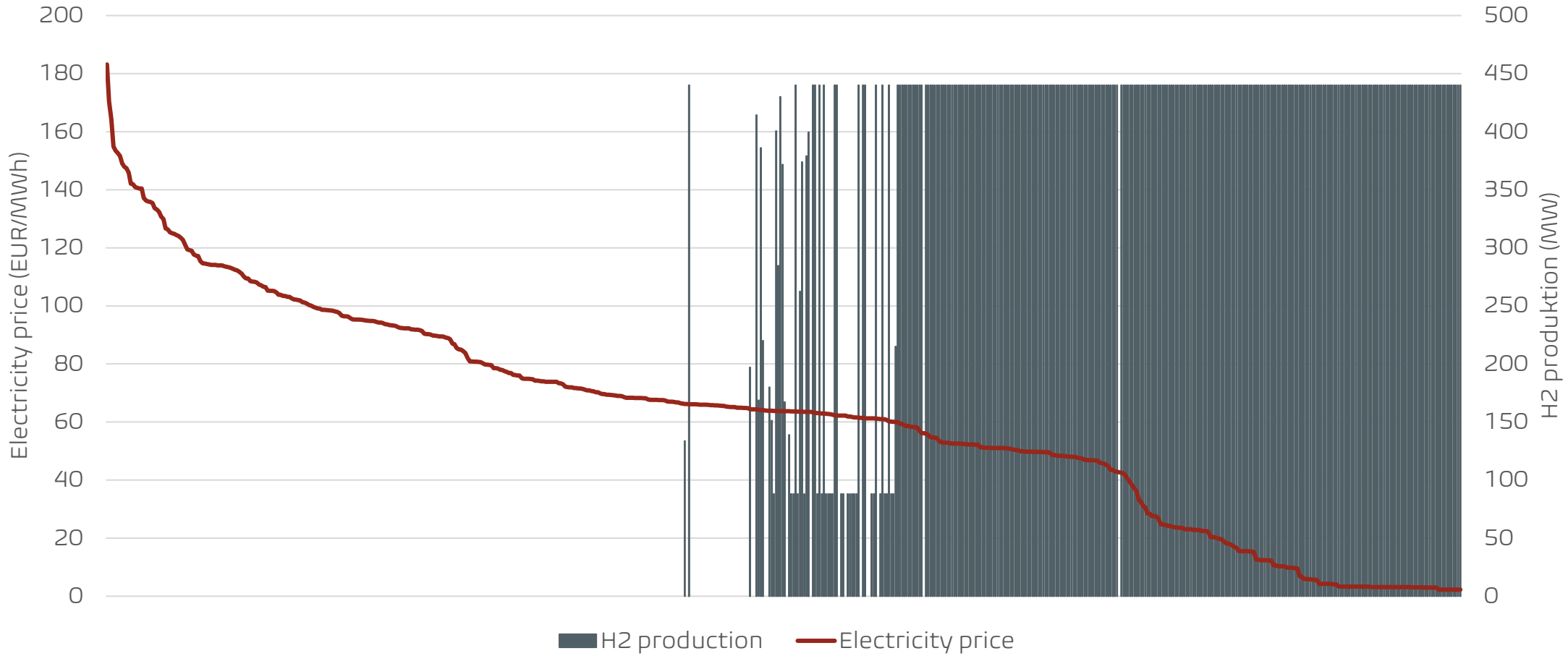
Impact of CCUS on Skærbæk CHP

- The increase in district heat generation comes from the surplus heat in the CCUS processes.
- About 20% of the generated heat is cooled away
- The maximum heat output increases from 229 MW to 460 MW

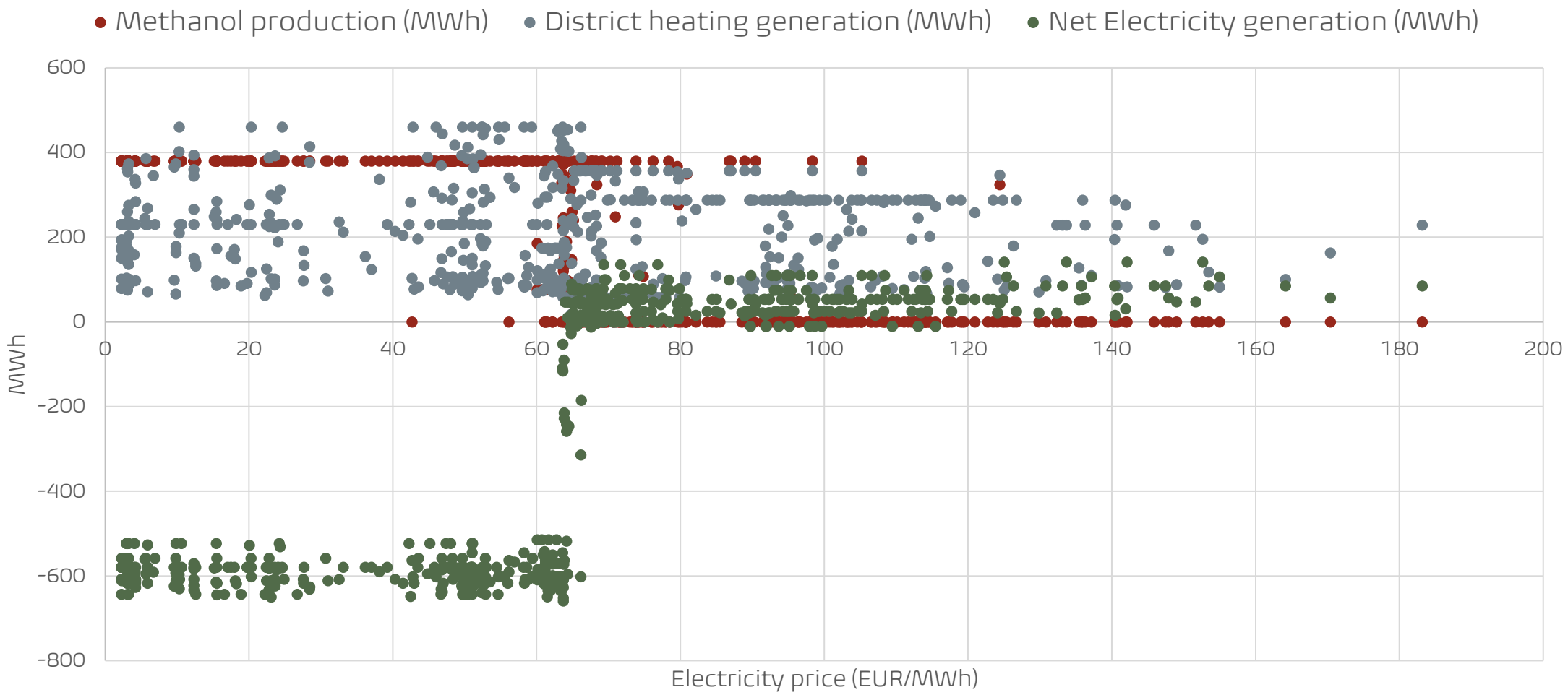




Duration curve for hydrogen production on electrolyzer



Load diagram for Skærbæk with CCUS



Preliminary conclusions

- With CCUS, the plant will serve "triple" markets: power market, heat market and PtX market.
- With CCUS the overall net electricity production from Skærbækværket is transformed to net electricity consumption on average.
- The operation of the boilers will be more distributed over the year and not only in the heating season
- The value of energy in the power and DH markets varies hour by hour.
  - Hydrogen will only be produced when value of electricity is low.
  - DH demand is only significant in winter times.
- Storage of CO_2, hydrogen and/or district heating could be essential for economy and for overall energy efficiency.
- Evaluation of adjusted scenarios and sensitivity analyses in next phase

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