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Future low-carbon energy systems - case of Greater Copenhagen, Denmark*

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Introduction

Urban areas are frontrunners of the climate action. In Denmark, the City of Copenhagen is to achieve a CO_2-neutral energy system already in 2025. This study aims at constructing and evaluating scenarios for sustainable electricity and heat supply in Greater Copenhagen (encompassing 17 municipalities in the region) with a particular focus on the new district in Copenhagen called Nordhavn. The existing district heating network will be partly extended to Nordhavn, but the expected low energy consumption of buildings may also increase the attractiveness of other solutions.

We use an open-source energy system optimisation tool, **Balmorel**, to model our scenarios. Implemented in GAMS, Balmorel is a bottom-up partial equilibrium model.

We model and evaluate the following energy scenarios for Greater Copenhagen and Nordhavn, analysing years 2020, 2025, 2035 and 2050:

- Reference: model investment optimization in Nordhavn in either technology: seawater heat pump, heat storage, solar heating and ground-source heat pumps
- Seawater HP: investing in a large seawater HP with thermal storage in Nordhavn
- DH extension: extension of Copenhagen's district heating capacity to cover all Nordhavn
- Individual solutions: optimizing investments in Nordhavn in: solar thermal collectors, ground-source HPs, thermal storage and electric boilers

Results

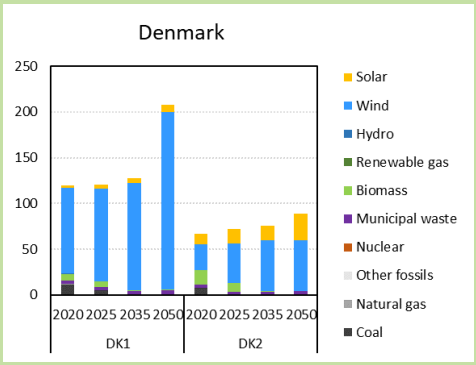
Our simulations show that in **Greater Copenhagen there is a steep CO_2 reduction already between 2020 and 2025**, followed by the transition to carbon-neutrality. Greater Copenhagen **can reach zero emissions in the DH and electricity sectors in 2025**, thanks to the phase-out of fossil fuels (see also fuel mixes on the next page).

Results (continued)

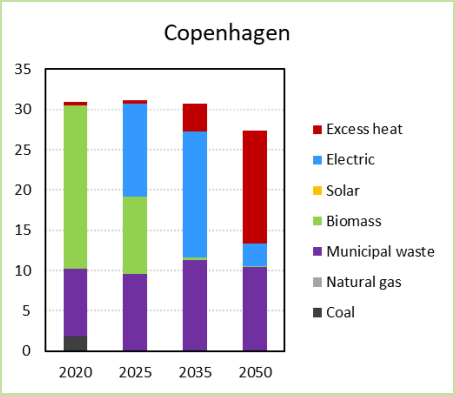
The resulting power production relies mainly on wind and solar. In DK2 (where Copenhagen is situated), **this means that biomass is phased out** after 2025.

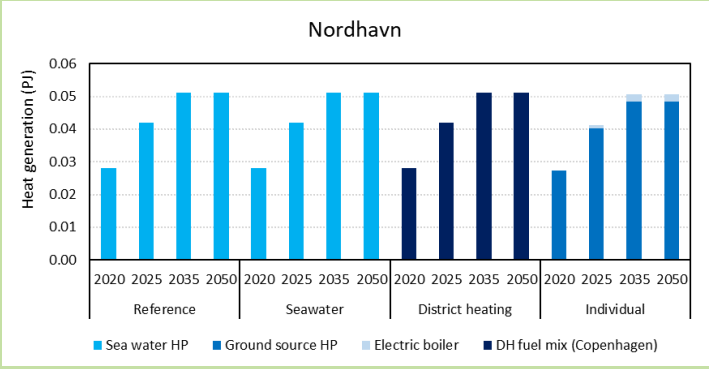
As of now, a large share of heat in the Copenhagen DH network is produced using biomass, municipal waste and coal. However, due to CO_2 emission reduction and renewable energy targets, coal is to be phased out, as well as it is socio-economically optimal to stop using biomass in Copenhagen after 2025. A decrease in district heating demand is caused by assumed heat savings. **The results also show that power-to-heat has a large potential in the area.** Focusing on Nordhavn, a local seawater HP or individual HPs seem to be promising solutions in the case of lacking connection to the Copenhagen's DH network - otherwise a DH expansion is chosen by the model.

Electricity production per fuel (PJ)



Heat production mix (PJ)





The resulting annual average heat prices are higher in Nordhavn than in Copenhagen in all modelled years except for 2035. A sensitivity analysis shows that applying a 2% discount rate results in a lower heat price in both Copenhagen and Nordhavn and the opposite happens for a 6% discount rate.

Conclusions

- **All of the scenarios result in a significant CO_2 emissions reduction** in the electricity and district heating systems already after 2020, followed by a transition to carbon-neutrality.
- P2H technologies, municipal waste, heat storages and excess heat, as well as wind and solar in the power sector, **could be main supply technologies** in future energy transition.
- **The challenges discussed are relevant for other urban areas** in Europe that aspire to have sustainable energy systems.
- **The method developed is useful for developing sustainable energy plans** for new urban developments and to decide for a relevant heat supply option. Therefore, it could be also used by energy planners in other cities, especially for planning from a socio-economic perspective.

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