Forecasting and Optimization Approaches Utilized for Simulating a Hybrid District Heating Network

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Background

The aim of the research project HDH Demo, funded by the Austrian Climate and Energy Fund, and conducted in close cooperation with the city of Neusiedl am See, Burgenland, Austria, is to integrate regional wind energy into the existing district heating network of the city. The main motivation behind this sector coupling is to increase the local consumption of wind energy and reduce the amount of energy marketed on the conventional electricity market which is subject to great price uncertainties. This reduces the amount of necessary of transport capacities, increases the revenues/reduces the costs and simultaneously provides green energy for heating purposes. Furthermore, the project investigates possible extensions of the hybrid energy system by evaluating the efficiency and economic feasibility of power-to-gas solutions, e.g., electrolyzers.

The evaluations are conducted using a mathematical optimization approach, i.e., mixed integer linear programming (MILP). Its key ingredients are accurate forecasts of the required input data, e.g., heat demand. Hence, it is important to asses different data-driven forecasting methods, including Random Forests and Nonlinear Autoregressive Exogenous (NARX) models.

Hybrid Energy System of Neusiedl am See

The hybrid energy system in Neusiedl am See includes local wind parks, a biomass plant, a gas burner, four different heat pumps and several thermal storages. The operation of these components rely heavily on accurate forecasts of available wind power and district heating demand. The unit commitment is computed based on a MILP optimization problem.

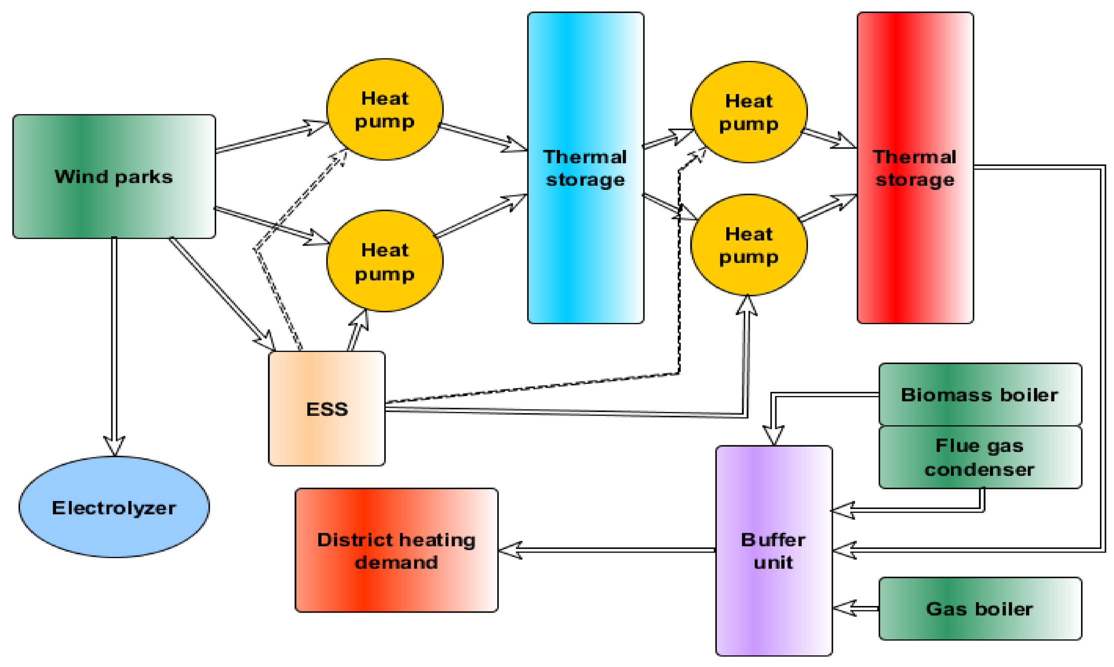

Fig. 1: Hybrid energy system in the city Neusiedl am See, Burgenland, Austria.

Data-Driven Forecasting Methods

Research shows that the weather as well as the social behaviour has most influence on the heat load in district heating grids. The outdoor temperature and humidity correlates the most with the heat demand in a district heating grid. Hence, these parameters are chosen as inputs for the investigated models. Three different artificial intelligence (AI) models are utilized in this project besides the NARX model. In this work, static ensemble approaches that combine these models to exploit their strengths due to flexibility of AI algorithms and stability of autoregressive models, i.e. mean ensemble (MENS), weighted mean ensemble (WENS), and seasonal weighted mean ensemble (SWENS) are used. The predicted heat demands using these different approaches are shown in Fig. 2-3.

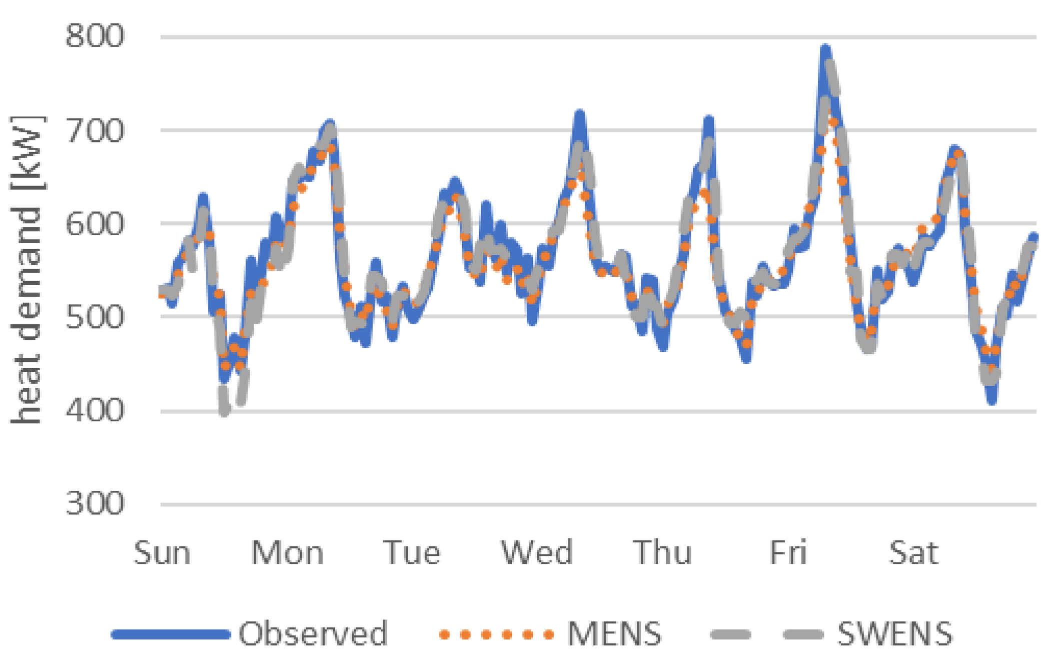

Fig. 2: Exemplary heat load for a representative winter week.

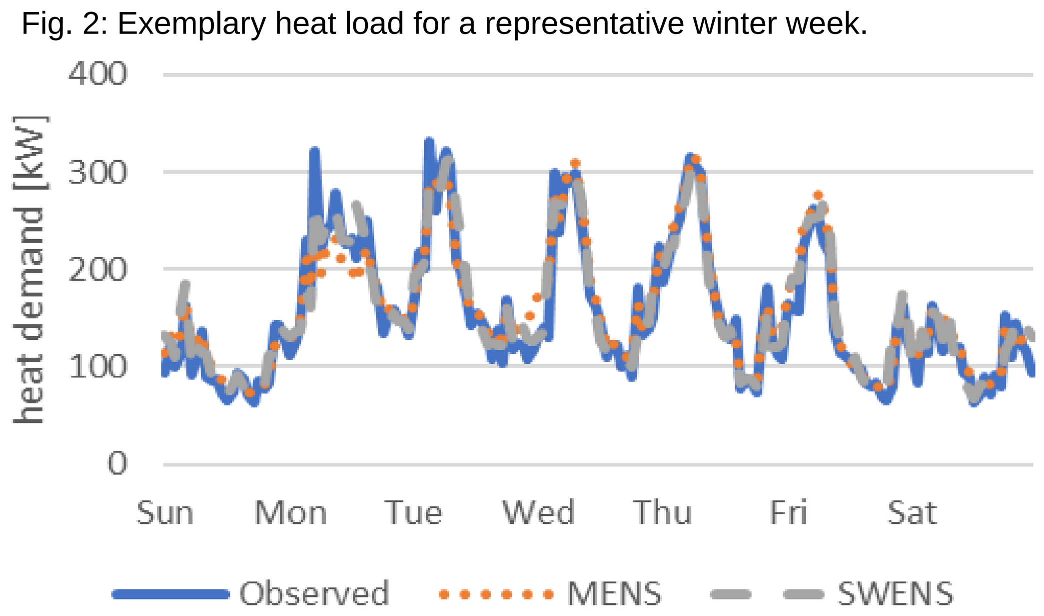

Fig. 3: Exemplary heat load for a representative spring week.

Results of MILP Optimization

In order to show the applicability of the forecasting and optimization approaches to the real-world test bed of Neusiedl am See, different scenarios of the hybrid district heating system were set up.

1. Heat pumps as the only consumers of the locally produced wind energy
2. A 1.75 MW electric storage system is added to scenario 1
3. A 17 MW electrolyzed is added to scenario 1
4. Scenario 1 with electric storage system and electrolyzer.

Using these four different scenarios the amount of energy marketed with high price uncertainties is computed and depicted in Fig. 4., showing that an electrolyzer drastically reduces this share of energy.

The evaluation proves that incentives and funding are of utmost importance to increase the attractiveness of power-to-gas solutions in order to produce green hydrogen. This ensures a successful pursuing of the ambitious goal of transforming the existing energy system into a sustainable and clean system and thus guaranteeing a future-fit and climate friendly energy system.

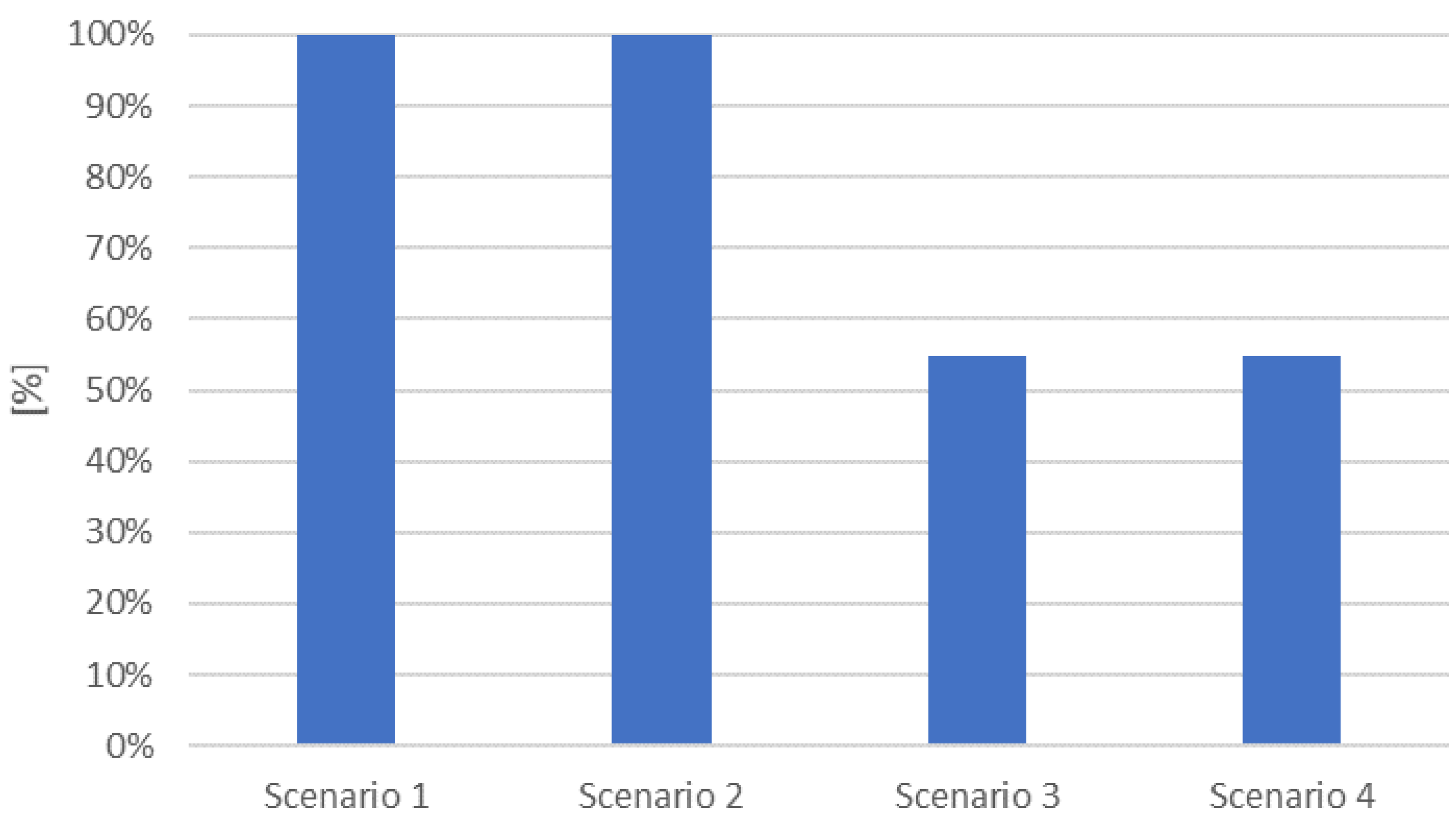

Fig. 4: Amount of energy marketed with high price uncertainties computed for the four different scenarios of the hybrid district heating system.

Acknowledgements

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