User Story

District Heating: Cost-optimal heat generation for a municipal utility company of a midsize city

Stadtwerke Pirmasens

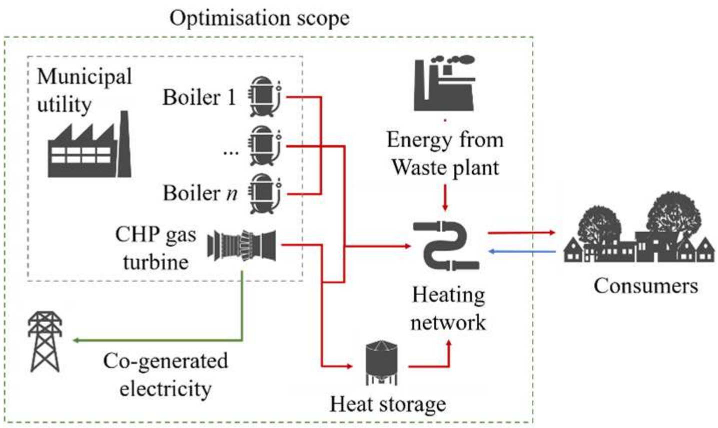

Figure 1: District heating network and optimisation scope for this case study

THE CHALLENGE

Develop an optimisation framework to improve heat generation scheduling for a thermal grid operator. Cost-optimal operations depend on a variety of dynamic and time-dependent inputs with complex interdependencies.

THE SOLUTION

- Model Predictive Control (MPC) embedded hierarchical optimisation model to minimise total generation cost under dynamic conditions
- Prediction models for key input parameters, i.e., heat demand and grid temperatures, based on historical data and external forecasts

THE RESULTS

The optimisation framework has been tested with actual data from a municipal utility company of a midsize city and:

- Derived significant simplification potential with regards to current operations
- Identified potential reduction of operational cost in the range of 20 - 26 %
- Suggested a CO_2 abatement potential of 38 – 50 %

OVERVIEW

District heating could play an essential role in the cost-effective decarbonisation of the energy system due to its flexibility to integrate a large share of renewable energy sources. However, it faces certain challenges related to the increasing energy efficiency at the consumer side, changing technical requirements, and increasingly dynamic markets.

Resource-optimised management of district heating networks requires consideration of a wide range of factors, including demand forecasting, flexibility of heat provision mix, and volatile market conditions. While traditional approaches often rely on static models and heuristics, dynamic cross-domain interoperability is essential to holistically optimise thermal grid operations.

This use-case demonstrates a proof-of-concept for a Knowledge-Graph-based optimisation framework for minimising total generation cost for a thermal grid operator, including forecasting routines for key system parameters.

CASE DESCRIPTION

- Municipal utility company operates a district heating network with several residential and industrial customers
- Heat can be provided via *n* conventional gas boilers, a CHP gas turbine, and external sourcing from an energy-from-waste (EfW) plant
- An optimisation algorithm with transparent decision criteria has been developed to replace currently used heuristics and personal judgement
- Forecasting models have been developed to predict key input parameters
- Optimisation and forecasting models have been embedded in a MPC framework

Table 1: Identified operational improvements for client

	Identified improvement potential p.a.			
Year	**Heat generation cost**	**Gas demand**	**CO_2 emissions**	**EfW purchase**
Year 1	−26.2 %	−50.7 %	−4913 t	+22.2 p.p.
Year 2	−20.3 %	−38.3 %	−2181 t	+9.0 p.p.

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RESULTS

Key sensitivities of the optimisation model are shown in **Figure 2**. This study revealed that heat demand, fuel prices, revenues from co-generated electricity, and contract details with the EfW plant are the most influential model parameters. A detailed understanding of the influence of particular contract details with the EfW plant equips the client for future contractual arrangements with the EfW plant.

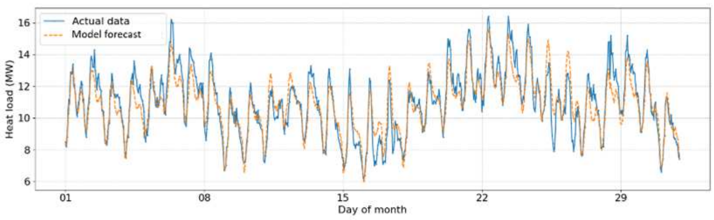
Table 2 provides an overview of the prediction accuracy of the developed forecasting models. The average absolute prediction error for the heat demand is approximately 0.6 MW and has been shown to be below the sensitivity of the optimisation model. Hence, a reliable generation optimisation can be conducted based on the forecast system parameters. The average forecast performance is illustrated in **Figure 3** for a representative winter month.

Figure 4 compares the actual historical heat generation mix with its optimised equivalent for an entire heating period, i.e., one full year. It can be seen that the optimised generation mix is less noisy by following a more rigorous generator selection and scheduling approach driven by continuous cost control. Minimising total OPEX leads to maximising sourcing from the EfW plant, a theme with a promising potential to be considered by the municipal utility.

Table 2: Average prediction performance of developed forecasting models

Forecast variable	MAE	RMSE	Maximum Error	MAPE
Heat load	0.62 MW	0.84 MW	5.46 MW	16.3 %
Municipal utility flow temperature	1.36 °C	2.00 °C	20.22 °C	1.5 %
Municipal utility return temperature	1.21 °C	1.64 °C	11.51 °C	1.6 %
EfW plant flow temperature	1.46 °C	2.08 °C	15.37 °C	1.6 %
EfW plant return temperature	1.1 °C	1.42 °C	7.65 °C	1.6 %

Figure 3: Heat load prediction of forecasting model



Delivering business value: *"The successful collaboration between Stadtwerke Pirmasens (SWPS) and CMCL Innovations on this complex use case has paved way for significant savings in operating costs and reduction of CO_2"*

- Christoph Doerr, CEO, SWPS

Figure 2: Key model sensitivities

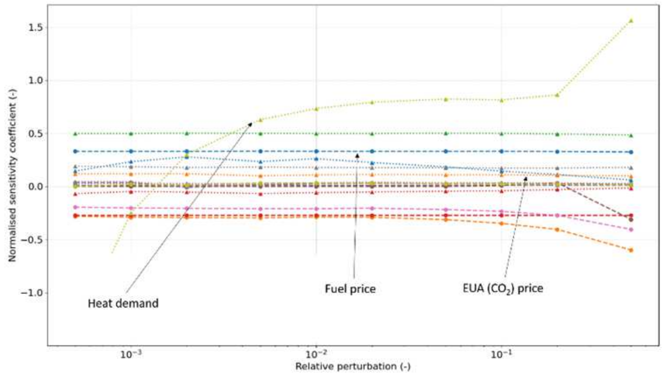
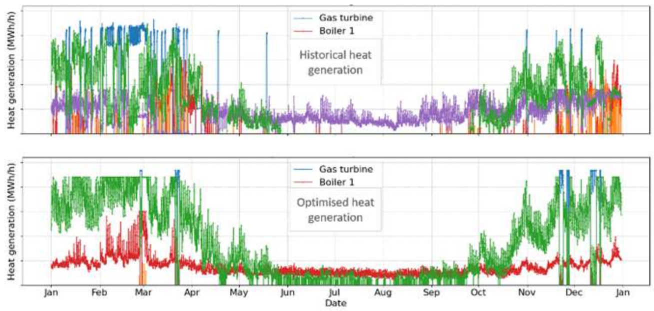


Figure 4: Comparison of historical and optimised heat generation



An overview of key improvement potentials for the municipal utility client are provided in **Table 1**. Identified OPEX savings range between 20% and 26% and associated CO_2 reductions are estimated between 38% and 50%. Increasing its current sourcing share from the EfW plant can help the municipal utility to realise lowering of both cost and emissions.

APPLICATION AREAS

- District heating
- Municipal utilities

PRODUCTS/SERVICES USED

- *Technical Services team*