Innovation Fund Denmark

Market-intelligent district heating

The transition to fully renewable energy systems requires intelligent and flexible system operation. District heating systems can react to electricity prices in a smart way by consuming electricity during periods of low electricity prices and co-producing heat and power during high-price periods. Acting as efficiently as possible on power markets is a complex cost-optimisation problem with uncertain data. DTU Compute develops mathematical models to solve this problem for district heating operators in a smart and automated way lowering costs for heat consumers and supporting the uptake of renewable energy.

Already today, Denmark is a frontrunner in green energy: In 2020, more than 60% of Danish electricity generation came from wind and solar energy. The 2050 target is a fossil-fuel independent energy system.

To transition to fully renewable energy systems, we need to make energy system operation smarter. That means that energy system actors and components react to the state of the system. This requires intelligent operation across sectors, such as integrating the transport sector by charging electric vehicles during periods of excess wind energy and utilising the potential of the district heating sector to react flexibly to the state of the electricity system.

Electricity markets are one way of communicating the state of the electricity system and incentivising district heating systems to react accordingly: When prices are low, district heating operators are incentivised to utilise excess electricity generation by running their heat pumps and electric boilers at low cost. During periods of high electricity prices, combined heat-and-power generators can be run to generate additional revenue for district heating systems to deliver heat at a lower price. Excess heat can be stored easily in heat tanks, and at much lower cost compared to storing electricity in batteries.

In mathematical terms, such a setup is often called "indirect control", since the electricity market controls the reaction of district heating systems indirectly through prices, assuming that market participants try to minimise their costs. That means that, in order for electricity markets to support renewable energy integration efficiently, district heating systems must run cost-efficiently.

To do so, district heating operators must plan at least one day in advance. Electricity market rules require all market participants to submit bids for the coming day one day in advance. Every bid contains the offered quantity, price, and time of electricity consumption or generation.

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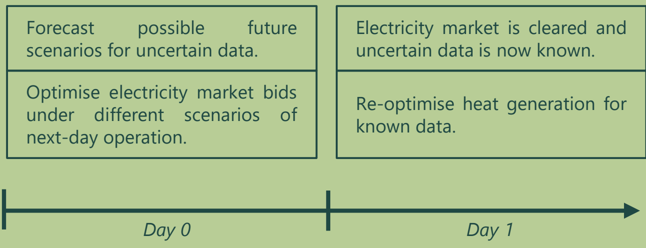
District heating operation under uncertainty

DTU Compute applies *Stochastic Programming* to determine optimal power market bids for district heating systems before all relevant data is known. Stochastic programming uses information on forecast uncertainty by considering different scenarios of unknown data and evaluating possible decisions under each scenario.

By taking into account real-time operation under each scenario, a mathematical model connects electricity market bidding and next-day operation. This way, the decisions take into account different stages in system operation.



More about HEATman

- Innovation Fund Denmark's investment: DKK 25 million
- Total budget: DKK 36 million
- Duration: 3 years
- Official title of Innovation Fund Denmark's project: HEAT 4.0 – Digitally supported Smart District Heating

Identifying the correct bids to submit in advance is a complex problem: district heating operators need to consider not only uncertain electricity prices one day ahead, but also predict heat consumption and often solar heat generation in their systems.

DTU Compute develops mathematical optimisation methods that solve this problem. The innovation of these methods is two-fold: First, they can model practically any district heating system configuration by utilising a mathematical formulation based on graph theory, overcoming a typical shortcoming of many other methods. Second, the optimisation tools utilise smart decision-making tools to explicitly account for uncertainty in forecasting future prices, consumption or generation in an intelligent way.

This allows district heating operators to react to the electricity system in a smart and automated way supporting the integration of green energy and lowering costs for their customers.

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