Optimization under Uncertainty for Managing Heat & Power Systems

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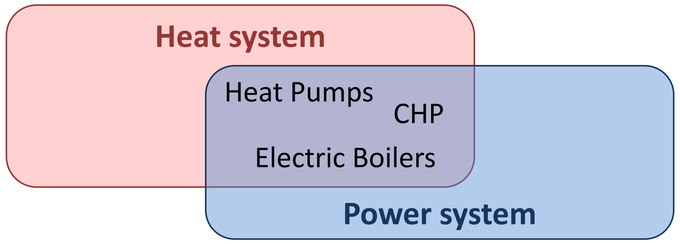
CITIES – Centre for IT-Intelligent Energy Systems in Cities

Background

- The large scale integration of **renewables** into the Danish energy system will involve both the power and the heat sector through expansion of wind and biofuels
- Heat and power systems are **interdependent**, due to the presence of CHP units, heat pumps, electric boilers



- The heat system can provide the **flexibility** needed to integrate larger shares of fluctuating sources of power. However, joint decision-making tools must be developed to exploit these synergies
- Heat and power systems are largely uncertain (due to demands, wind and prices). We account for stochasticity through **stochastic programming** and **robust optimization**

Modeling as a Problem of Optimization under Uncertainty

FIRST STAGE
Day-ahead decisions x
- Unit on/off status (binary)
- Production plan
- Market trade

Uncertainty δ realizes
- Heat demand
- Power price
- Wind power production

SECOND STAGE
Real-time decisions y(δ)
- Actual production

Second-stage decisions are functions of the uncertainty realization

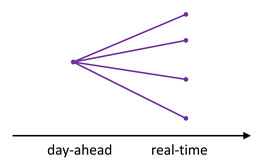
Day-ahead cost (profit changed in sign) | Projection of real-time cost (profit changed in sign)

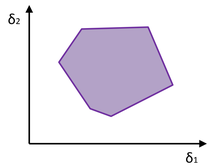
$$\underset{x,\, y(\cdot)}{\text{Minimize}} \; c_x^{\mathrm{T}} x + \mathrm{Exp}_{\delta}\{c_y^{\mathrm{T}} y(\delta)\}$$
$$A_x x + A_y y(\delta) \geq b(\delta), \qquad \forall \delta$$

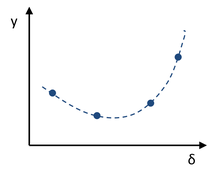
The planning must guarantee feasible real-time operation under a number of plausible realization of the uncertain parameters

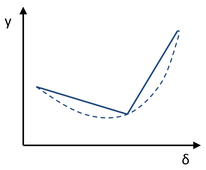
Comparison Between Stochastic Approaches

Uncertainty Model	Stochastic Programming	Robust Optimization
Recourse approximation	scenario-based	uncertainty set
	discretization	piecewise-linear





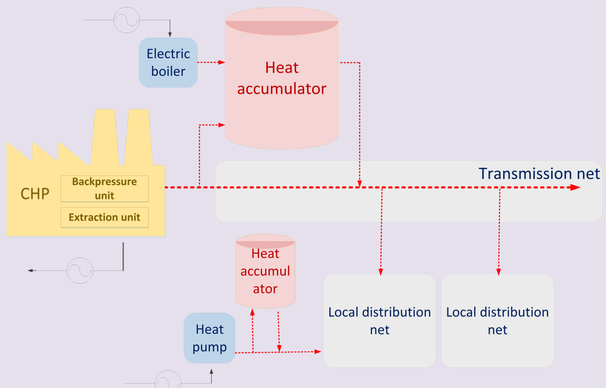




Probabilistic Forecasting and Optimization for CHP Systems

Maria G. Nielsen, Juan M. Morales, Marco Zugno, Henrik Madsen, Henrik Å. Nielsen, Jørgen Boldt, Thomas Engberg

This Masters project is aimed at developing a **stochastic programming** model to manage heat and power systems that include **electric boilers** and **heat pumps** in the local distribution network. Uncertainty in power prices and heat load is modeled via scenarios. An estimation of the **societal value** of heat pumps and electric boilers will be among the outputs of this project.

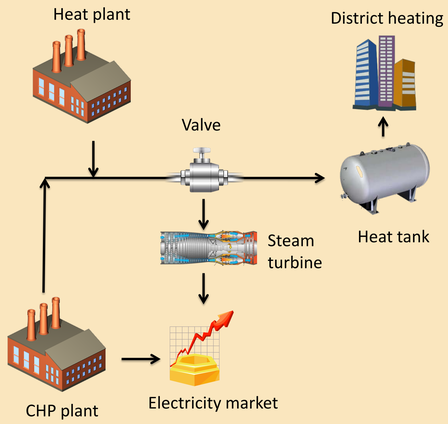


Further reading: M. G. Nielsen, J.M. Morales, M. Zugno, T. E. Pedersen, H. Madsen (2015). Economic valuation of heat pumps and electric boilers in the Danish energy system. *Applied Energy*, in press

Robust Management of Heat & Power Systems via Decision Rules

Marco Zugno, Juan Miguel Morales, Henrik Madsen

The aim of this research project is to develop tools to optimize planning, trading and operation of heat and power systems, accounting for the uncertainty in heat demand and power prices. In particular, we aim at a solution that guarantees heat supply even in extreme realizations of the stochastic heat demand.



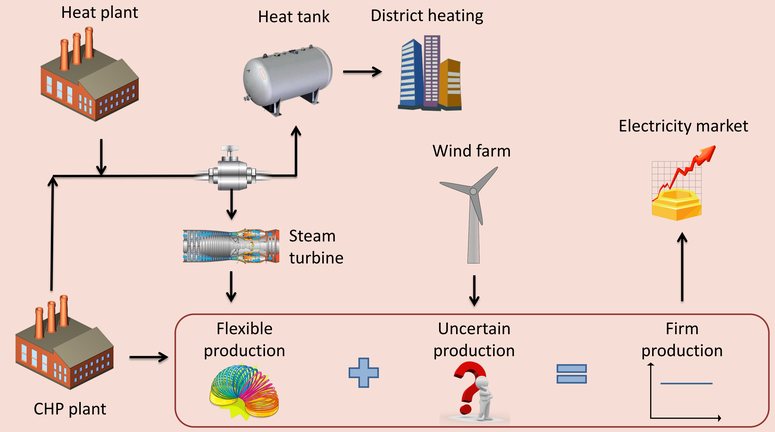
- We cast the problem as a **robust optimization** model
- Uncertainty in future heat demand modeled via **budget uncertainty set**
- Piecewise-linear **decision rules** approximate optimal recourse
- We model trading in multiple commodity markets
- Uncertainty enters optimization model via **simple** descriptions (support set, mean, correlation, etc.)

Further reading: M. Zugno, J.M. Morales, H. Madsen. *Robust management of combined heat & power systems via linear decision rules*. In proceedings of ENERGYCON 2014, Dubrovnik, Croatia

Optimizing Electricity Market Trading for Wind Turbines and CHPs

Anna Hellmers, Juan Miguel Morales, Marco Zugno, Anders Skajaa

This Masters project focuses on the development of a **stochastic programming** model for optimizing the joint trading, planning and operation of a heat and power system comprising a **wind farm**. Scenarios model the uncertainty in heat demand, power prices and wind power production. We aim to assess to what extent the heat system can help **balance** the output deviations of wind power.



Further reading: A. Hellmers, M. Zugno, A. Skajaa, J.M. Morales (2015). Operational strategies for a portfolio of wind farms and CHP plants in a two-price balancing market. IEEE Transactions on Power Systems, in press.

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