Joint Optimization under Uncertainty for Heat & Power Systems (WP7)

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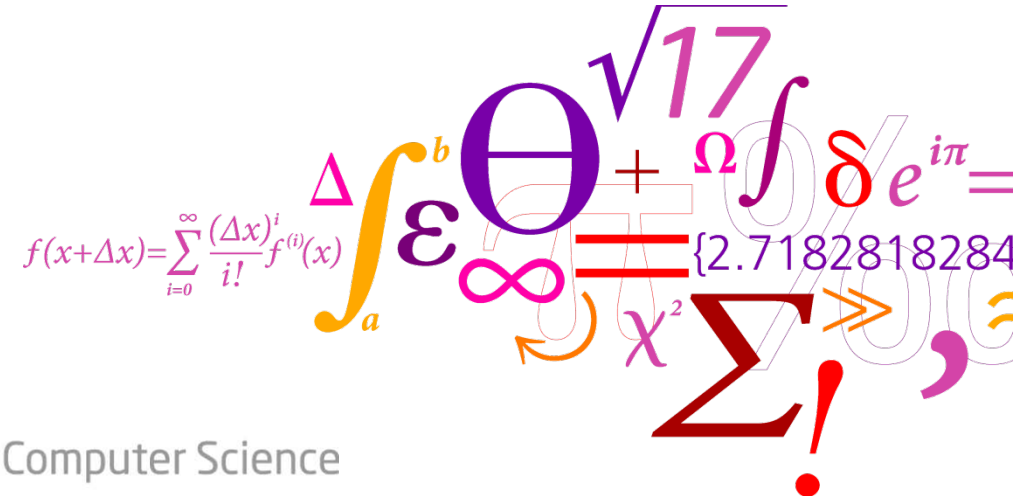


DTU Compute
Department of Applied Mathematics and Computer Science

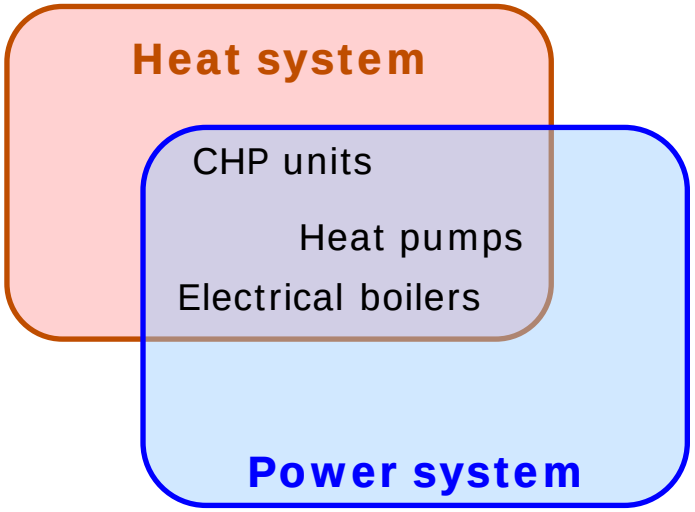
Me, me, me!

- Italian, in Denmark since 2006
- Background: Electrical/Automation Engineer
- PhD awarded in 2013 at DTU Compute
  - Managing renewables in power systems
  - Optimization/modeling uncertainty
- Recently PostDoc within CITIES
- Research focus:
  - Stochastic programming
  - Robust optimization
  - Decision rules
  - Hierarchical optimization
  - …
  - Applications in energy markets/systems

Why Considering Heat & Power Systems Jointly?

Motivation:

- Integration of **renewables** in Denmark will involve both sectors (wind, biofuels, etc.)
- Heat and power systems are **interdependent**
- Heat system can provide **flexibility** to integrate renewables



Challenges:

- Need for joint decision-making tools to exploit these synergies
- Optimization models ought to account for **uncertainty** (demand, prices, etc.)
- System **dynamics** (multistage)

Optimization under Uncertainty Framework

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 uncertainty realization

Day-ahead cost (profit changed in sign)

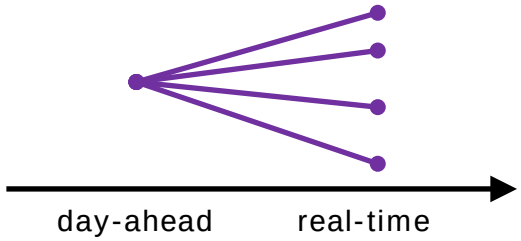
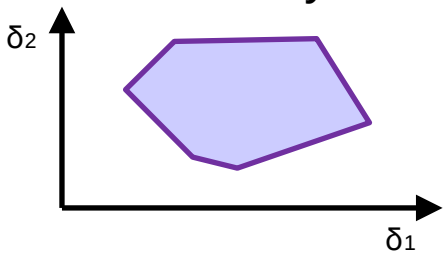
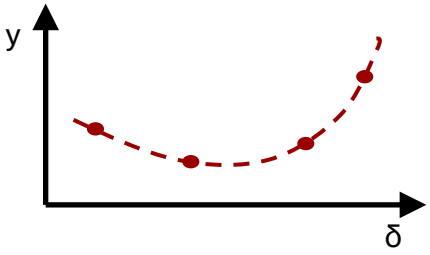
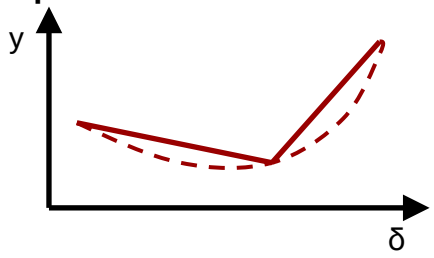
Projection of real-time cost (profit changed in sign)

$$\underset{x,\, y(\cdot)}{\text{Minimize}} \; c_x^{\mathrm{T}} x + \mathrm{Exp}_{\delta}\{c_y^{\mathrm{T}} y(\delta)\}$$

$$A_x x + A_y y(\delta) \geq b(\delta), \qquad \forall \delta$$

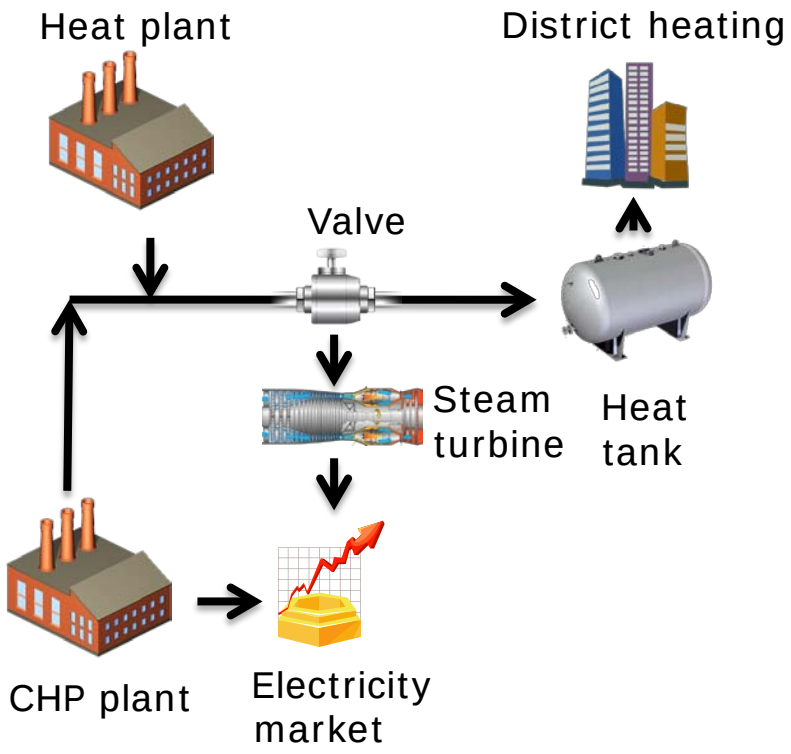
The planning must guarantee feasible real-time operation under a number of plausible realizations of the uncertain parameters

Stochastic Programming vs Robust Optimization

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

Robust Management of Heat & Power Systems

- Optimize management of heat and power systems:
  - planning
  - trading
  - operation
- Want to account for **uncertainty:**
  - heat demand
  - power prices
- We aim at a **conservative solution**: heat supply guaranteed for the most extreme realization of heat demand

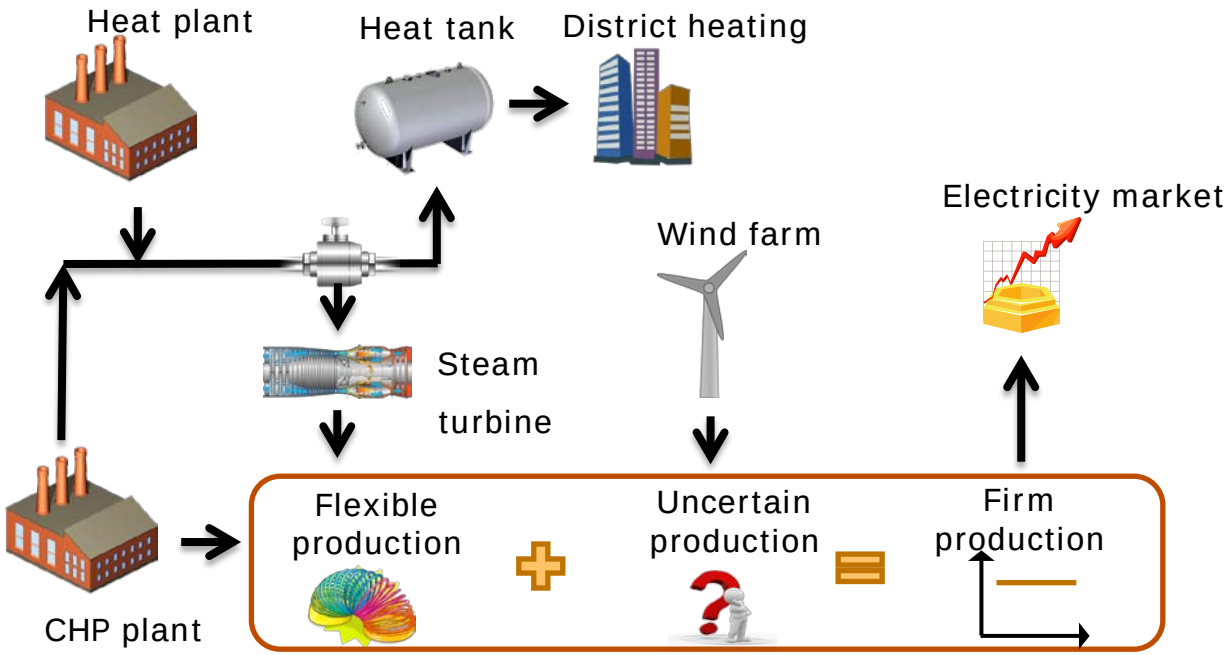


Peculiarities of the model

- We cast the problem as a **robust optimization** model
- Piecewise-linear **decision rules** approximate optimal recourse: recourse is affine function of the uncertainty
- We model trading in multiple commodity markets
- Uncertainty enters optimization model via **simple** descriptions (support set, mean, correlation, etc.)

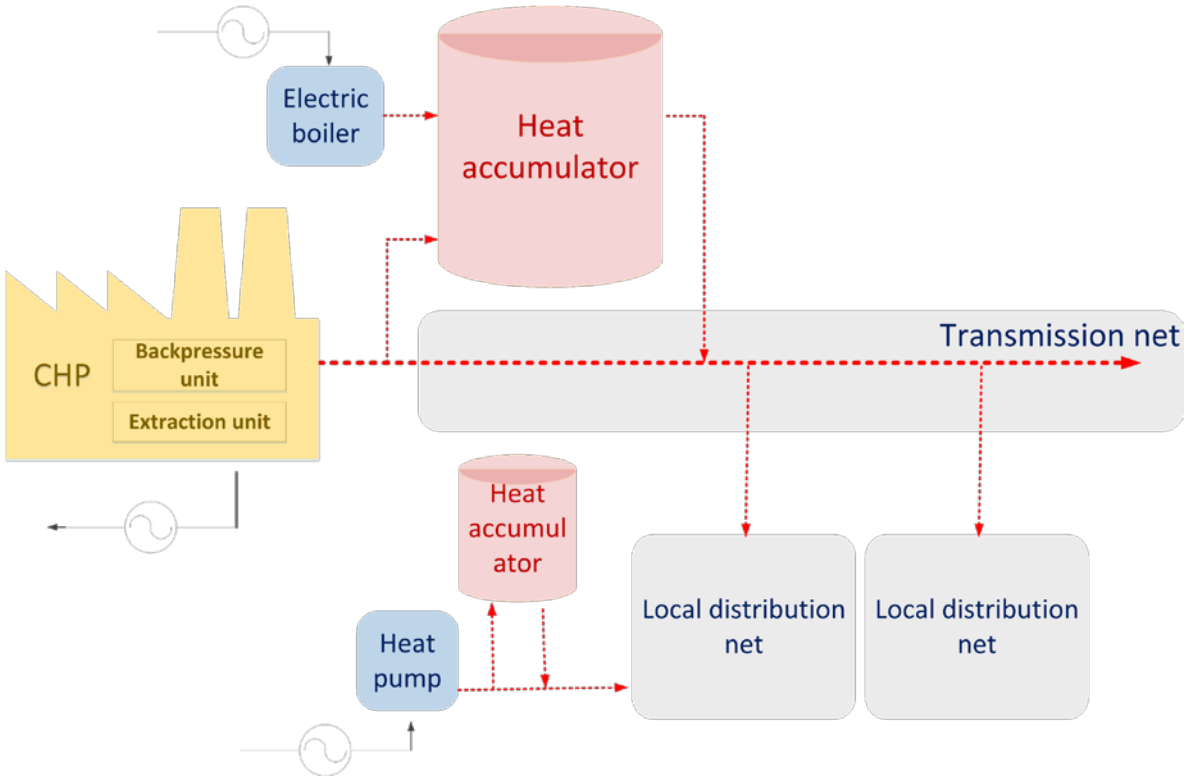
Optimal Trading for Wind Farms and CHP Plants
(Anna Hellmers' M.Sc. project)

- Analysis of joint trading strategies for wind/CHP plants in the balancing market
- Assessment of how the heat system can help **balance** the deviations of wind power
- **Real-world** data from existing plants
- **State-of-the-art forecasting** models for uncertainty (heat demand, power prices, wind)



Probabilistic Forecasting and Optimization for CHP Systems
(Maria Nielsen's M.Sc. Project)

- Assessment of societal value of **electrical boilers** and **heat pumps**
- Real-world data from the Greater Copenhagen area including taxes and subsidies
- Model based on **stochastic programming** to account for uncertain heat demand



Ongoing and Future Work

- Production of three peer-reviewed articles (ongoing)
  - *Commitment and Dispatch of Heat and Power Units via Affinely Adjustable Robust Optimization* (Zugno, Morales, Madsen)
  - *Assessing the Role of Heat Pumps and Electrical Boilers in the Danish Heat and Power Systems* (Nielsen, Zugno, Morales, Madsen)
  - *Portfolio Operation Strategies for Wind Farms and CHP Plants in a Dual-Price Balancing Market* (Hellmers, Zugno, Morales, Skajaa)
- Realistic case-study assessing the potential of RO vs current management strategies for heat and power systems (ongoing)
- Refinement of RO model
  - More realistic modeling of the trading process
  - More sophisticated modeling of the uncertainty