Decision-making under uncertainty for energy companies in smart cities

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Agenda

- Introduction work package 7
- Decision-making under uncertainty
- Previous work in work package 7
- Work in progress: Biomass supply planning for CHP plants
- Summary and outlook

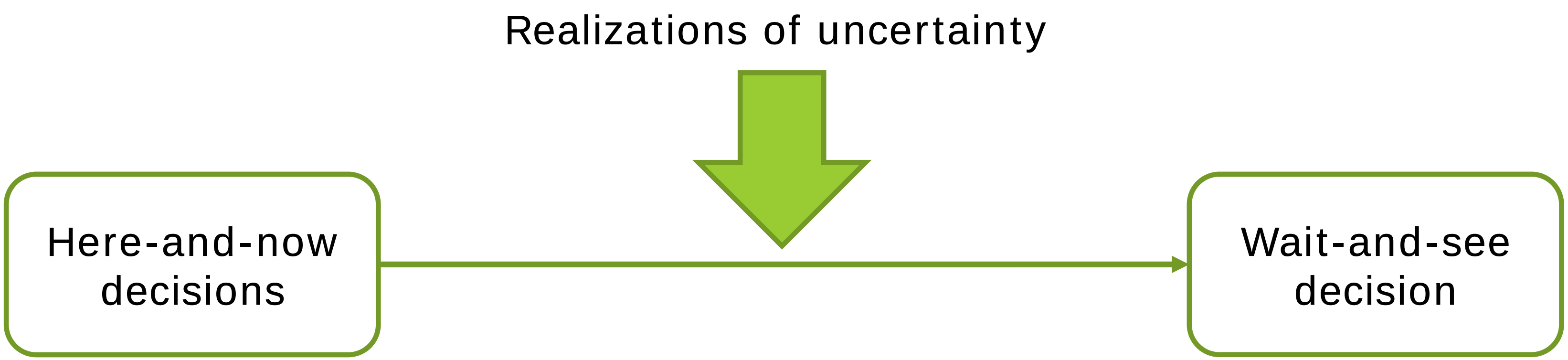
CITIES WP 7 –
Decision Making and Support Methods

Objectives:

1. Development of decision-making models for the optimal market participation of energy companies

2. Using the decision-making models to perform cost/benefit analyses for smart cities

Decision-making under uncertainty



Here-and-now decisions:

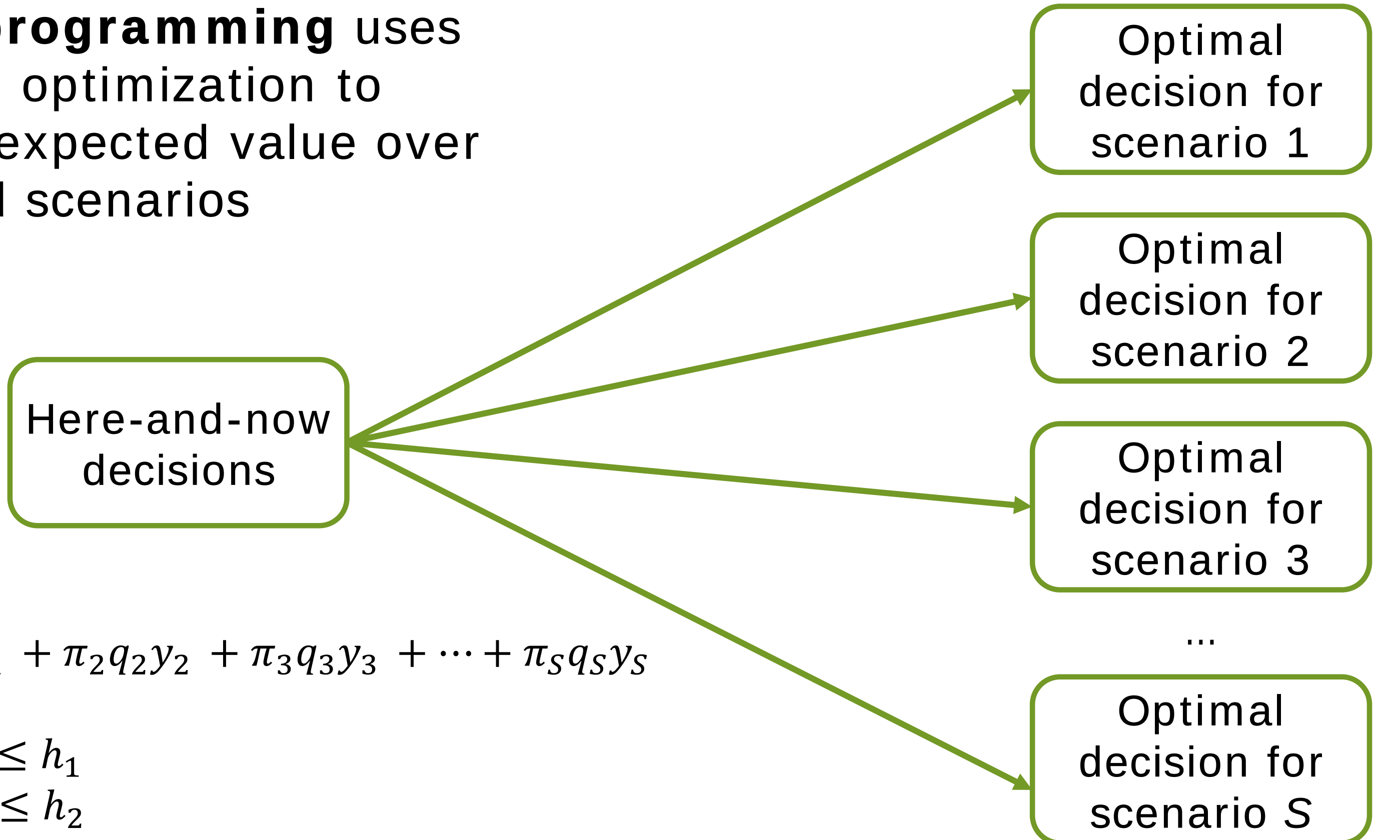
- have to be optimal for all considered future realization of uncertainties

Wait-and-see decisions:

- depend on the here-and-now decisions
- can be taken after realization of uncertainty (react to the uncertainty)

Decision-making under uncertainty

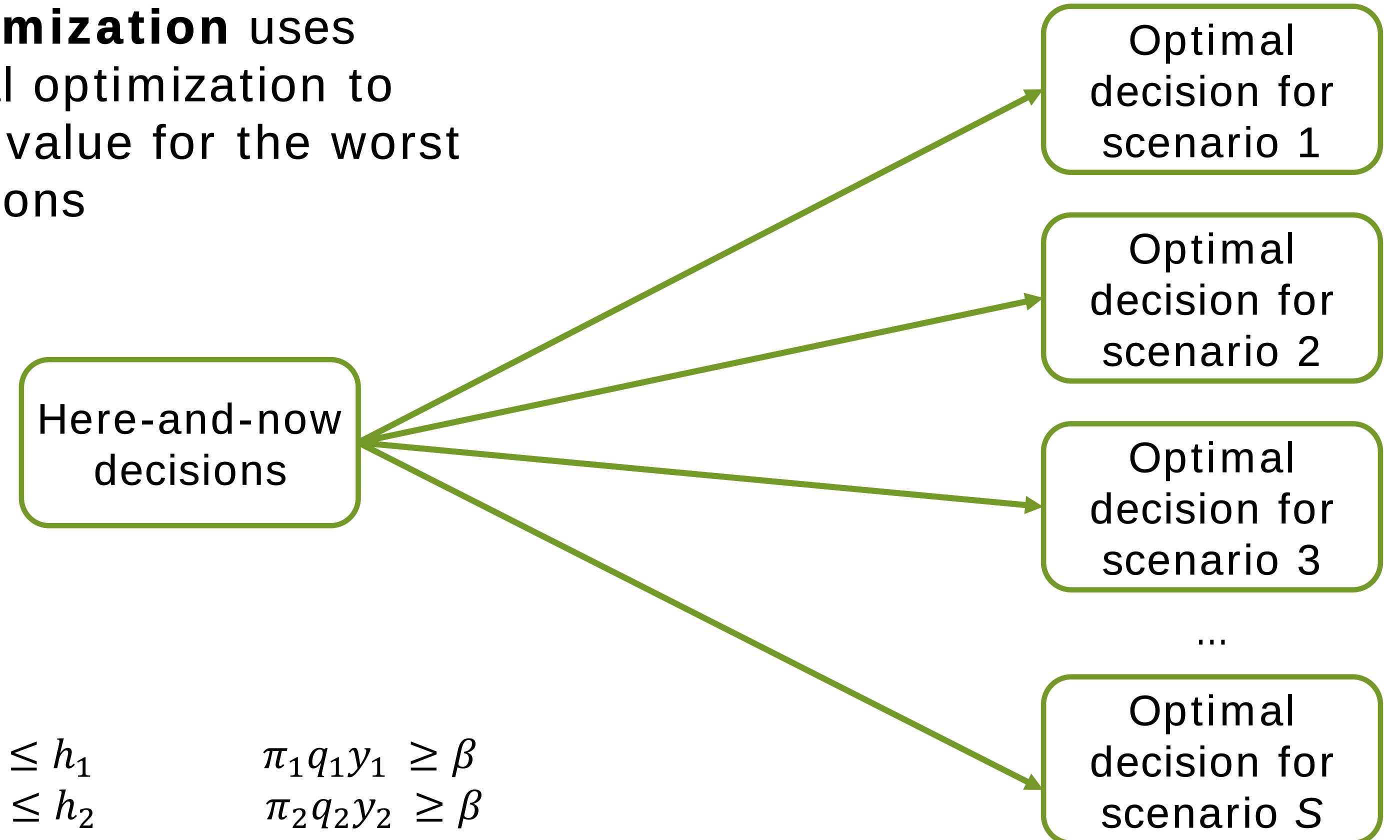
Stochastic programming uses mathematical optimization to optimize the expected value over all considered scenarios



$$
\begin{aligned}
\min \quad & cx + \pi_1 q_1 y_1 + \pi_2 q_2 y_2 + \pi_3 q_3 y_3 + \cdots + \pi_S q_S y_S \\
s.t. \quad & Ax \leq b \\
& Tx + W_1 y_1 \leq h_1 \\
& Tx + W_2 y_2 \leq h_2 \\
& Tx + W_3 y_3 \leq h_3 \\
& \quad \ldots \\
& Tx + W_S y_S \leq h_S \\
& x, y_1, y_2, y_3, \ldots, y_S \geq 0
\end{aligned}
$$

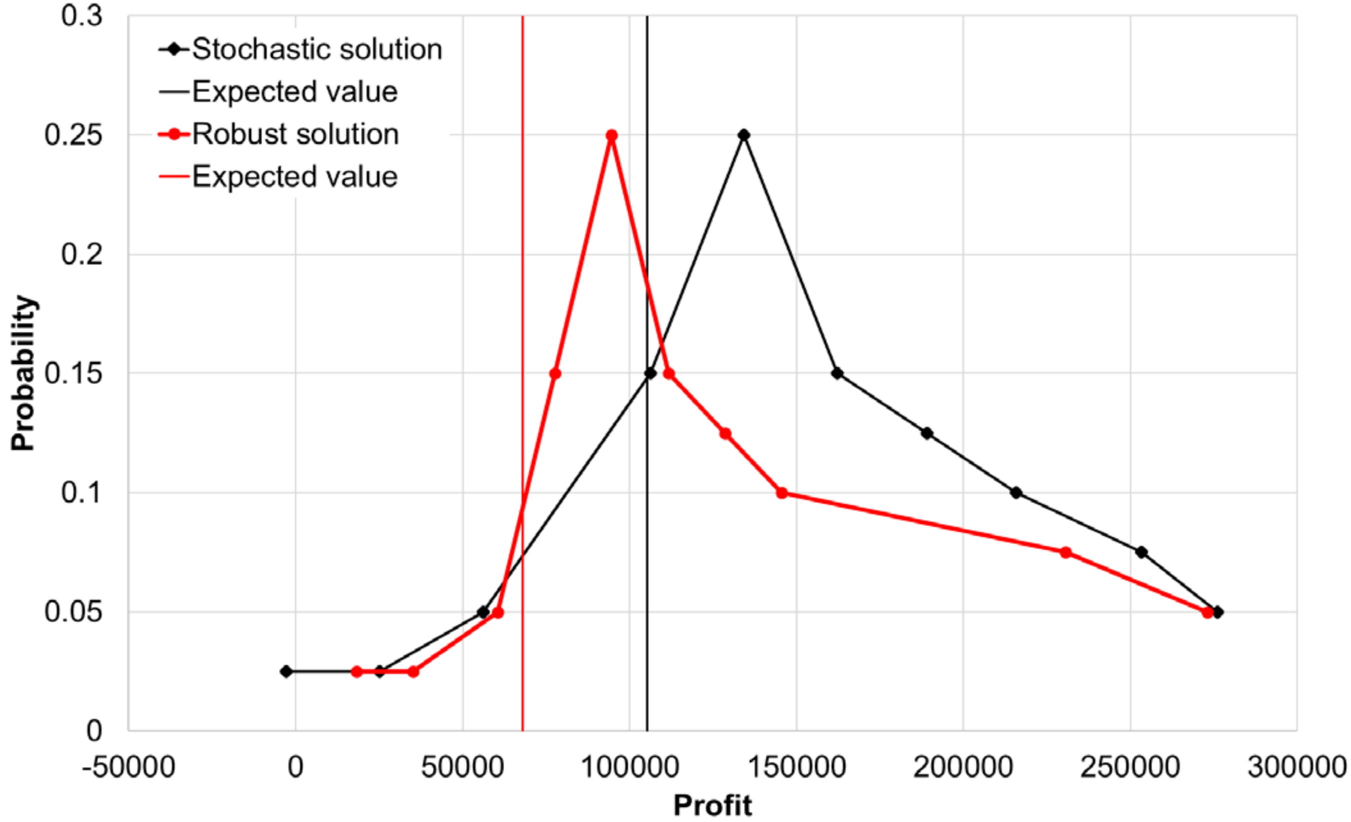
Decision-making under uncertainty

Robust optimization uses mathematical optimization to optimize the value for the worst case realizations



$$
\begin{aligned}
\min \quad & cx + \beta \\
s.t. \quad & Ax \le b \\
& Tx + W_1 y_1 \le h_1 \qquad \pi_1 q_1 y_1 \ge \beta \\
& Tx + W_2 y_2 \le h_2 \qquad \pi_2 q_2 y_2 \ge \beta \\
& Tx + W_3 y_3 \le h_3 \qquad \pi_3 q_3 y_3 \ge \beta \\
& \quad \dots \qquad\qquad\qquad \dots \\
& Tx + W_S y_S \le h_S \qquad \pi_S q_S y_S \ge \beta \\
& x, y_1, y_2, y_3, \dots, y_S \ge 0
\end{aligned}
$$

Decision-making under uncertainty



- Hybrid methods of stochastic and robust optimization can be used to control the risk in the decision problem
- Both are widely applied successfully to applications cases in energy and finance

CITIES WP 7 – Overview

Methods:

- Decision-making under uncertainty
- Large-scale optimization (decomposition, heuristics)

Application areas:

- Planning problems of energy companies
- Evaluation of different energy systems

Taking into account:

– Energy systems integration (mostly power and heat)
– Flexibility and controllability of those sources
– Portfolios of energy sources
– Different sources of uncertainty

CITIES WP 7 – Previous work on decision-making under uncertainty

(WP leader: Juan Miguel Morales)

- Models for the optimal operation of CHP plants in markets with high share of wind energy [Zugno et al. 2014, Zugno et al. 2016]
  - Robust optimization has be shown successful to model this
- Aggregated models for a portfolio of producers [Hellmers et al. 2015, Hu et al. 2015]
  - CHP plant (in collaboration with DONG Energy) or diesel power systems with wind farm
- Managing risk in unit commitment problem using a novel hybrid approach of stochastic and robust optimization [Blanco and Morales 2017]
- Investment decisions for heat production by electricity [Nielsen et al. 2016, Bach et al. 2016]
  - Modelling and evaluation of heat pumps in existing systems with renewable energies
  - In collaboration with HOFOR and COWI and EA EnergyAnalyse

Work in progress:
Fuel supply planning for CHP plants

Decision-making under uncertainty to support for the planning of **biomass** supply, especially the **selection of biomass contracts for combined heat and power (CHP) plants**

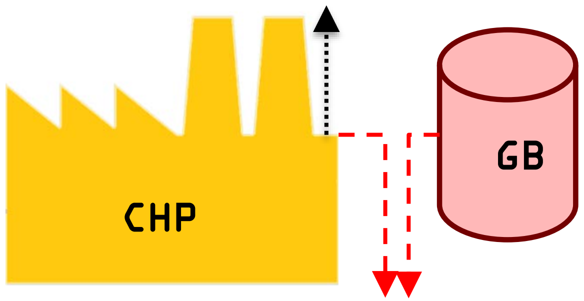
Background and assumptions:

- Biomass contracts are negotiated in advance for a period of up to 1 year
- Heat demand and prices are uncertain at this point in time
- The quality of contract decisions is evaluated using the operational costs of the heat and electricity production

Work in progress:
Fuel supply planning for CHP plants

Setting:

- CHP plant producing heat and power
- Gas boiler covering peak demands
- Heat storage



Here-and-now decisions:

- Selection of biomass suppliers and the contract amounts

Wait-and-see decisions:

- Revised weekly delivery schedules of biomass supply (if possible)
- Operation of CHP plant and gas boiler
- Gas supply

Goal: Minimize expected cost

Work in progress:
Fuel supply planning for CHP plants

Requirements:

- Characteristics of biomass suppliers
  - Capacities
  - Delivery pattern / frequencies
  - Flexibility

- Technical characteristics of the units
  - Start and stop restrictions of the CHP plant
  - Feasible production capacities
  - Heat storage capacity

- Covering the heat demand

Work in progress:
Fuel supply planning for CHP plants

Current implemented solution approach:

Two-stage stochastic program

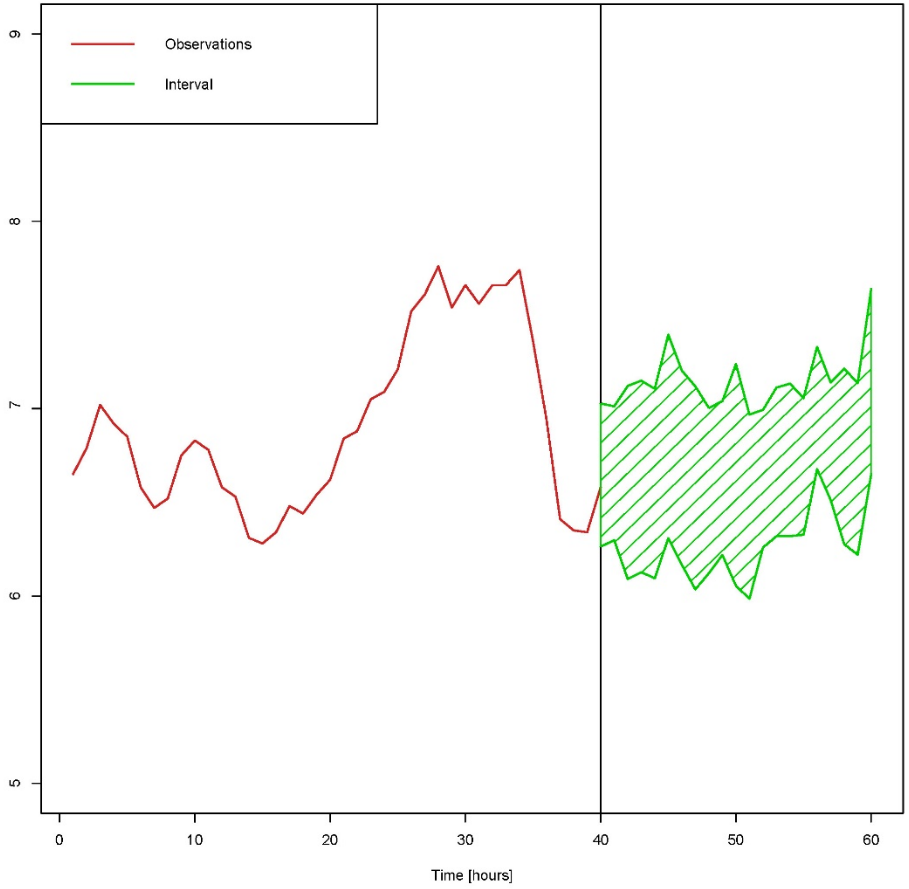
- With a planning horizon of one year in hourly resolution
- Including scenarios for heat-demand, electricity price and gas prices

$$\begin{aligned}
\underset{\mathbb{X},\mathbb{Y}_\omega}{\text{minimize}} \quad & \sum_{t \in T} \Bigg[\sum_{j \in J} \left(C_j^B b_{j,t}^{FX} + C_j^{B+} b_{j,t}^{FX+} + C_j^{B-} b_{j,t}^{FX-} \right) \\
& + \sum_{\omega \in \Omega} \pi_\omega \Bigg(\left(L_{t,\omega}^B - L_{t,\omega}^E \right) p_{t,\omega} + C^{SU} y_{t,\omega} + C^{SD} z_{t,\omega} \\
& + C_{t,\omega}^{GB} q_{t,\omega}^{GB} + \left(C_{t,\omega}^{NG} + Q^{MISS} \right) g_{t,\omega}^{CHP} \\
& + \sum_{j \in J} \left(C_j^B \left(b_{j,t,\omega}^{SP+} - b_{j,t,\omega}^{SP-} \right) \right) + C^{STO} \delta_{t,\omega} \Bigg) \Bigg]
\end{aligned}$$

- most detailed representation
- high complexity, long computation times
- forecasting of electricity and gas prices for one year?

Work in progress:
Fuel supply planning for CHP plants

- Forecasting of electricity and gas prices for one year:
  Use robust optimization to cover price ranges instead of scenarios



Work in progress:
Fuel supply planning for CHP plants

- Apply a two-phase solution approach that is also applicable in practice

Long-term planning

Selection of biomass contracts based on heat demand scenarios

- 1 year - weekly resolution
- Without most of the technical requirements

→ Contracts →

Operational planning

Weekly production scheduling

- 1 week– hourly resolution
- Higher level of detail

- Evaluate and compare methods on a real-world case study

Summary and outlook

- WP 7 addresses decision making and planning problems for companies in smart cities / integrated energy systems
  - Special focus on uncertainty due to intermittency of some renewable energy resources
  - Using mathematical optimization methods based on stochastic programming, robust optimization, decomposition, heuristics

- Outlook:
  - Finish biomass supply planning method
  - Develop methods to further planning problems of industry partners in CITIES
  - Combine different models to perform cost/benefit analyses for integrated energy systems

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Thank you very much for your attention.

Questions?

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