House of Energy Markets & Finance

Stochastic optimization under price uncertainty in auction-based electricity markets – A Case study

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Electricity prices and heat delivery present challenges for portfolio/asset management

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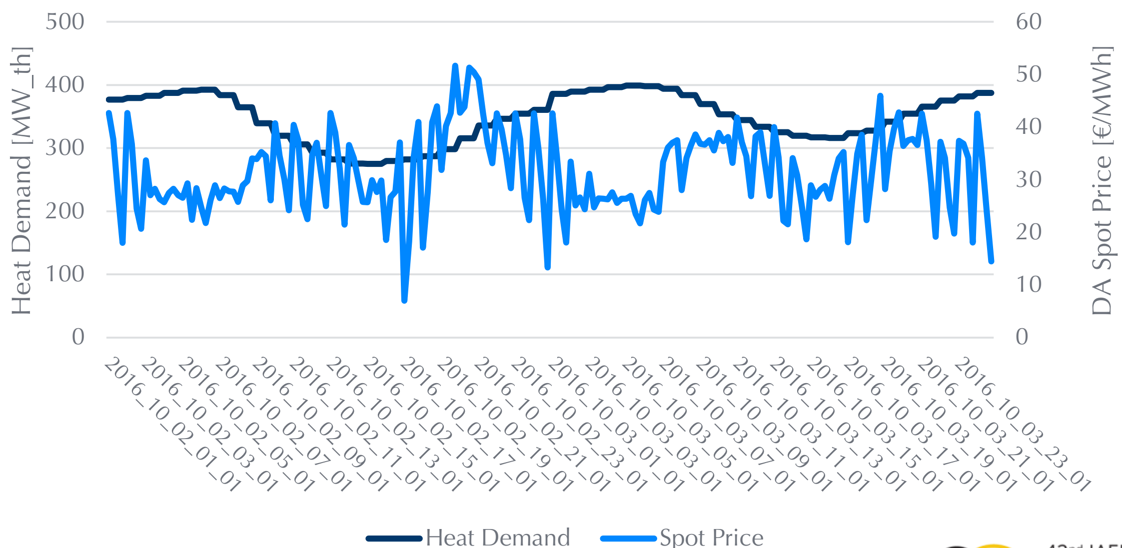
Motivation

- Portfolio owners in electricity markets often struggle to stay competitive

- On an everyday basis, this is even more evident for cogeneration units
  - Non-deferrable heat demands may induce inflexibilities in electricity generation from CHP or Power-to-Heat conversion technologies
  - → Heat and electricity storages are useful means to decouple supply and demand



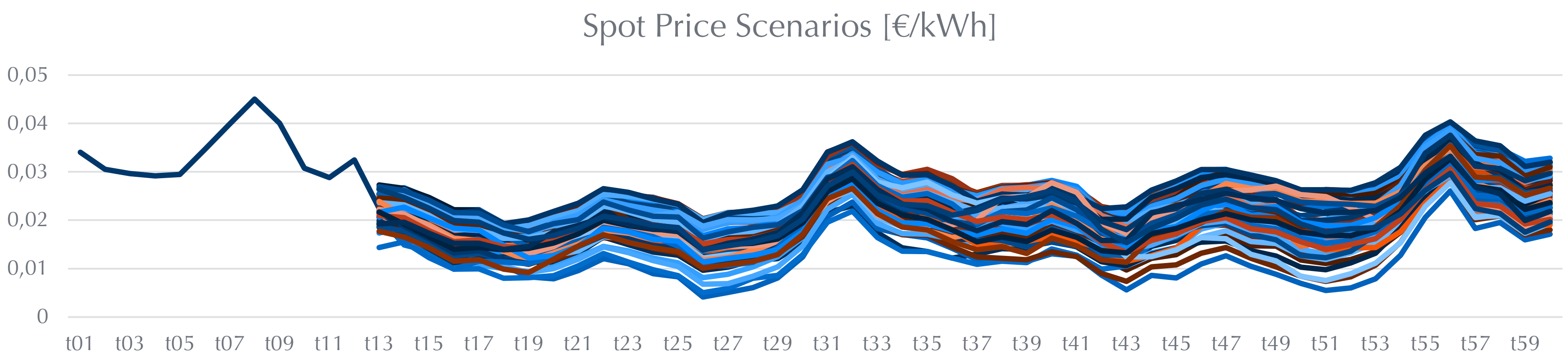
Electricity price uncertainty – opportunity and threat for flexible portfolios

Motivation

- Optimal marketing of flexible portfolios needs to account for price uncertainty
- However, many small portfolio owners like municipalities often lack resources for elaborate market analysis

→ Wanted: elaborate but easily replicable method to capture price uncertainty

→ Stochastic optimization?



Agenda

About stochastic optimization

Stochastic Optimization and its Merits

- Key characteristics of stochastic optimization/programming:
  - Framework for modelling optimization problems **under uncertainty**
  - Taking into account **probability distributions** of random variables
  - Enabling **decision-making**
  - on **two-** or even **multi-stage decision problems**

- **New here:**
  - **Consideration of bidding into two subsequent spot markets (EEX: day-ahead and intraday)**
  - **Only few works have considered simultaneous optimization of heat and electricity storage units**

Methodology: Uncertainty/Optimization Modelling

Specifics of the Used Model

- Portfolio optimization model:
  - Adjusted unit commitment and bidding model implemented in GAMS, based on dissertation thesis by Kempgens (2018)
  - Optimization of submitted piece-wise linear bidding functions to the market (EEX)

- Spot price uncertainties of quarter-hourly products are modelled with the approach of Pape, Vogler, Woll, Weber (2017)
  - OLS regression, PCA, ARMA(1,1)-GARCH, 173 days rolling window approach
  - Use of Monte Carlo Simulation to generate 1000 independent price paths
- Scenario Reduction by application of k-means algorithm (k: no. of clusters)
  - k=1: point forecast for deterministic optimization, choice of k=15 and k=60 for stochastic optimization
  - Hourly price is assumed to be the mean of quarter-hourly prices
- Heat demand for the next 60 hours is not modelled as uncertainty

Stochastic Program (I) - Overview

- For optimizationPeriod 1 to 365
  - Assign Parameters (Fuel costs, deterministic prices, price simulations, heat demand)
  - 1st Optimization: Day-Ahead Auction
    - Fixation of DA marketing results
  - 2nd Optimization: Intraday Opening Auction
    - Fixation of ID marketing results
  - 3rd Optimization: Dispatch
    - Fixation of generation for part of marketed hours, and quarter-hours (12 am- 12 am)
    - Calculate profit (quarter-hourly resolution) for this period
  - Rolling forward of horizon by 24 hours
- Calculate sum of profits

Stochastic Program (II) – Day-Ahead and Intraday-Auctions

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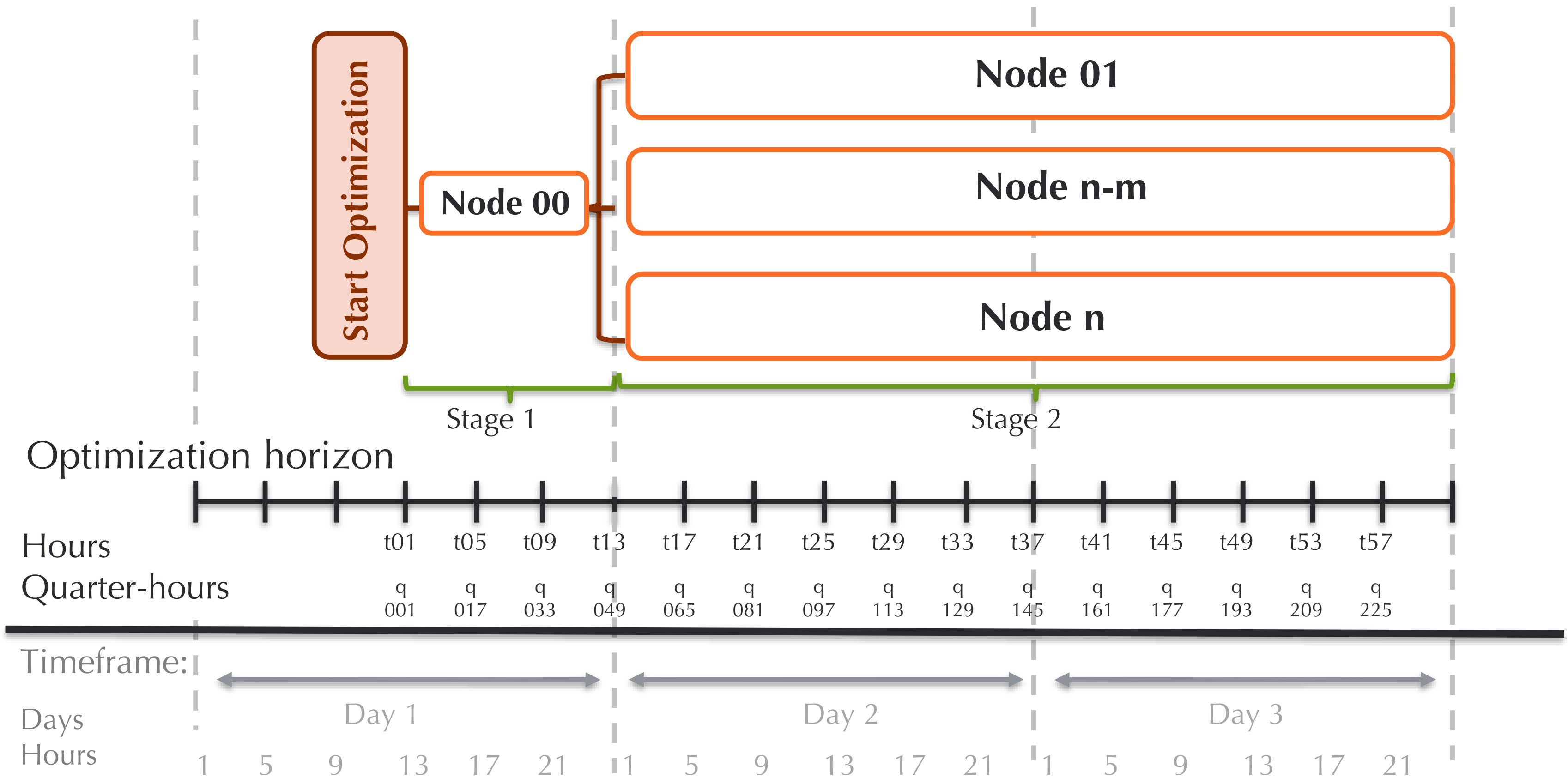
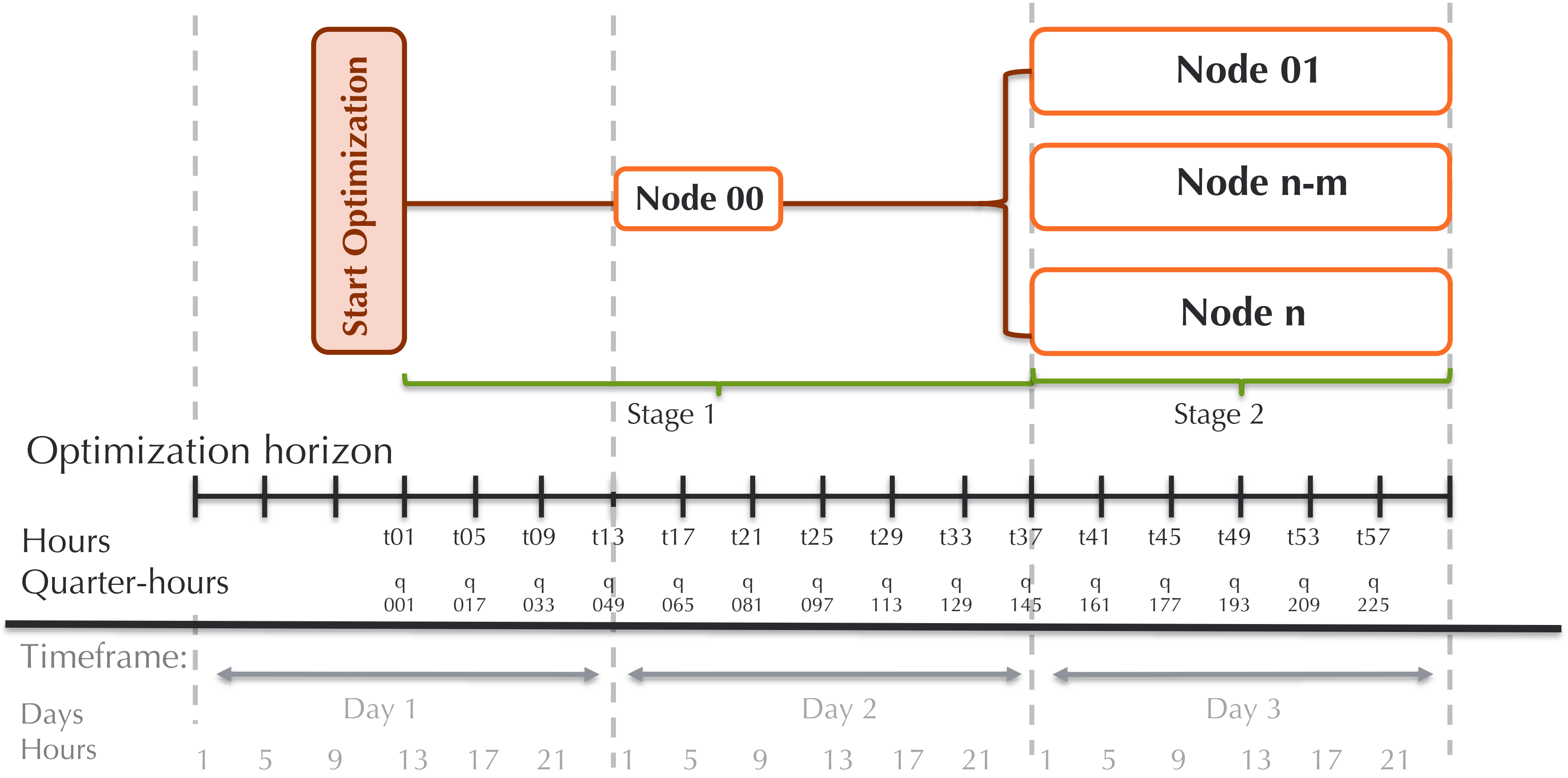
Specifics of the Used Model

- Rolling horizon approach:



- Rolling horizon approach:



Assets in the portfolio

Modelled Portfolio and Sensitivities

Unit no.	Name /Type	Heating grid	Additional units in this grid	P_{el}^{max} [kW]	P_{heat}^{max} [kW]	P_{el}^{min} [kW]
1	CHP 1	1	2 peak boilers, 1 heat storage	19	34	10
2	Heating Pump 1	2	1 heat storage	3.02	16.157	-
3	Electric Storage Heater	3	-	12	12	-
4	Heating Pump 2	4	1 heat storage	5	15	-
5	Heating Pump 3	5	1 heat storage	4.4	23.54	-
6	Electric Storage	-		50	-	-
7	CHP 2	6	1 heat storage (ca. 5,000 kWh)	420	540	210
8	CHP 3	7	1 peak boiler, 1 heat storage	50	80	25

Assets in the portfolio

Modelled Portfolio and Sensitivities

Unit no.	Name /Typ	Heating	Additional units ... grid	P_{el}^{max} [kW]	P_{heat}^{max} [kW]	P_{el}^{min} [kW]
1	CH		boilers, storage			
2	Heat Pum		t storage			
3	Elec Stor Hea		-			
4	Heat Pum		t storage			
5	Heat Pum		t storage			
6	Electric Storage	-				
7	CHP 2	6	1 heat storage (ca. 5,000 kWh)	420	540	210
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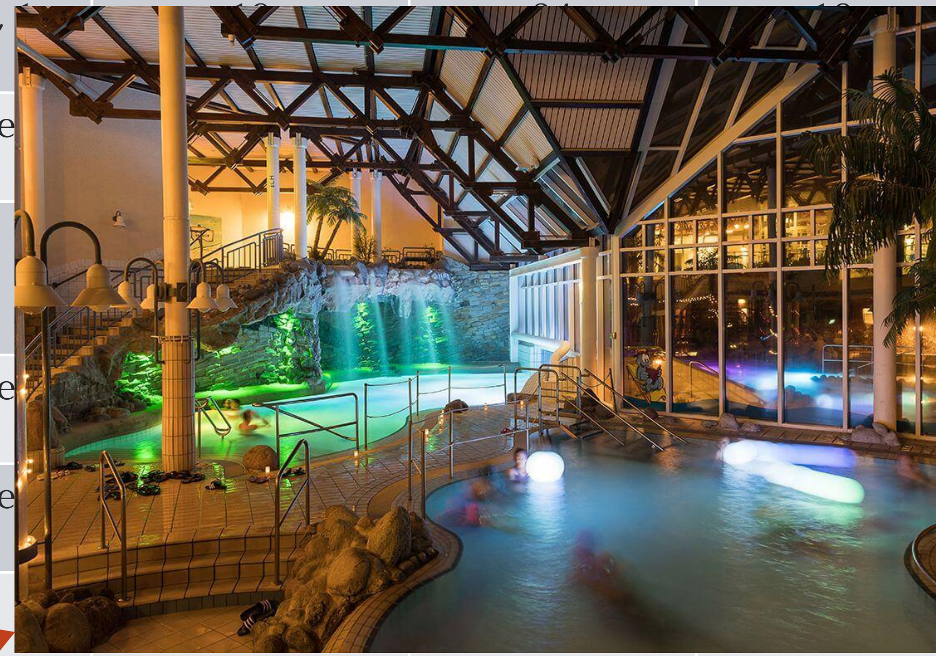
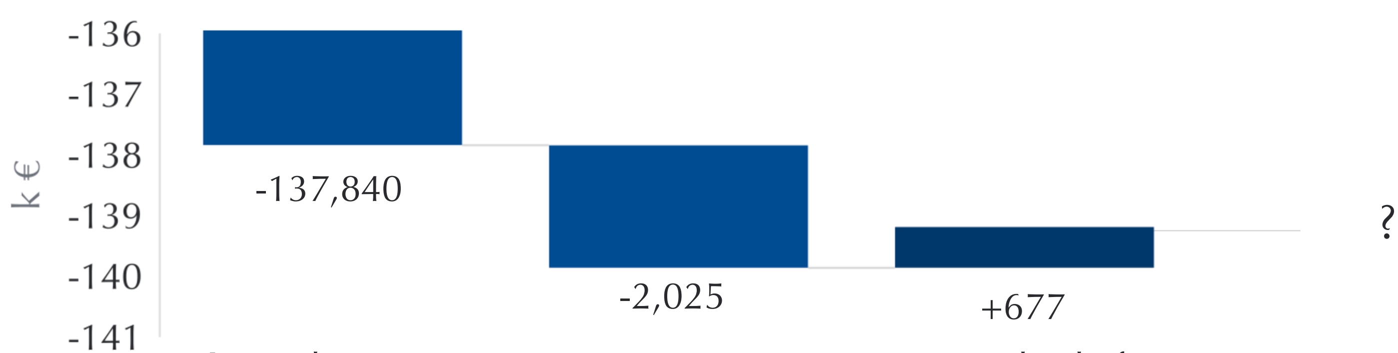


First results, inc. battery storage of 50 kW

Results

	WS	EEV	17scen	62scen
Objective (€/year)	-137,840 €	-139,868 €	-139,187 €	n.a.
EVPI	2,025 € (1.5%)			
VSS			677 € (0.5%)	n.a.
Computation Time per opt. (gap = 0.1%)	<1min	<1min	0:02:46	2:15:39



→ Stochastic Optimization (17 scen) recovers one third of EVPI

Further (indicative) results of our sensitivity analyses

- The Expected Value of Perfect Information (EVPI)
  - Increases, when flexibility is added to the system
  - Increases, when fuel costs and electricity revenues have similar magnitudes
  - Decreases, when heat demand is dominating dispatch decisions

- The Value of Stochastic Solution (VSS)
  - Increases with a rising number of scenarios (but converges quickly)
  - Is depending on EVPI levels
    - No EVPI → no VSS
  - However, a rise in EVPI levels does not have to translate to a higher VSS!

- Computation times are exploding quickly, especially when there are multiple district heating grids

Lessons learned

Conclusion

- Stochastic optimization is a functional tool that may assist and improve the decision-making process when managing flexible assets

- However, in the given setup, there seems to be a limited additional value of stochastic optimization, possible reasons:
  – Only one stochastic variable modelled
  – Restrictiveness of heat demand is high in the given setting
  → Optimal dispatch strategies do not differ very much between deterministic and stochastic optimization

- After surpassing a certain number of scenarios, additional value and optimization times are resulting in a non-reasonable cost/benefit ratio
  – Optimization times not appropriate for related marketing decisions

Thank you very much for your attention!

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