



Optimization and bidding strategies for the operation of district heating plants

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Motivation

Setting:

Increasing share of heat production units in DH systems that challenge the operation of the system

Opportunity:

Make use of the flexibility given by the heat production units connected to the power grid (CHP units, electric boiler and heat pumps) to increase our profits in the electricity market minimizing the heat production cost

Goal:

Create optimization models for DH producers that consider the power market and heat production uncertainties to optimize bidding strategies and minimize the heat production cost



Agenda

- 1. Optimization and bidding based on electricity price forecasts
 - Includes uncertain renewable production
 - Day-ahead and balancing market
 - Price-dependent bids (bidding curves)

Blanco, I., Guericke, D., Andersen, A., & Madsen, H. (2018). Operational planning and bidding for district heating systems with uncertain renewable energy production. Energies, 11(12), 3310, <u>https://doi.org/10.3390/en11123310</u>

- 2. Optimization and bidding based on heat demand
 - Bid prices are not dependent on the electricity price forecast
 - Robust solution for day-ahead market
 - So far no uncertain renewable production

Blanco, I., Andersen, A. N., Guericke, D., & Madsen, H. (2018). A novel bidding method for combined heat and power units in district heating systems. Preprint available at <u>https://arxiv.org/abs/1810.10757</u>



Optimization method

Mathematical model including several scenarios for uncertainties (stochastic programming)

Optimization goal:

Hourly bidding amount for each price scenario

 \rightarrow Price-dependent bids

- with scenario prices The amount that is best for all scenarios of heat and power production (minimize expected costs)
- Two models: Day-ahead market and balancing market



Electricity Price (DKK/MWh)

Results



- Reduced costs compared to single bids based on forecasts
- Addresses the uncertainties appropriately on both markets
- BUT: Bidding price depends on electricity price forecast

Results

Setting	Total System Cost (DKK)	Diff.
Perfect information incl.balancing market	2,499,205	-
Perfect information excl.balancing market	3,414,310	+37%
Stochastic incl. balancing market	3,655,798	+7%
Stochastic excl. balancing market	3,956,530	+8%

 Potential improvements in the operation of the balancing market

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A novel bidding method



→The approach before and all methods in literature place bids, if the electricity price forecast indicates its beneficial

Our new approach:

Heat Unit Replacement Bidding (HURB) method

- Make use of the fact that we have to produce the heat for the district heating network anyway
- Bidding amount: replace heat production of other units by CHP production
- Bidding price: price where we are indifferent whether we produce with the CHP plant or with the other heat unit
- We use a (mixed-integer) linear program to determine the cost-minimal production in the algorithm



HURB – Step 1



Optimize heat production without market participation



HURB – Step 2

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Replace iteratively heat-only units by CHP production (in descending order of operational costs)

1. Iteration: Replacing the gas boiler (GB)



- Bidding amount: Power production amount of the CHPs.
- Bidding price: Cost CHP Cost GB = (610.84 404.02) * 1.18 = 244.045

HURB – Step 2

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Replace iteratively heat-only units by CHP production (in descending order of operational costs)

2. Iteration: Replacing the wood chip boiler (WCB)



- Result: 8 additional bids
- Bidding amount: Power production amount of the CHPs
- Bidding price: Cost CHP Cost WCB = (610.84 211.45) * 1.18 = 471.279



Use real electricity prices instead of forecasts



- Set CHP commitment based on realization of prices.
- Optimize the remaining units

Results - Bids

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Percentage of hours with bids and won bids in one month averaged over several samples

Method	Receding Horizon	CHP 1		СН	CHP 2	
		Bids	Won	Bids	Won	
HURB Worst	1	98.91	41.95	98.70	41.91	
HURB Avg.	-	99.79	42.19	99.75	42.15	
HURB Best	10	99.89	42.28	99.87	42.26	
Conejo et al.	10	44.92	39.34	44.92	39.31	
Rodriguez & Anders	5	82.52	35.85	82.40	35.82	
Schulz et al.	12	45.02	18.54	45.01	18.53	
Dimoulkas & Amelin	12	75.55	26.56	75.55	26.55	
Ravn et al.	5	44.84	32.58	44.83	32.57	

We can take advantage of the portfolio of heat production units and base the bidding amounts and prices on the heat production.



Receding Horizon Length [days]

Summary



Two optimization and bidding methods for district heating operators:

1.	Optimization dependent on price	2. HURB method
	scenarios	 Prices are indepedent of forecast
•	Bidding curves	No uncertain renewable production
•	Includes uncertain renewable	 Hourly bids on day-ahead market
	production	
•	Day-ahead + Balancing market	

Outlook

 Extend HURB method to consider bidding curves, uncertain renewable prodution and balancing market

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