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# A novel bidding method for combined heat and power units in district heating systems

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DTU Compute
Department of Applied Mathematics and Computer Science

# Motivation

**Setting:**

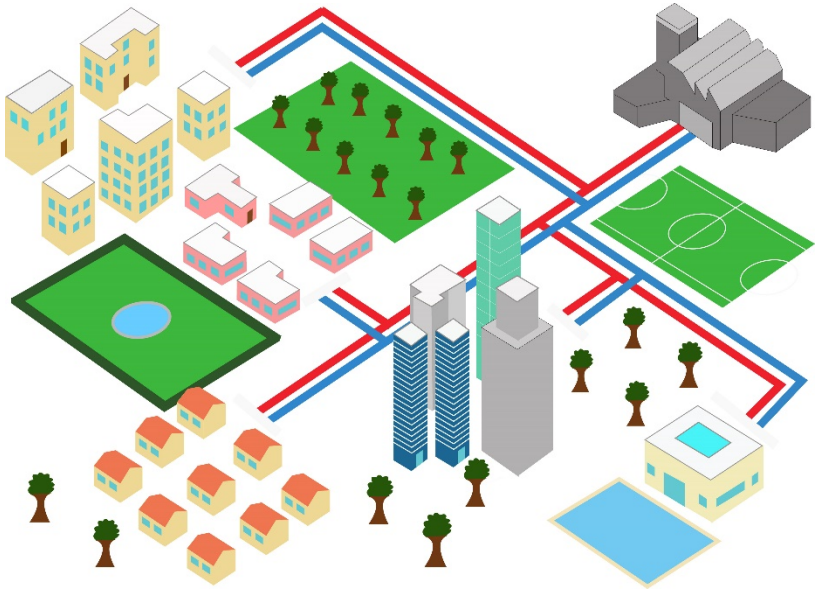
District heating provider with a portfolio of production units including combined heat and power (CHP) plant

**Goal:**

Optimize the daily production of heat to cover the heat demand at minimal cost

**Opportunity:**

- The operationally expensive CHP plant produces electricity while producing heat.
- Trade this electricity on the day-ahead market, if the income from the market lowers the overall cost.
- But the electricity price is uncertain.



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# Novel bidding method

**Related bidding methods for CHP units in literature:**

*[Conejo et al., 2002, Rodriguez and Anders, 2004, Schulz et al., 2016, Dimoulkas and Amelin, 2014, Ravn et al., 2004]*

→ Take a power producer perspective

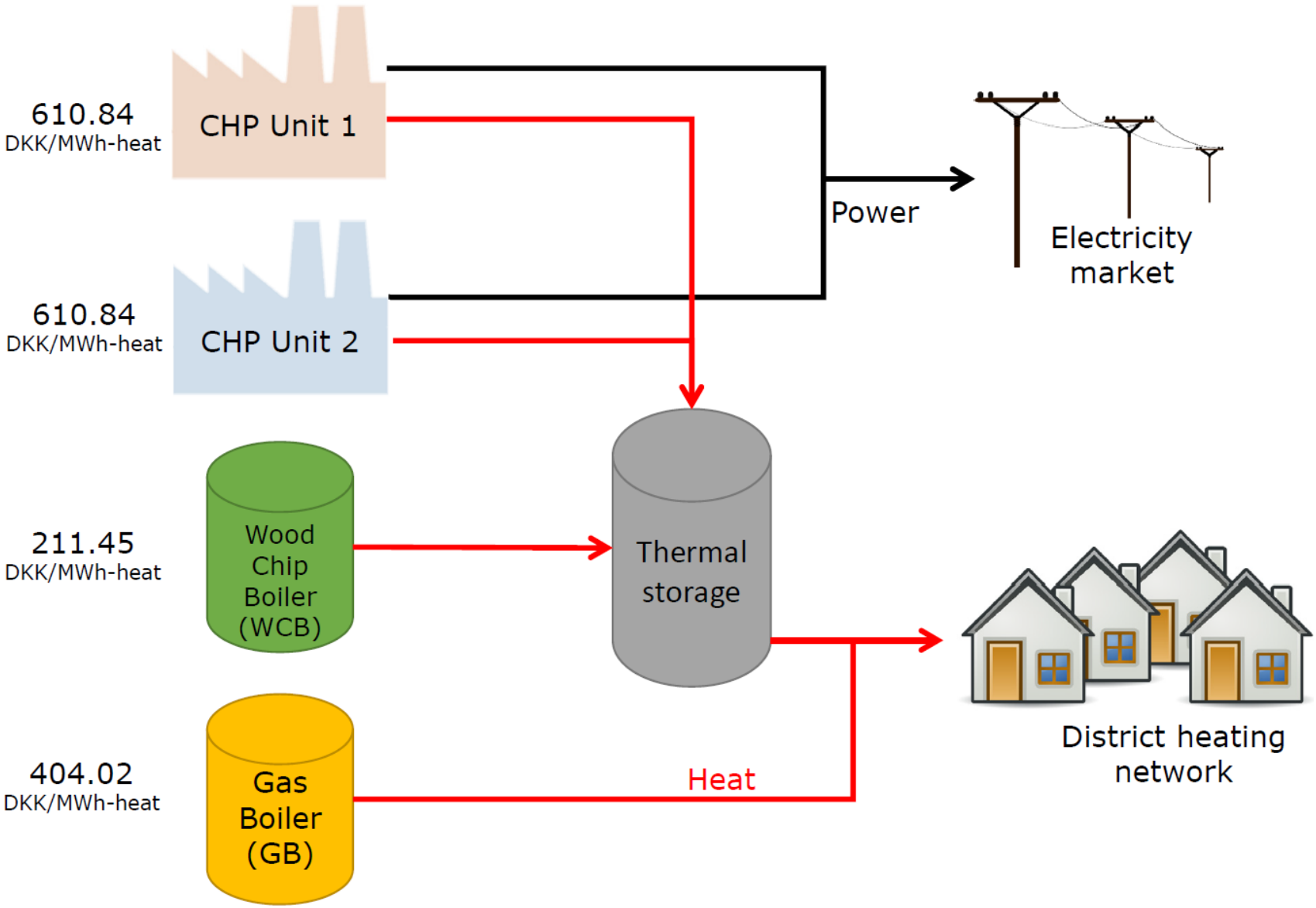
→all methods plan bids for the CHP units, if the electricity price forecast indicates its beneficial

**Our approach:**

**H**eat **U**nit **R**eplacement **B**idding (HURB) method

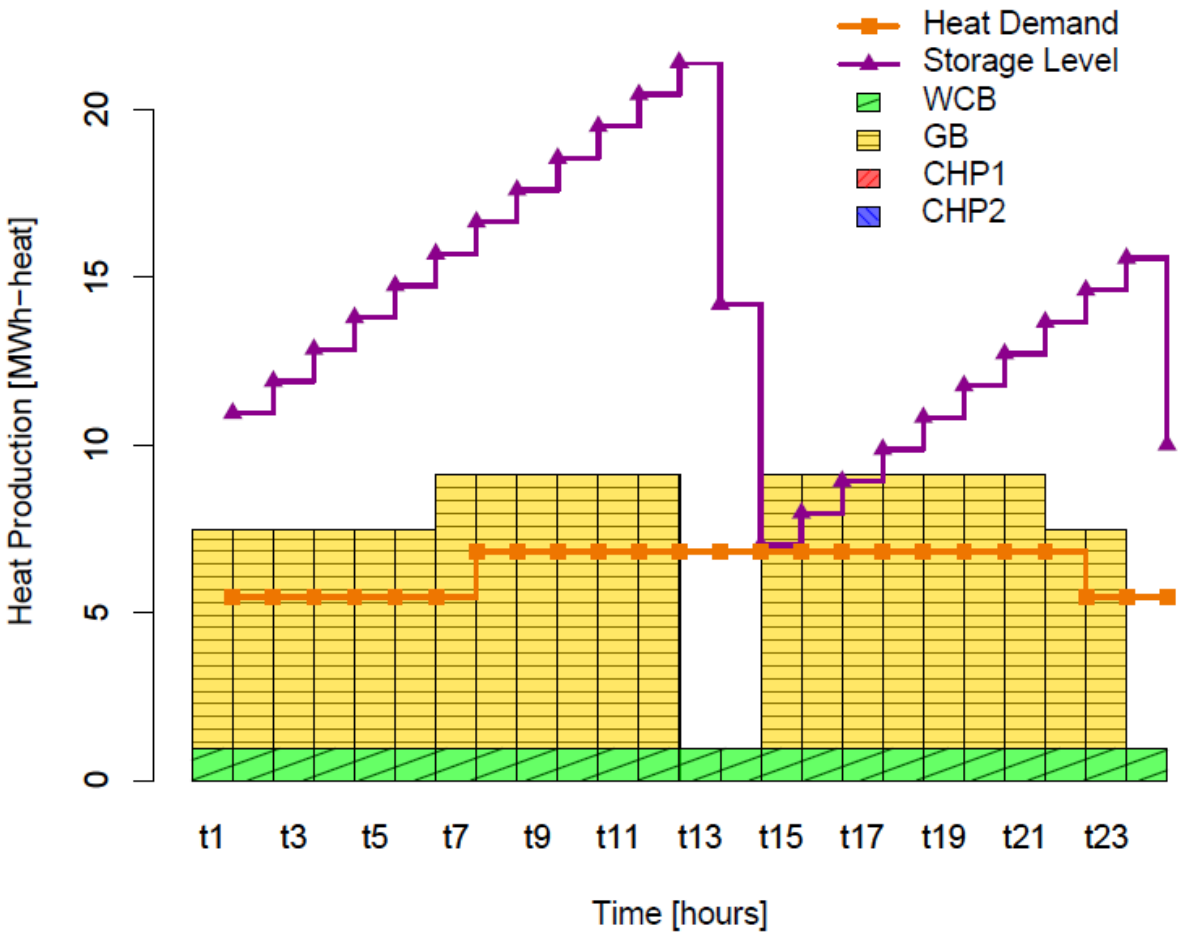
- Make use of the fact that we have to produce the heat for the district heating network anyway
- Bidding amount: **replace** heat production of other units by CHP production
- Bidding price: price where we are **indifferent whether we produce with the CHP plant or with the other heat unit**
- We use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

# Case study


610.84
DKK/MWh-heat
CHP Unit 1
610.84
DKK/MWh-heat
CHP Unit 2
Power
Electricity
market
211.45
DKK/MWh-heat
Wood
Chip
Boiler
(WCB)
Thermal
storage
404.02
DKK/MWh-heat
Gas
Boiler
(GB)
Heat
District heating
network

# HURB – Step 1

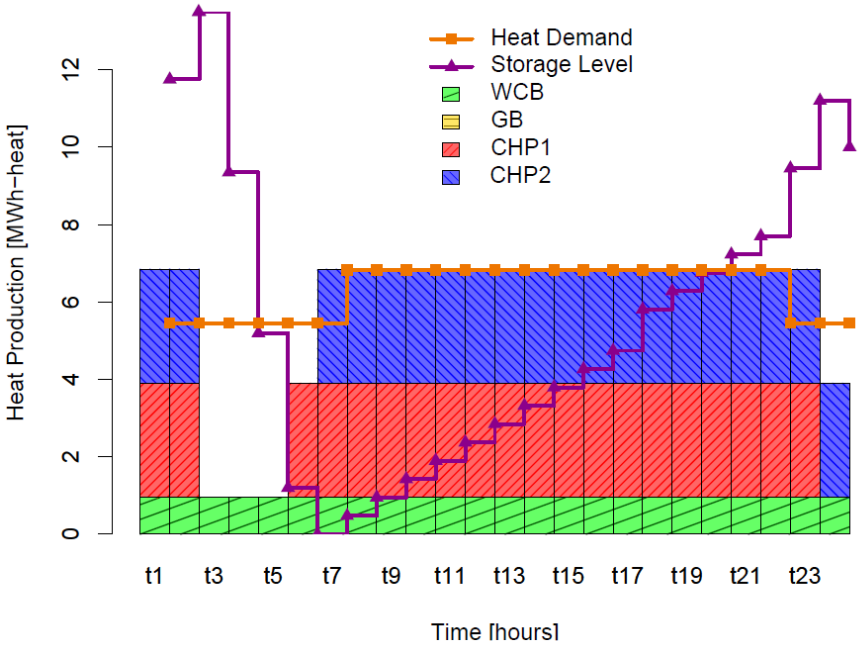
Optimize heat production without market participation



# HURB – Step 2

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

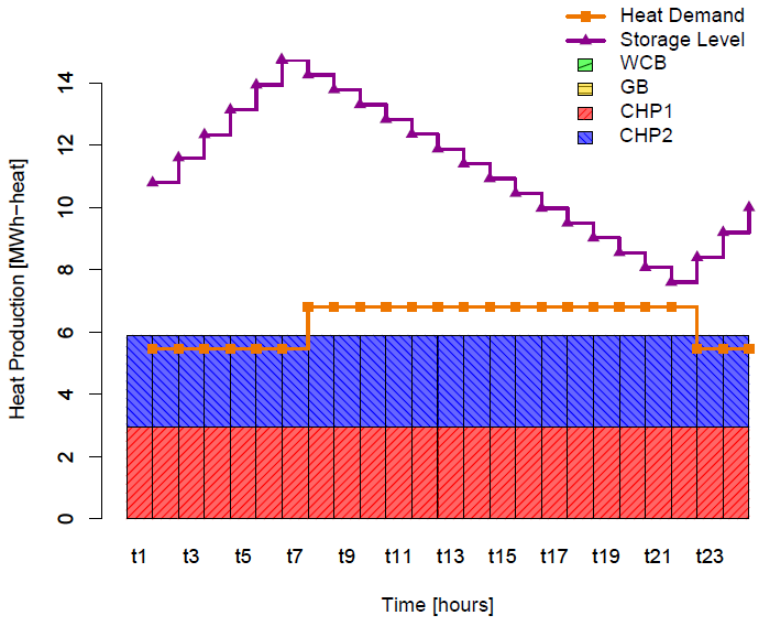
## 1. Iteration: Replacing the gas boiler (GB)

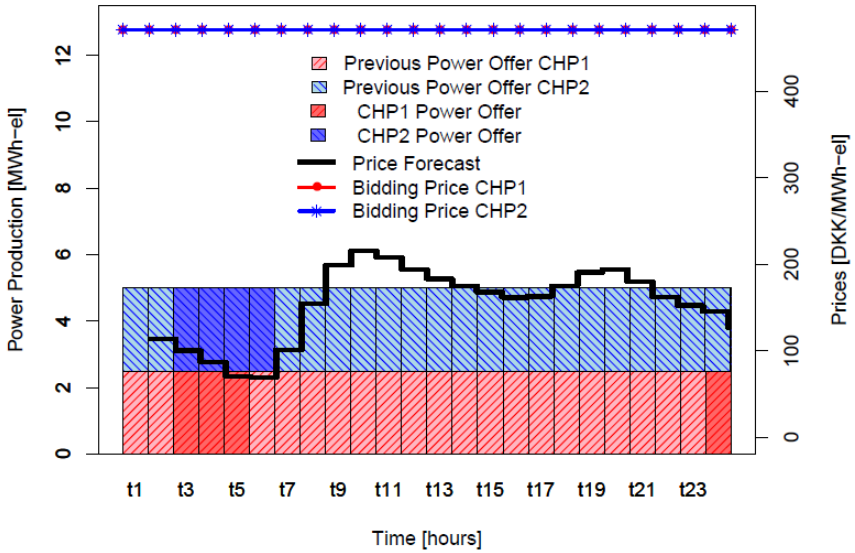


# HURB – Step 2

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

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

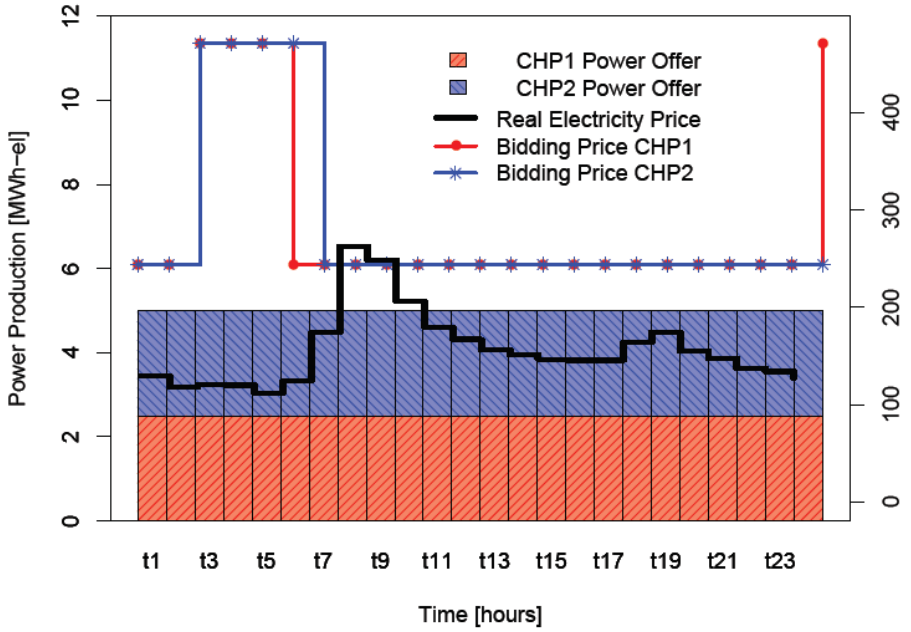



- **Bidding amount:** Power production amount of the CHPs
- **Bidding price:** Cost CHP - Cost WCB = (610.84 - 211.45) * 1.18 = 471.279

# Evaluation

Use real electricity prices instead of forecasts

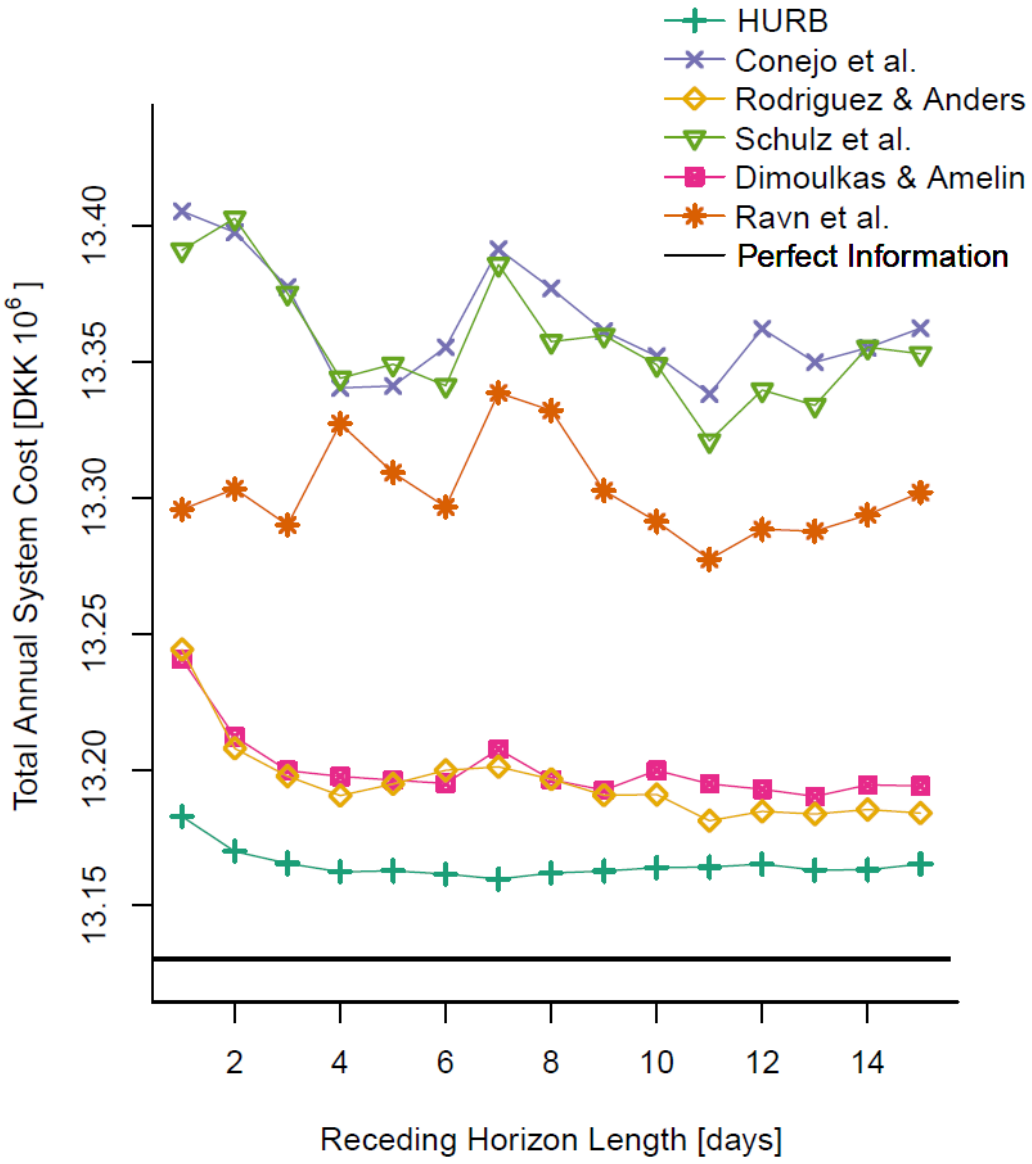


# Evaluation

- Comparison with the mentioned 5 bidding methods from literature [Conejo et al., 2002, Rodriguez and Anders, 2004, Schulz et al., 2016, Dimoulkas and Amelin, 2014, Ravn et al., 2004]
- Evaluation with real electricity prices from the NordPool market.
- Evaluation with different lengths of receding horizon to optimize the storage behavior.
- Electricity price forecast: Seasonal ARIMA model
- Heat demand and unit data from energyPRO test case (provided by EMD International)

# Results – Annual cost

Comparison with 5 bidding methods for CHP units from literature




Receding horizon length = Number of days considered in one optimization step

# Results - Bids

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

| Method | Receding Horizon | CHP 1 | | 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.

# Summary

Novel bidding method for district heating operators with CHP plants

- Iteratively replaces heat production to determine amount and prices
- Leads to lower systems costs compared to considering prices and amounts based on forecasts
- Preprint available: https://arxiv.org/abs/1810.10757

## Outlook

- Include uncertain production of e.g. solar thermal units
- Include electricity based heat production e.g. electric boilers, heat pumps


## Acknowledgements:

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Rodriguez, C. P. and Anders, G. J. (2004). Bidding strategy design for different types of electric power market participants. IEEE Trans. Power Syst., 19(2):964–971.

Schulz, K., Hechenrieder, B., and Werners, B. (2016). Optimal operation of a CHP plant for the energy balancing market. In Operat. Res. Proceed. 2014, pages 531–537. Springer.

# Results – 144 samples

Electricity prices from SE4 and DE prices