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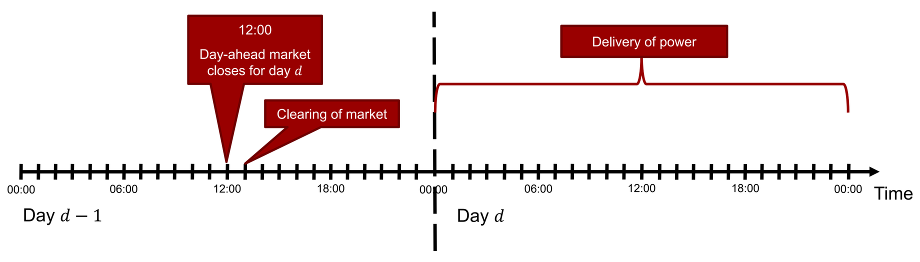
A novel bidding method for CHP units in district heating systems

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. By trading this electricity on the day-ahead market, we can lower the overall cost.



To trade in the day-ahead market tomorrow, we have to submit bids consisting of bidding amount and price for each hour tomorrow already at 12:00 today.

State-of-the-art

Related bidding methods methods for CHP units in literature:

- Use linear/mixed-integer programming
- Some bidding methods consider CHP units as **standalone production units** and **base the bidding price and amount on electricity price forecasts** [*Conejo et al. (2002); Rodriguez and Anders (2004); Schulz et al. (2016); Dimoulkas and Amelin (2014)*]
- Other methods use **marginal costs** of the units as bidding price and base the **production amount on the electricity price forecasts** [*Ravn et al. (2004)*]

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

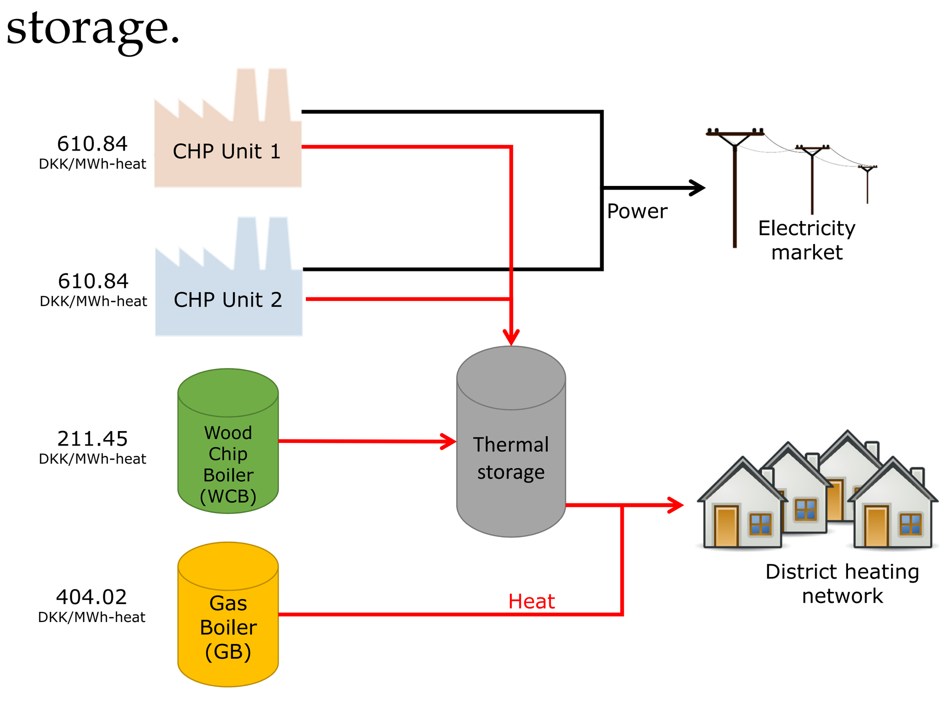
Heat Unit Replacement Bidding (HURB) method

Our HURB methods makes use of the fact that we have to produce the heat for the district heating network anyway. We determine the bids as follows:

- 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**

Case study

We use the following system as case study. The system contains two CHP units, one gas boiler, one wood chip boiler and a thermal storage.



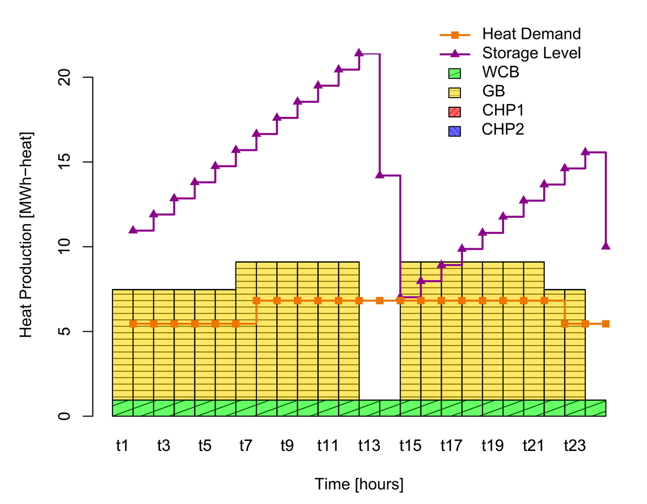
Algorithm

Our algorithm solves an mixed-integer linear program in each step of the algorithm to minimize the operational cost for tomorrow.

Objective function:
Minimize costs - income from electricity market (forecast)

Constraints:
Capacities of the units, Storage level and capacity, Heat-to-power ratio of the CHP units, Connections to grid and storage, Fulfillment of heat demand

Step 1: Optimization without market

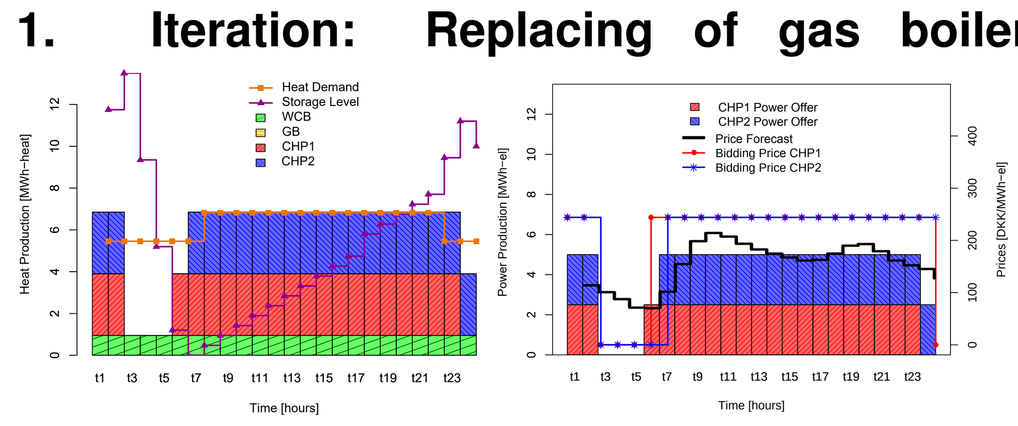


The first step optimizes the system without any market income, resulting in the cost minimal production. This heat production serves as the baseline for Step 2.

Step 2: Replacement of heat production

Afterwards we replace the heat production by heat-only units through CHP production by taking the heat-only units out of the optimization (in descending order of costs).

1. Iteration: Replacing of gas boiler

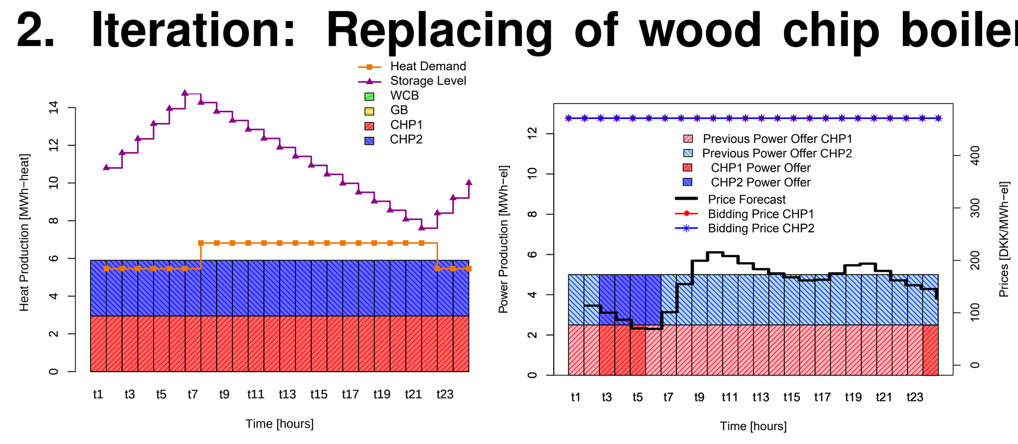


The CHP unit is now turned on in 40 hours resulting in 40 hourly bids.

Bidding Amount: Power production amount of the CHPs.

Bidding Price: Cost CHP - Cost GB = (610.84 - 404.02) * 1.18 = 244.045

2. Iteration: Replacing of wood chip boiler



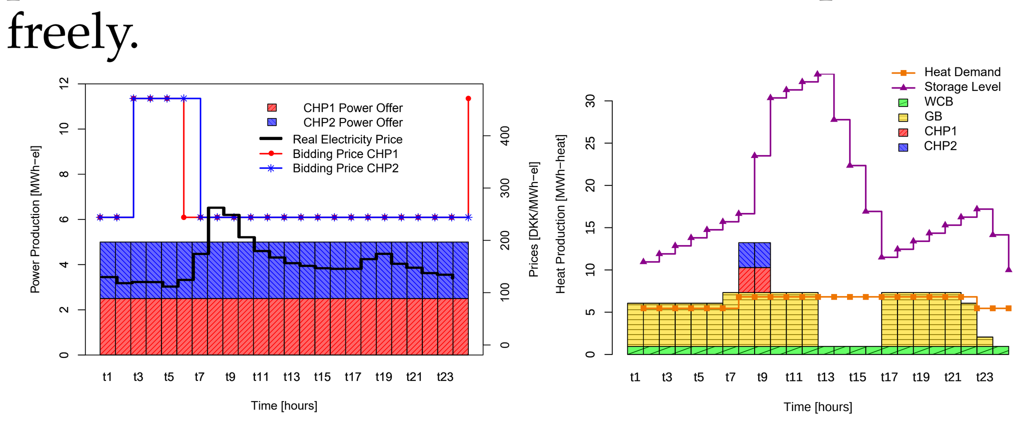
The CHPs are running in 8 additional hours resulting in 8 additional hourly bids.

Bidding Amount: the added production amount of the CHP in this iteration

Bidding Price: Cost CHP - Cost WCB = (610.84 - 211.45) * 1.18 = 471.279

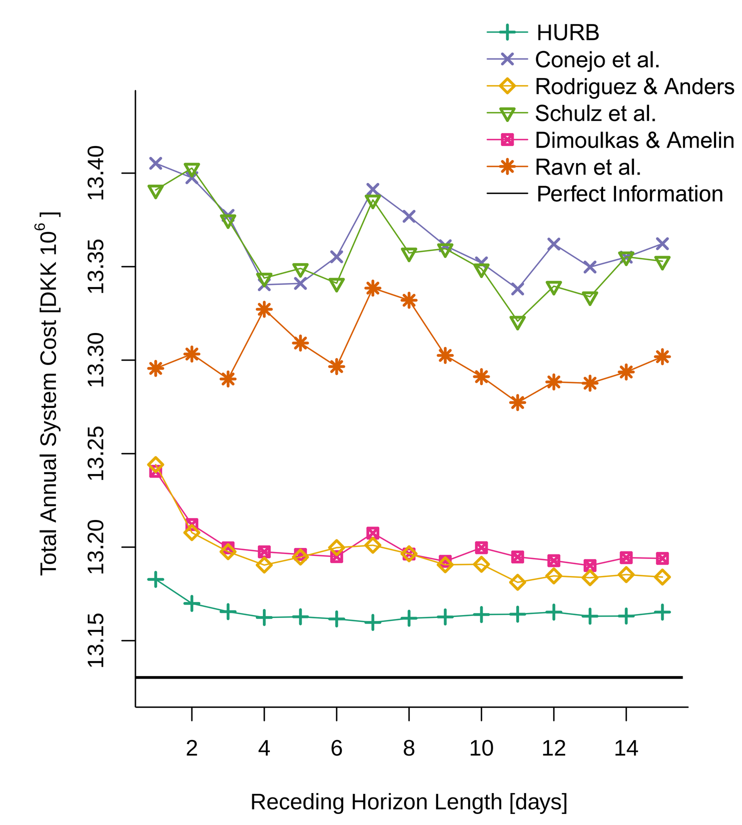
Evaluation

We evaluate the bids based on the real electricity prices, i.e., only if our bidding price is higher as the real price we are committed to produce. The other units can be optimized freely.



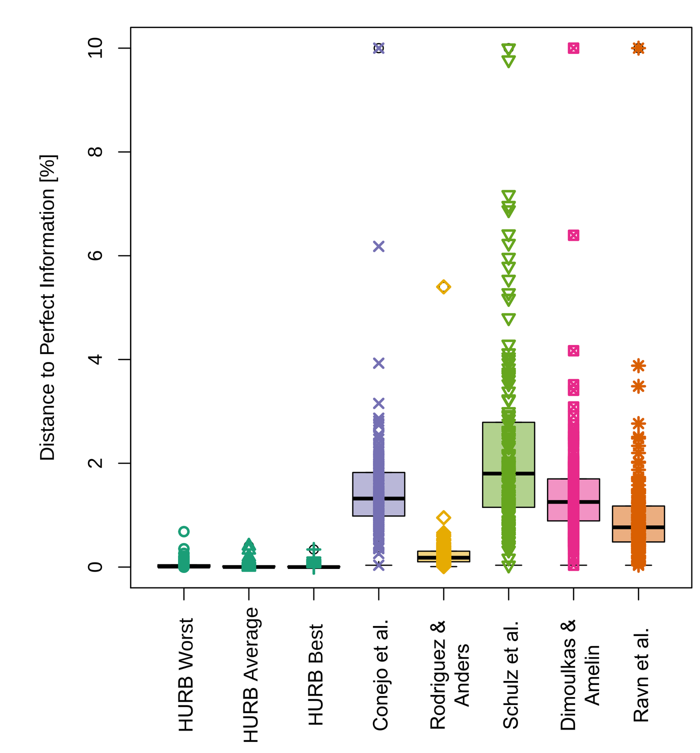
We also compare HURB to the methods of *Conejo et al. (2002); Rodriguez and Anders (2004); Schulz et al. (2016); Dimoulkas and Amelin (2014); Ravn et al. (2004)*.

Annual system cost 2016 (DK1 price area)



We evaluated the real system cost for 2016, where the HURB results in the lowest overall cost. Furthermore, the results show that considering a receding horizon of more than one day results in lower cost due to better operation of the storage.

144 monthly samples of electricity prices



We further evaluated 144 different monthly electricity prices to validate the results. The given amount in the figure above are the distance to best possible cost (optimization with perfect information). HURB clearly shows results closer to the best possible solution even with the worst length of receding horizon chosen (HURB Worst).

Conclusion

The HURB method does not base the bidding hours and amount on the electricity price forecasts, but shifts the needed heat production to CHP units in hours with high electricity price forecasts. Furthermore, the bidding price is set based on opeational cost of the units. This leads to a robust bidding strategy that offers in more hours than the other methods from literature and, therefore, lowers the overall costs.

References

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