

# Intraday Optimization of Hydro Power Plants in the German Electricity Market >



5th International Workshop on Hydro Scheduling in Competitive Electricity Markets

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## Market and regulatory environment

- Current situation of pumped hydro plants in Germany
- Regulatory requirements

## Intraday optimization of power plant deployment

- Modeling pumped hydro plants

## Trading on the continuous intraday market

- Methodology
- Example



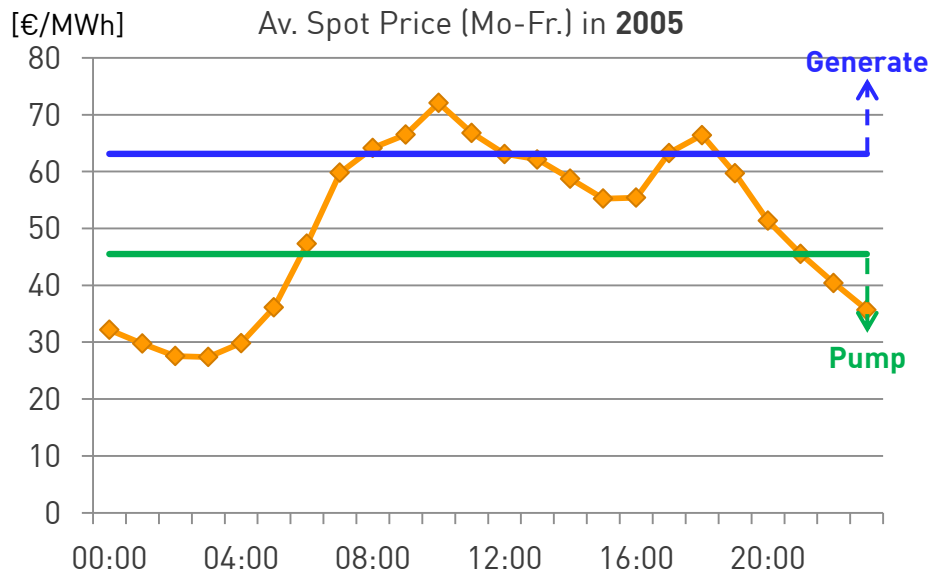


## Market and Regulatory environment

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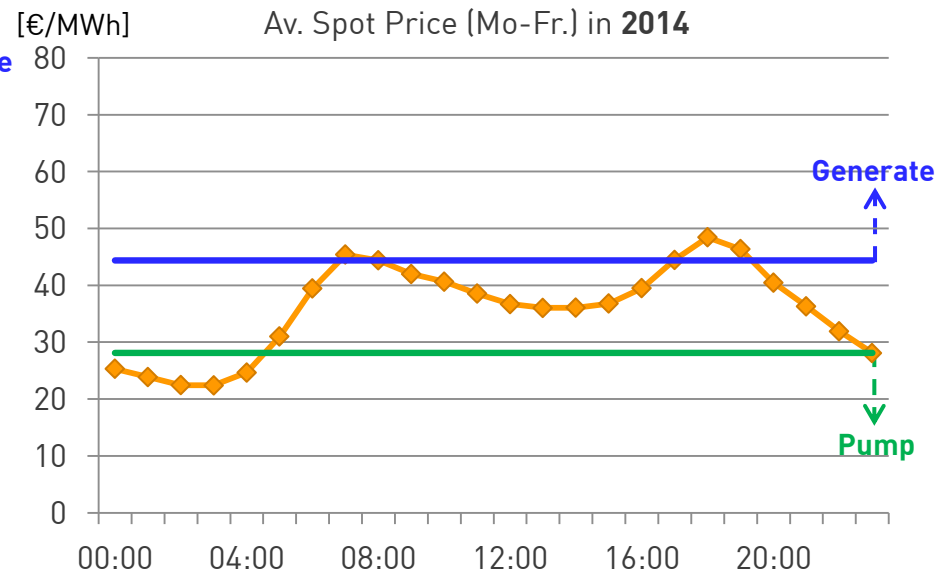
# Current situation of pumped hydro plants in Germany

**Example: Power of Turbine/Pump 500 MW; efficiency 80%; grid charges 4 EUR/MWh**



*On average:*

- spread: 32.21 EUR
- pumping: 9 hours
- generating: 7 hours

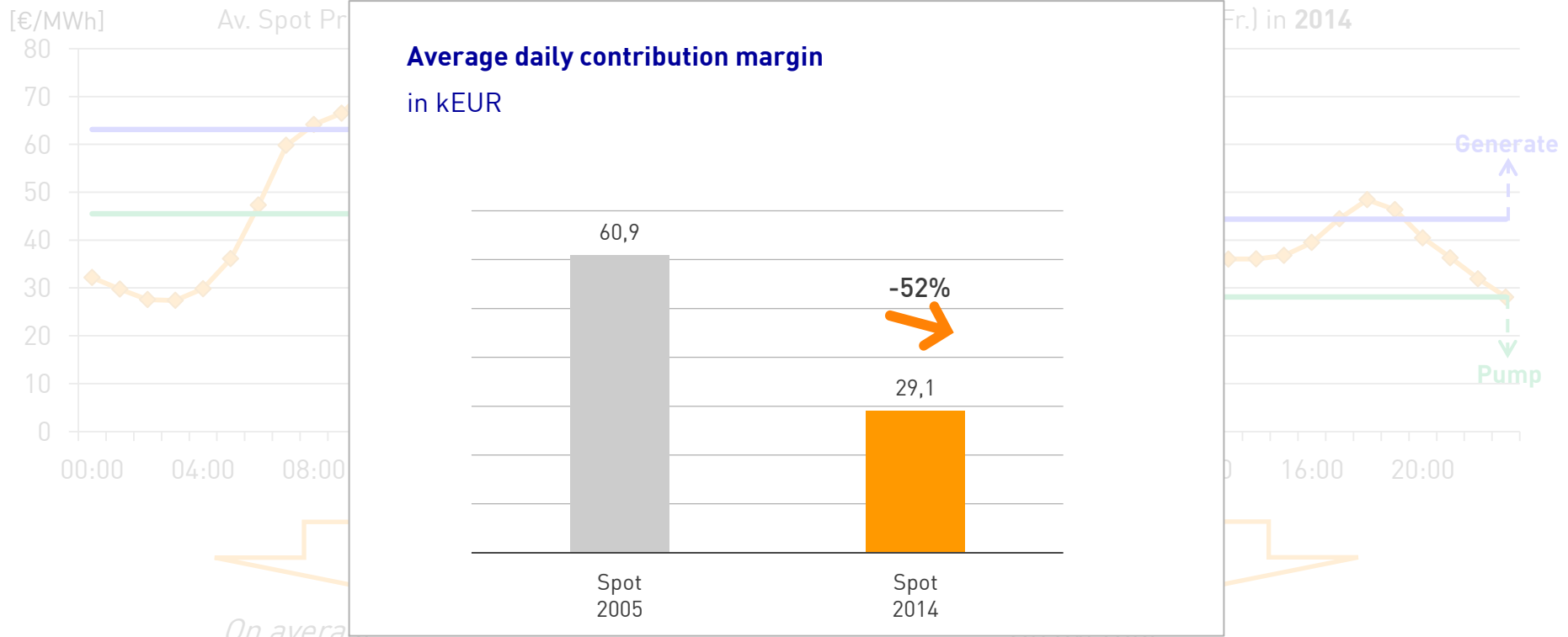


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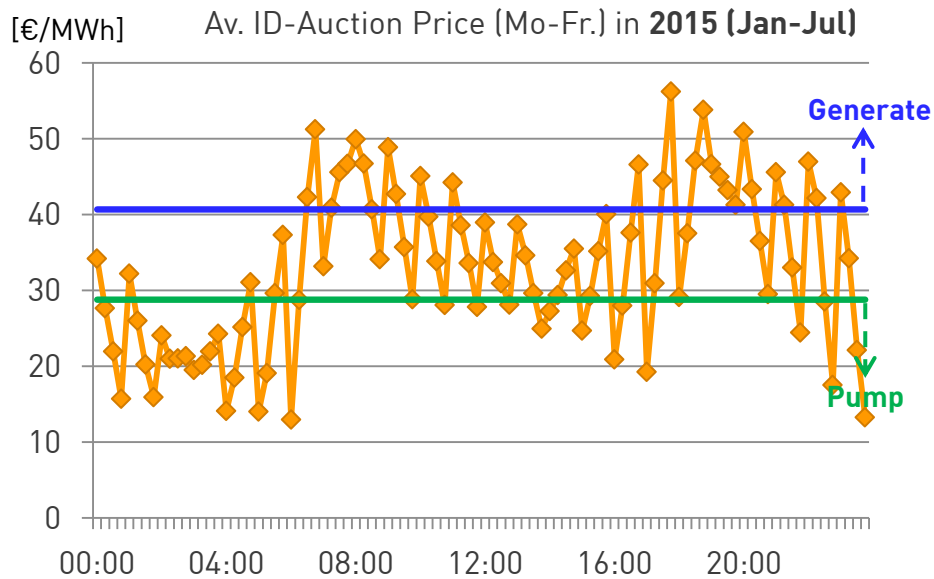
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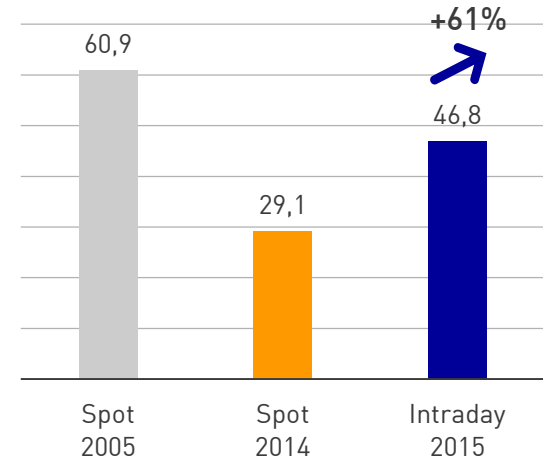
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**Average daily contribution margin**  
in kEUR



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## German Energy Act:

Power plant operators are obliged to **provide any information** that is necessary to secure reliable operation of transmission grids. This information has to be provided immediately and it may even include trade secrets.

### › Stabilization of grid is of great importance

## Federal Grid Agency introduced an enactment in 2014 which commits power plant operators to report extensive data to the TSOs:

For each generator/pump in a *quarter-hourly* resolution:

- › Maximum and minimum power
- › Planned production/consumption
- › Pos./neg. provision of balancing power (primary, secondary and tertiary reserve)
- › Pos./neg. provision of power for own reserves
- › Pos./neg. redispatch potential

*Data needs to be updated as soon as the plan changes!*



# Intraday optimization of power plant deployment

- > Modeling pumped hydro plants



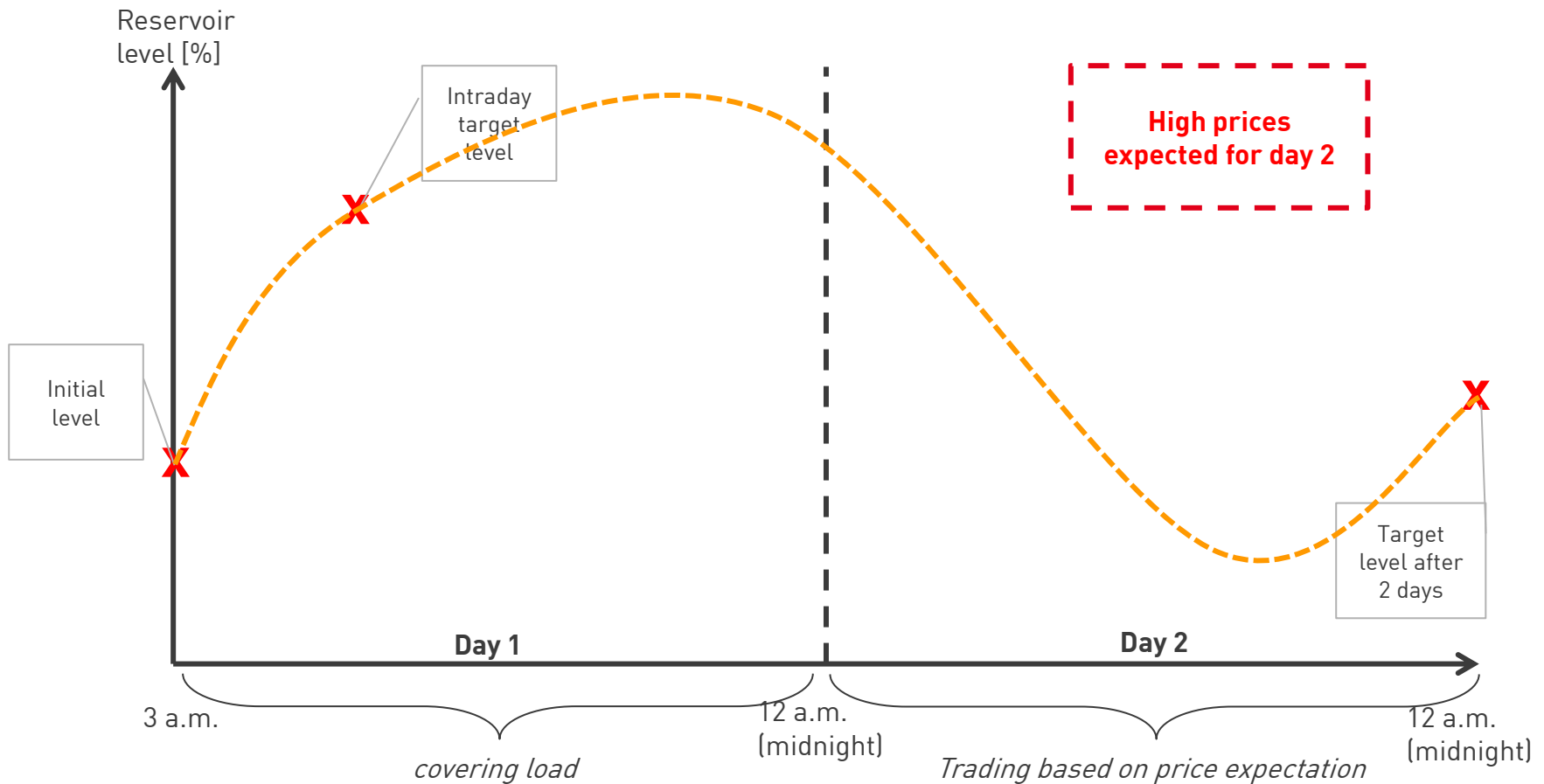
## **Model input:**

- plant characteristics:
  - technical (e.g. power)
  - financial (i.e. grid charges)
  - regulatory (e.g. pre-qualified power for provision of balancing energy)
- reservoir characteristics:
  - physical limits
  - initial reservoir level
  - target reservoir levels (during or at the end of planning horizon)

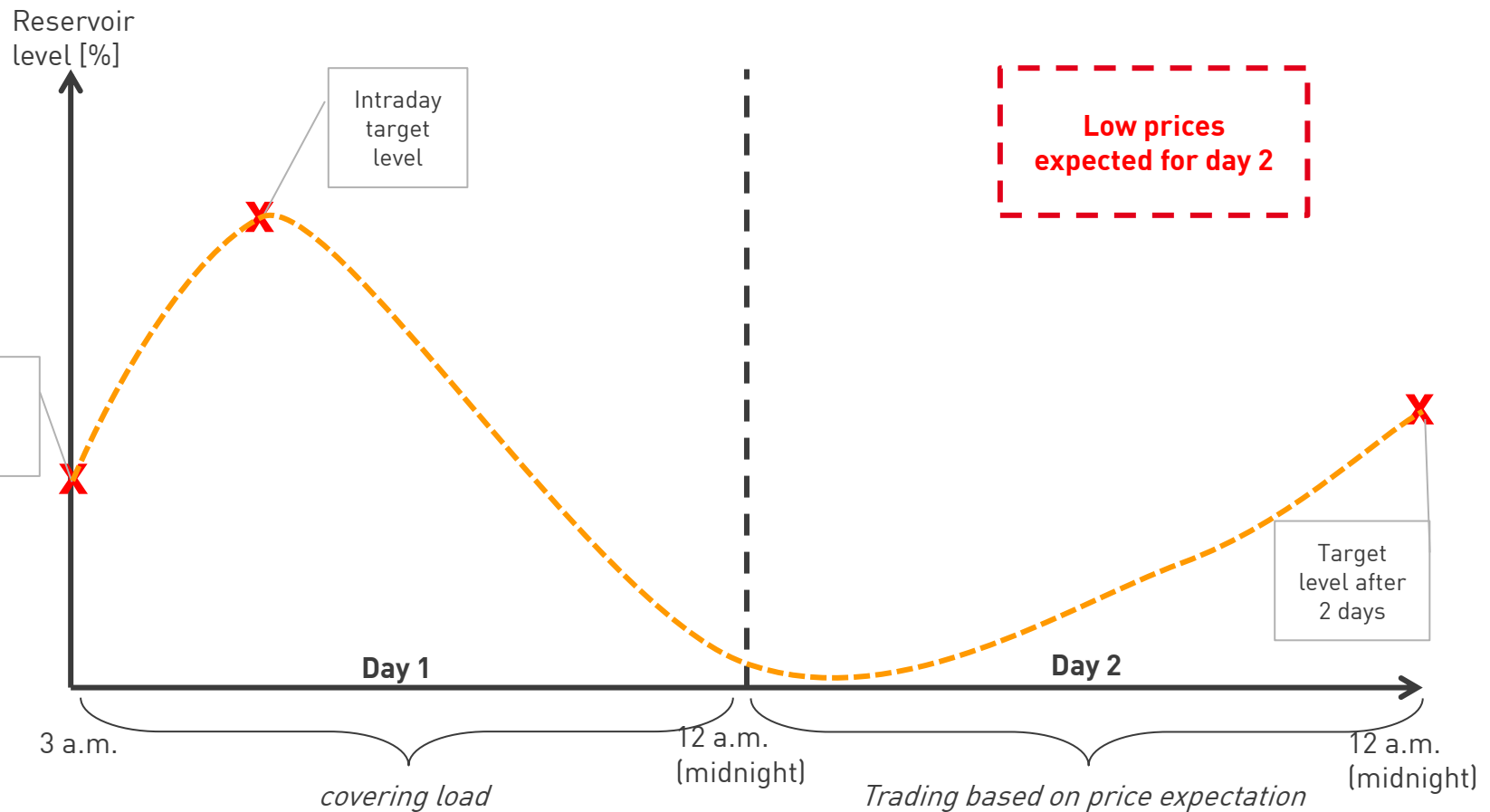
## **Model output (for each machine of the plant and quarter hour)**

- generation and consumption of power
- operating modes
- provision of balancing power
- provision of reserve power

# Modeling pumped hydro plants



# Modeling pumped hydro plants





# Trading on the continuous intraday market

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## **Characteristics of EnBW's pumped hydro reservoirs:**

- › Generating: 6 – 12 hours
  - › Pumping: 11 – 17 hours
  - › Energy: 600 – 3000 MWh
  - › Almost no natural inflow
- ➔ Operation of power plants close to reservoir limits

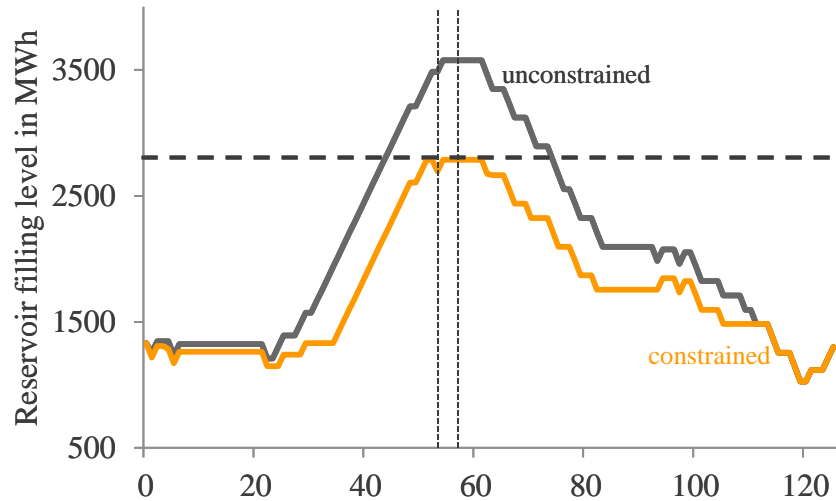
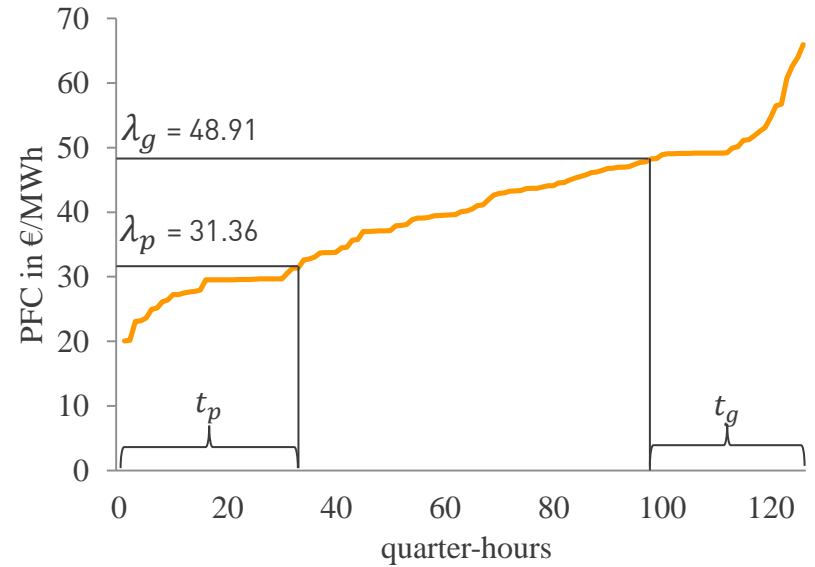
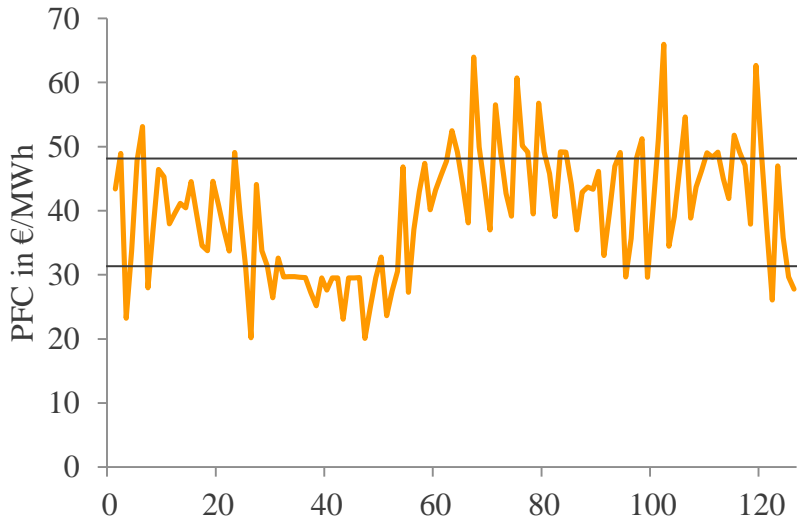
## > **Algorithm is based on**

Lu, N., Chow, J.H., Desrochers, A. *Pumped-Storage Hydro-Turbine Bidding Strategies in a Competitive Electricity Market*. IEEE Transactions on Power Systems, Vol. 19, No. 2, pp. 834-841, Max 2004

## > **Improvements**

- Generator/pump availability
- Non-monotone price forward curve
- Grid charges
- Flat price profiles (spread-based operation not possible)
- Different initial and terminal filling levels

# Example



| Time in quarter-hours | Pumping Marginal Cost in €/MWh | Generating Marginal Cost in €/MWh |
|-----------------------|--------------------------------|-----------------------------------|
| [0-52]                | 29.56                          | 47.82                             |
| [53-55]               | 27.26                          | 46.82                             |
| [56-126]              | 29.68                          | 49.13                             |

Thank you for your attention!







**EnBW Energie Baden-Württemberg AG**  
**Energy Market, Methods & Models**  
**Trading**

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