

# Merit order effect of flexibility options

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Solar Integration Workshop

2016-11-14

# Outline

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Motivation

2

Computational Model

3

Results

4

Conclusion

# Outline

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Computational Model

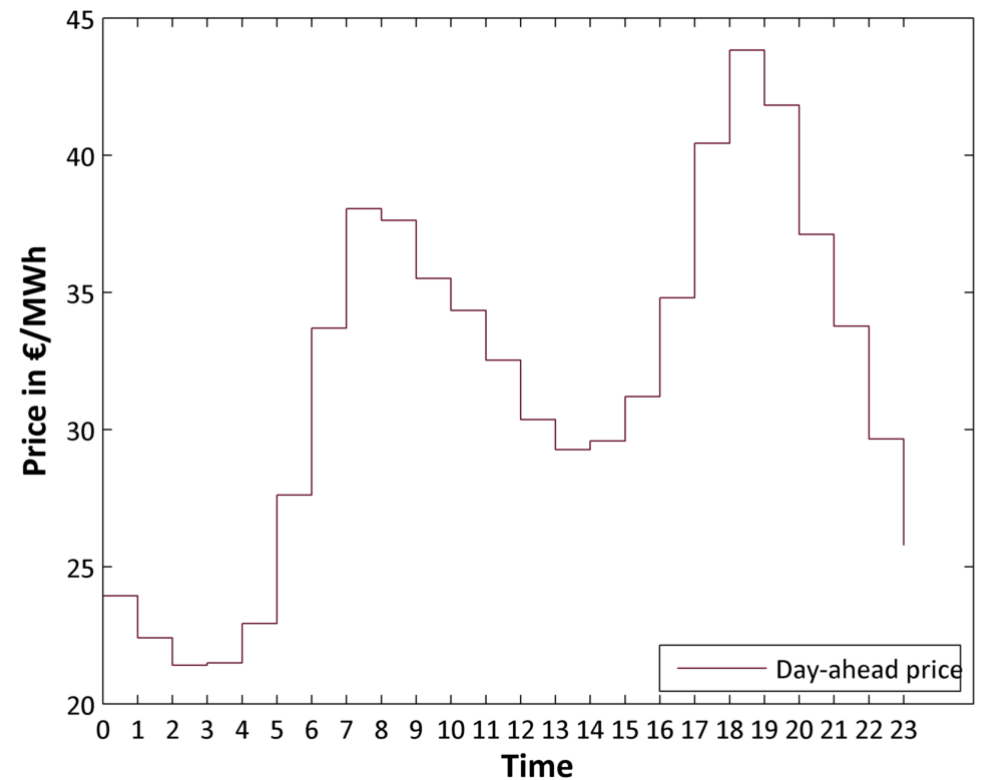
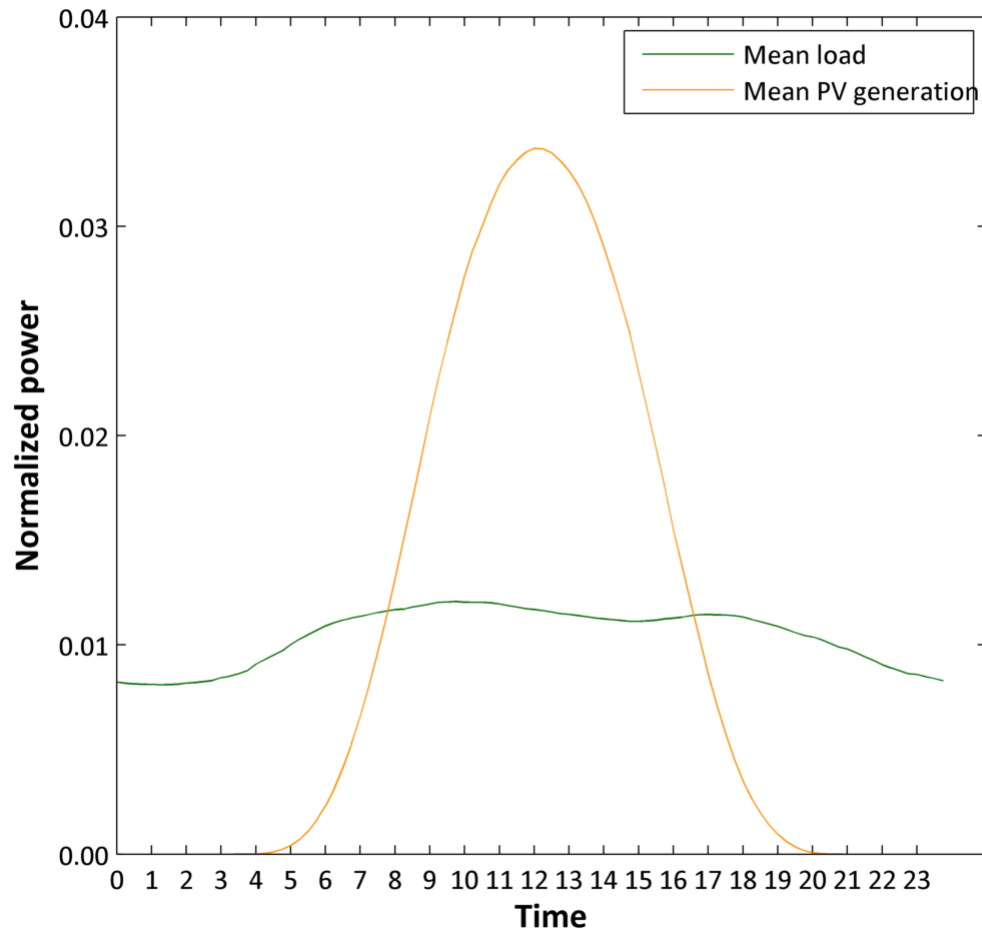
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# Motivation



- Mean electric load curve does not match mean PV generation curve
- PV peak around noon, morning and evening peak of load
- Current prices act as incentive for flexibility options to act PV-integrating
- Additional flexibility options also affect market prices
- What is the effect on profitability of flexibility options?

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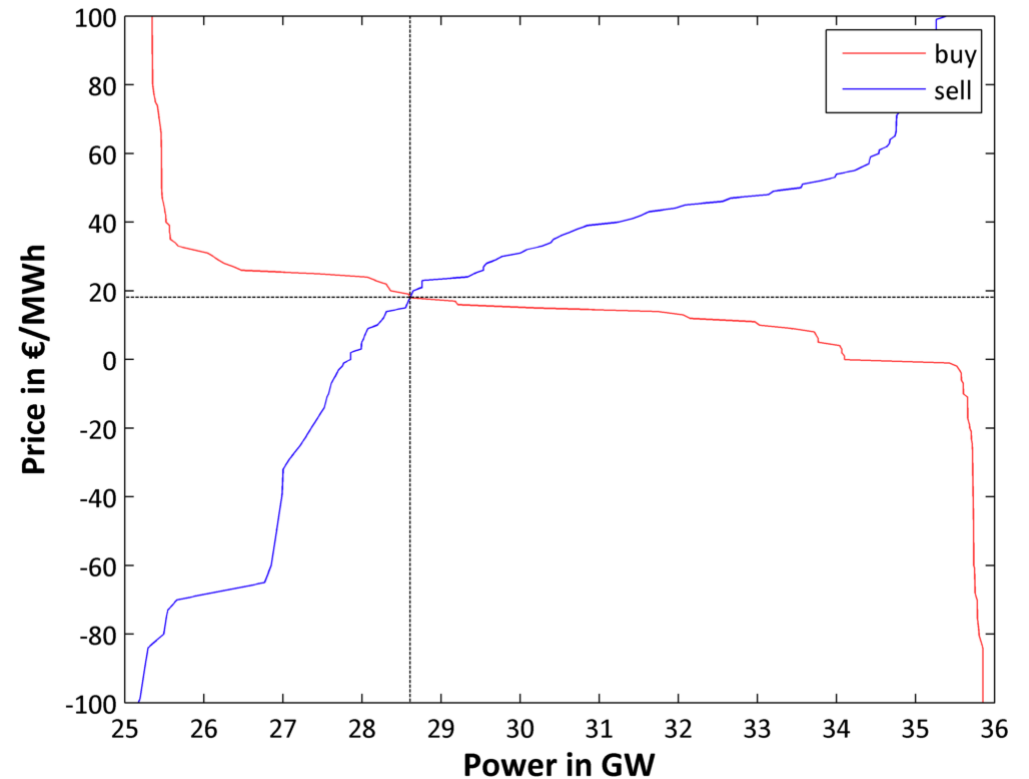
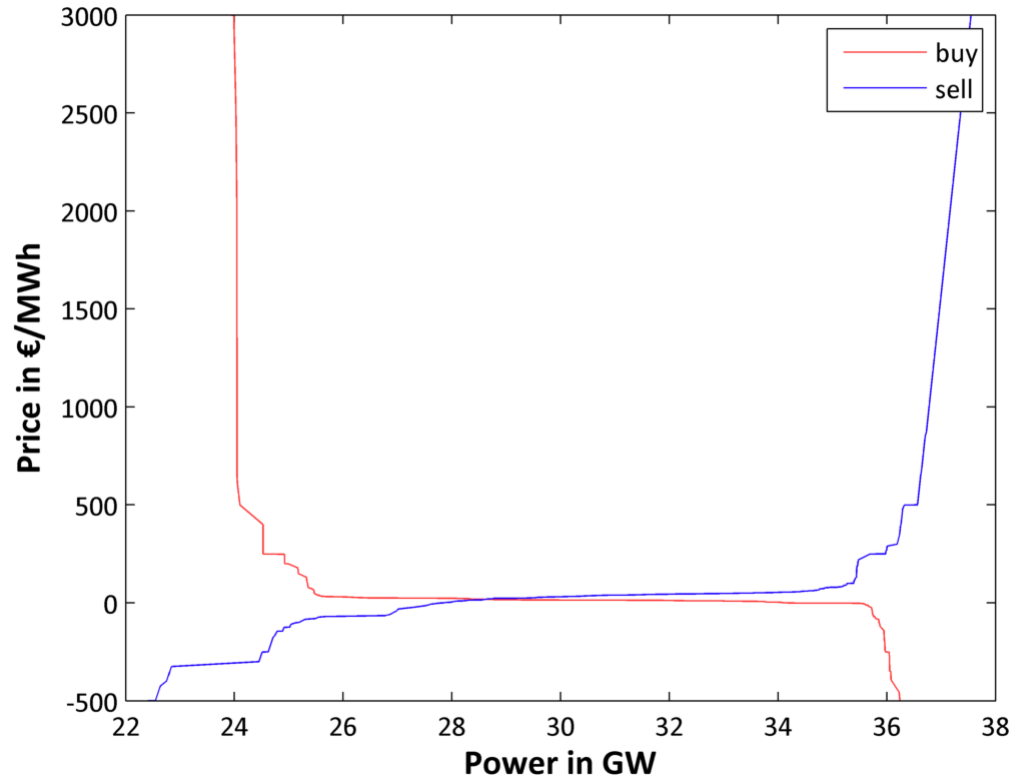
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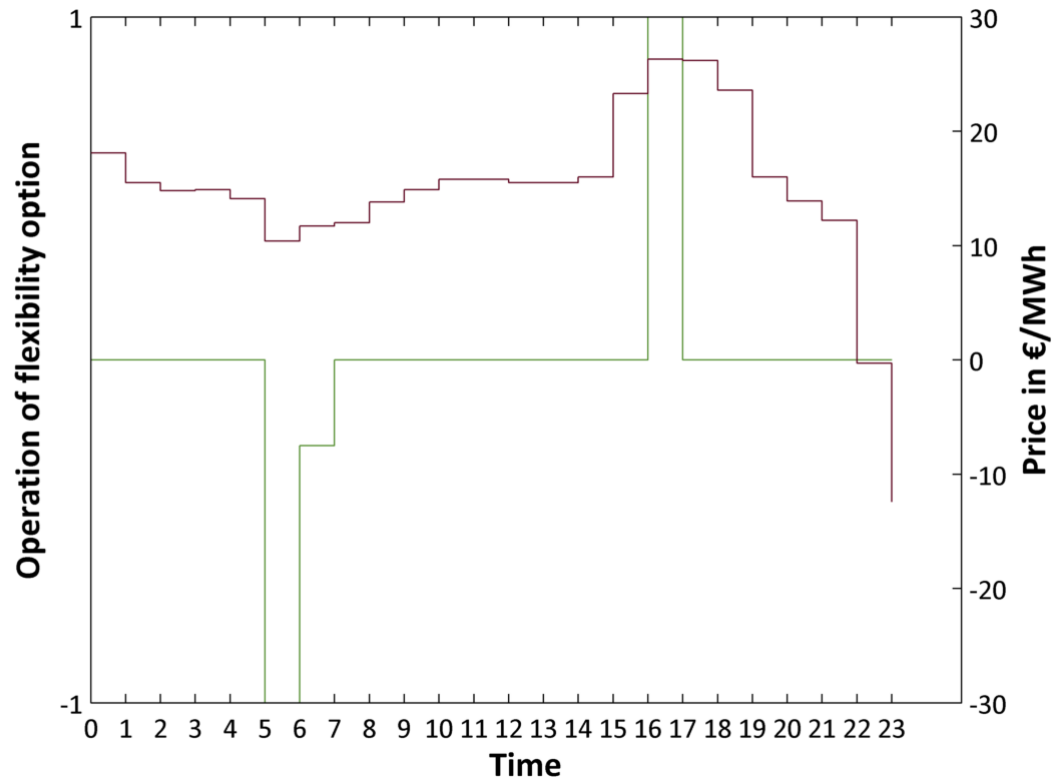
Conclusion

# Day-ahead bid curves



- Ordered day-ahead bids form buy and sell curve
- Intersection of these curves defines market clearing price
  - Example: 18.1 €/MWh, 28.6 GW
  - Adjustment of curves allows simulating of additional buy or sell bids

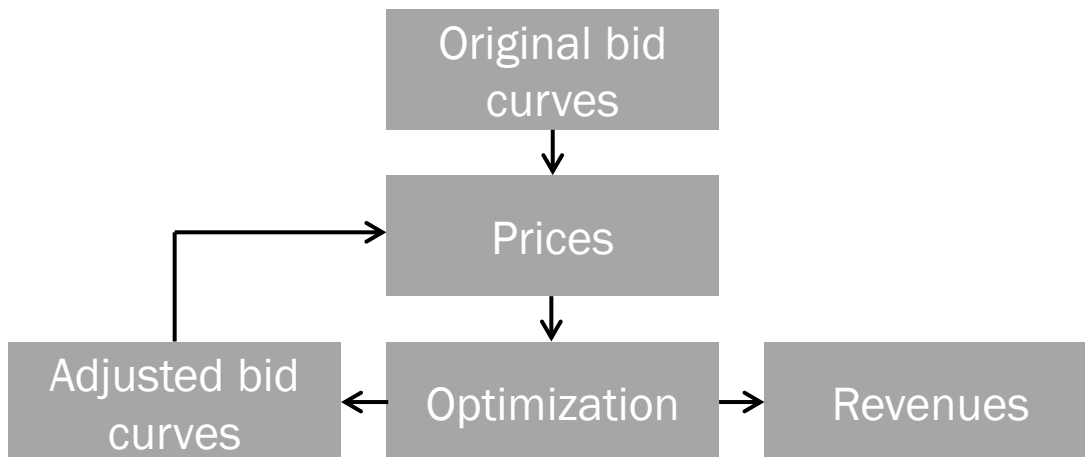
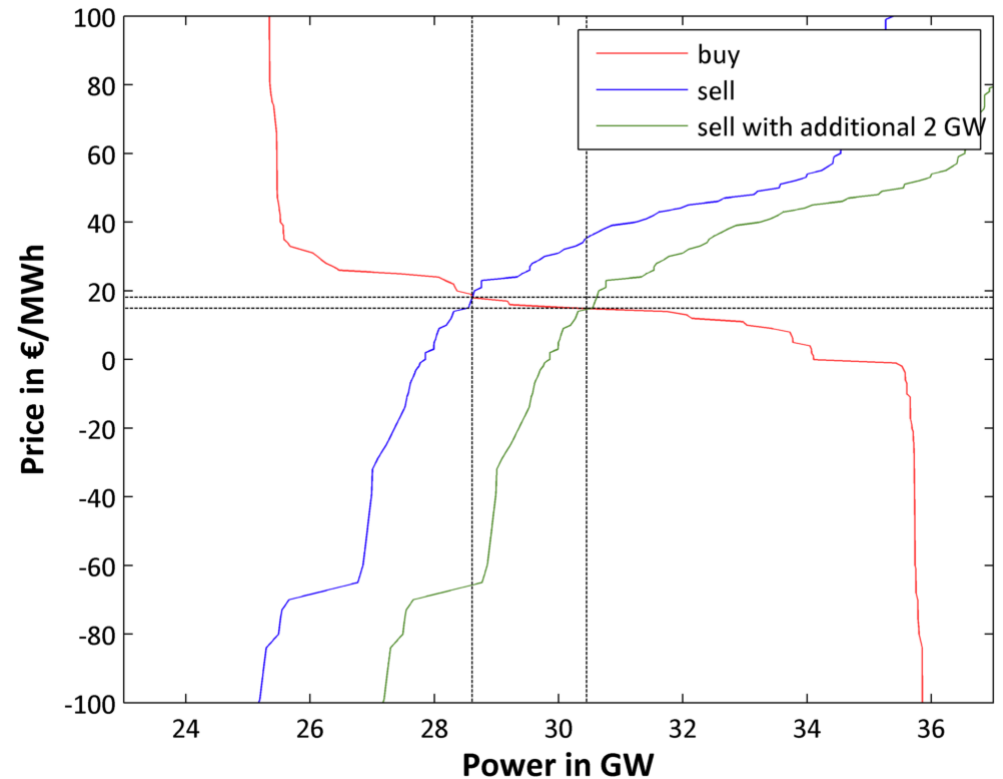
# Optimization



- Optimal operation for flexibility option is determined by linear optimization
- „Charging“ at low prices, „discharging“ at high prices
- Assumed efficiency  $< 1$ , therefore charged energy  $>$  discharged energy
- Taxes and fees are neglected for this calculations

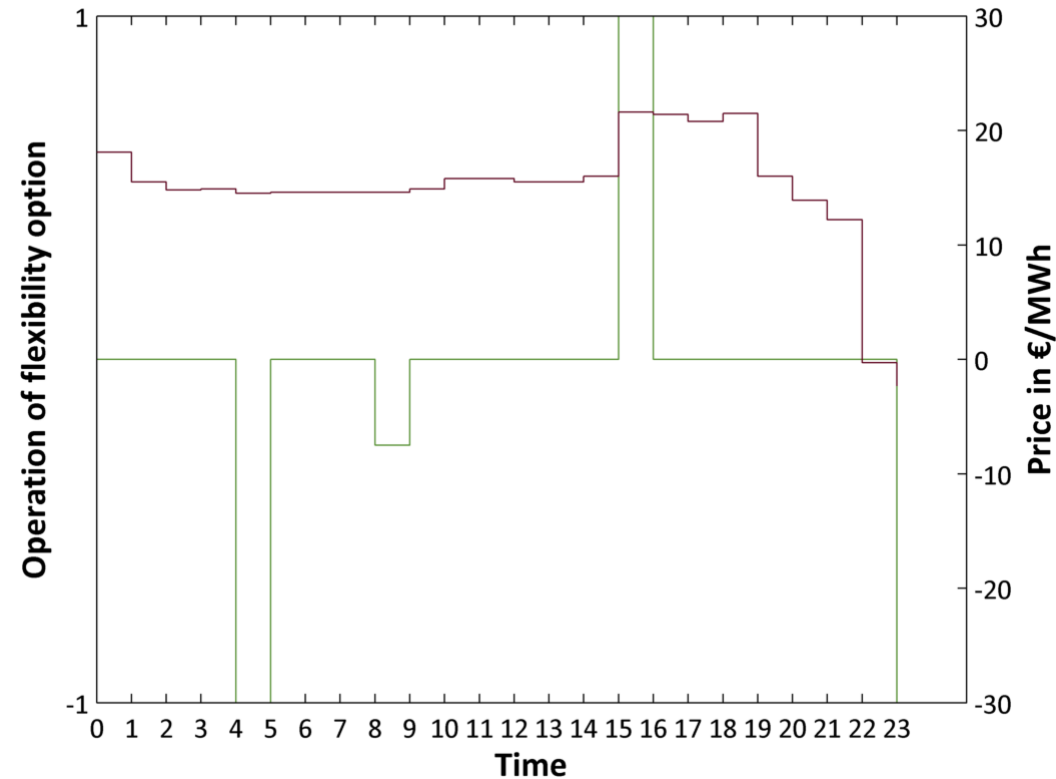
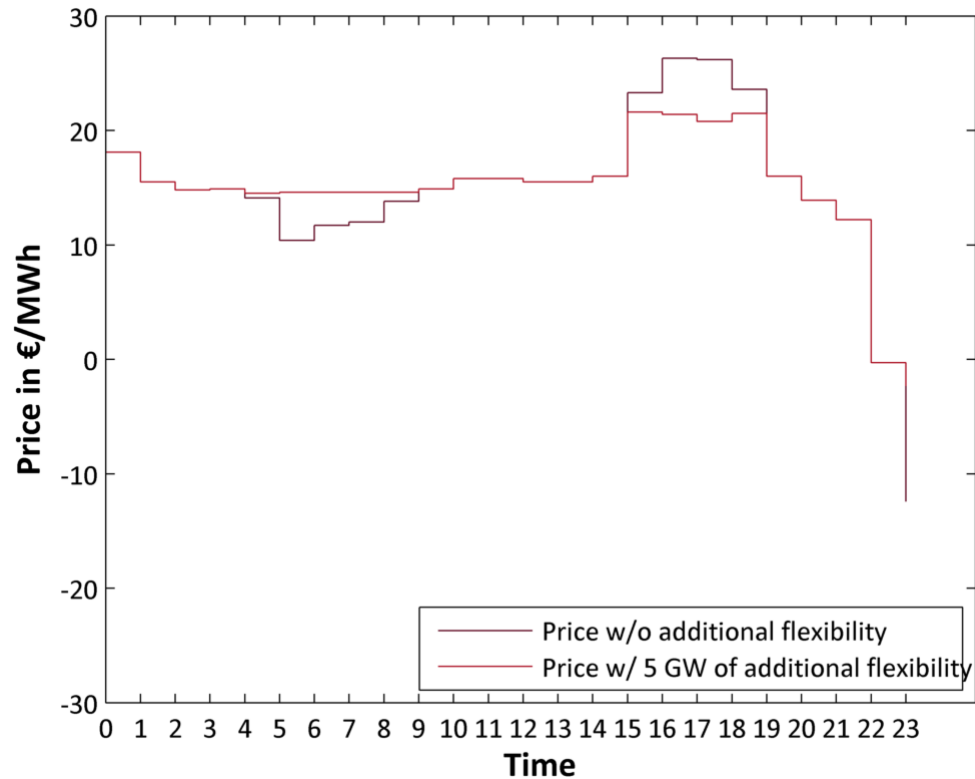
# Modelling of prices

- Prices with additional flexibility in the market are modelled by adjusting the respective curve
- Additional demand is added to the buy curve with maximum price
- Additional supply is added to the sell curve with minimum price
- Ex: 14.9 €/MWh, 30.5 GW
- Optimization of operation and adjusting of prices are iteratively repeated to simulate gradual expansion of flexibility options





# Adjusted prices



- Iterative optimization and adjustment leads to new price curves with smoothed peaks and therefore reduced spreads
- Optimal operation for new prices differs from the original one
- Optimization at each step important for reliable results

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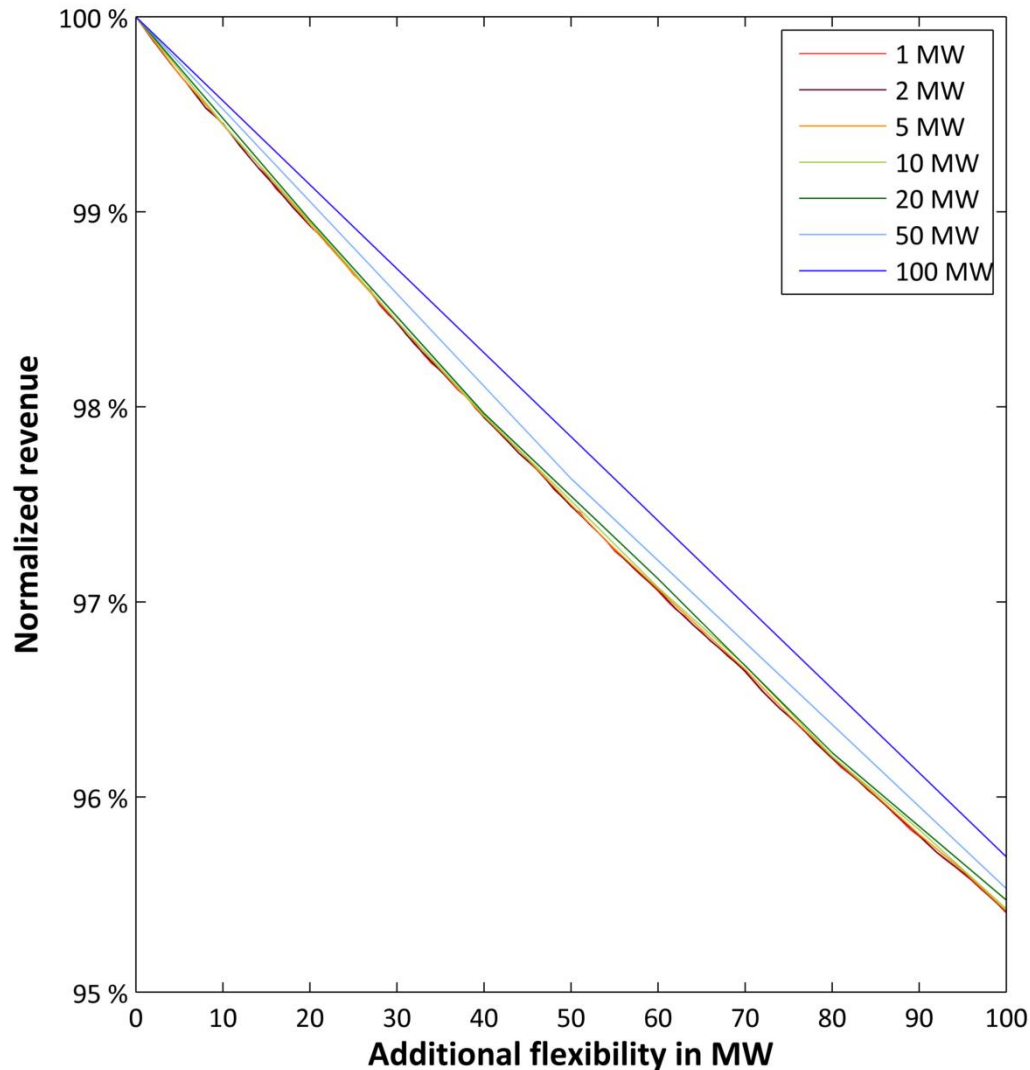
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# Step size



## Step size Normalized revenue

1 MW 95.4 %

2 MW 95.4 %

5 MW 95.4 %

10 MW 95.4 %

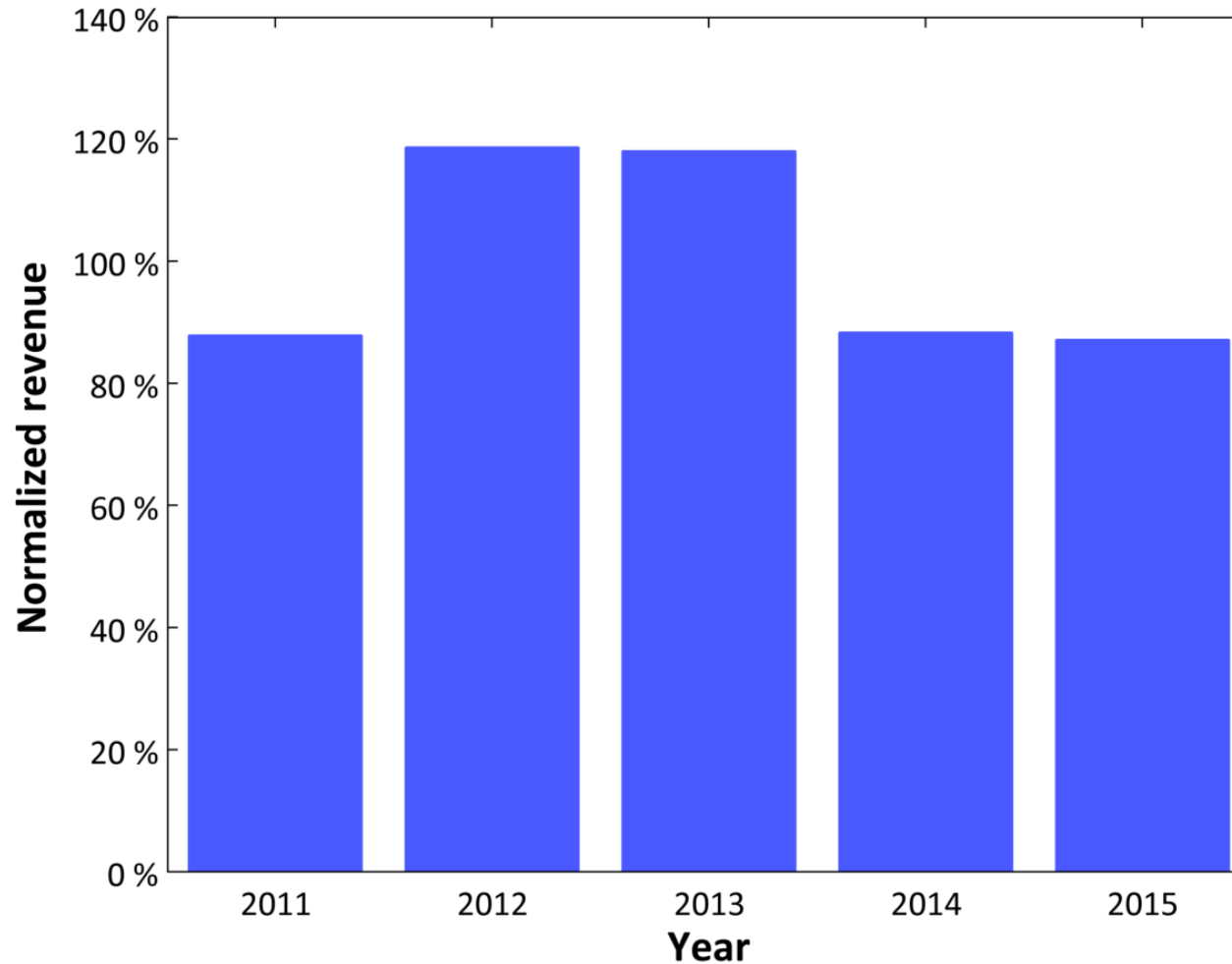
20 MW 95.5 %

50 MW 95.5 %

100 MW 95.7 %

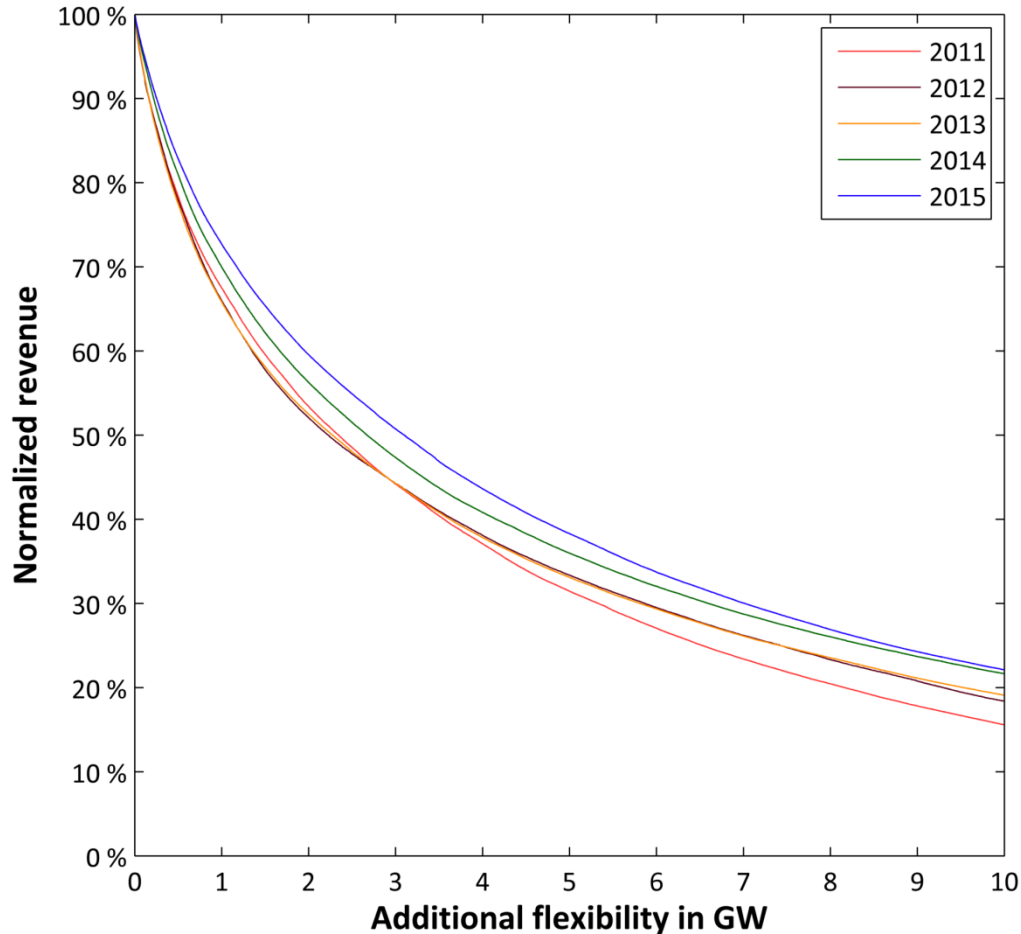
- Step size of iteration has to be chosen to achieve sufficient accuracy with reasonable computation time
- Reduction of revenue for additional flexibility options around 4 % at 100 MW for all step sizes
- Results show considerable deviations for 20 MW and above
- 10 MW sufficiently precise
- Step size for following simulations is 10 MW

# Revenue



- Calculating the potential revenue for flexibility options without expansion shows differences between the years
  - Significant increase in 2012 and 2013 compared to 2011
  - Lower revenues for 2014 and 2015

# Reduction of revenue



- Application of the described method yields normalized reduction curves for all years
- General shape quite similar, but slight trend to smaller reductions in recent years
- Reduction to 75 % of original value at 0.6-0.9 GW
- Reduction by 50 % of original value at 2.2-3.1 GW
- Considerable reductions of possible revenues due to additional flexibility in the system

Reduction to	2011	2012	2013	2014	2015
75 %	0.6 GW	0.6 GW	0.6 GW	0.7 GW	0.9 GW
50 %	2.4 GW	2.2 GW	2.3 GW	2.7 GW	3.1 GW

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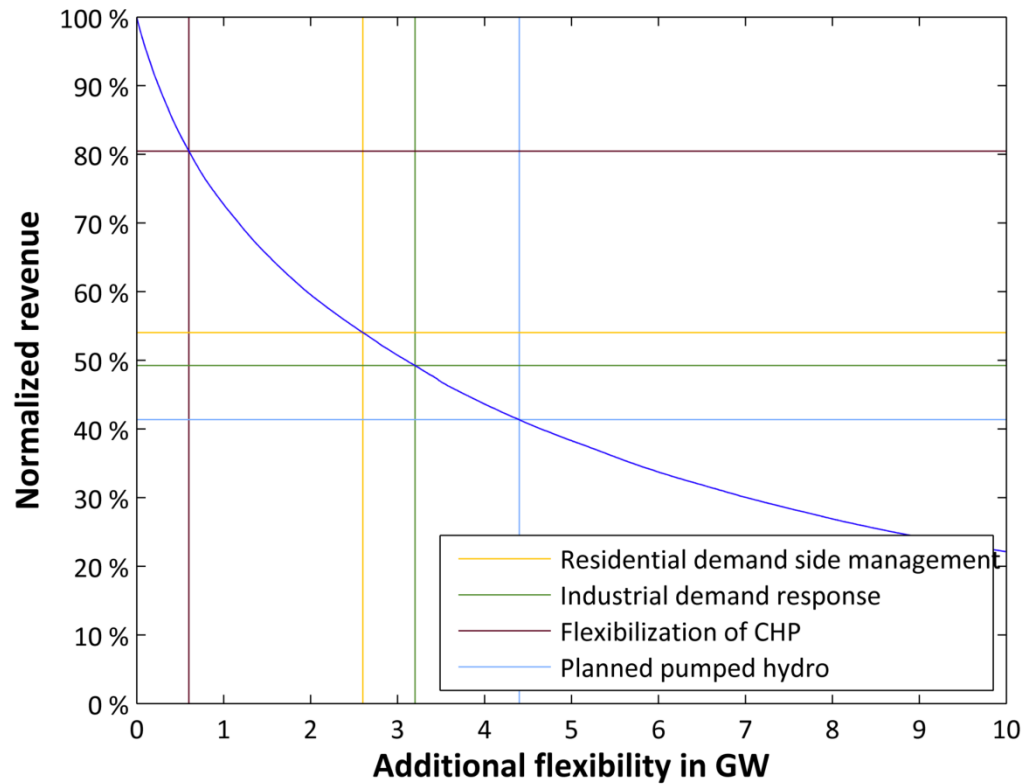
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# Conclusion



- Results for 2015 are displayed
- Evaluations show that the discussed effect is crucial for profitability of flexibility options like storage systems
- Several possible flexibility options lead to reduction of 20% up to 59 %

Thank you for your attention.

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