

Long-term modelling of electricity market prices to examine prospective revenues of storage agents

Martin Klein, *Christoph Schimeczek*

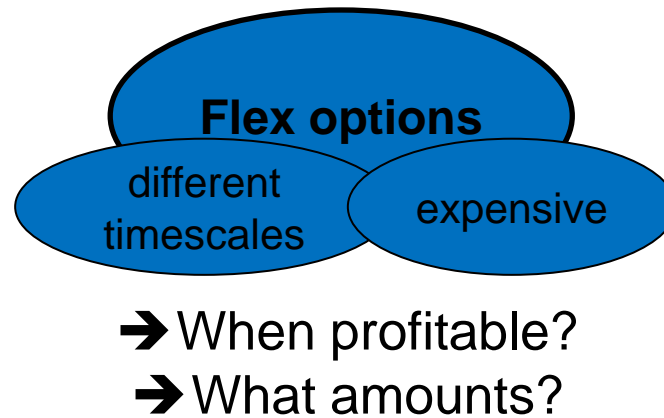
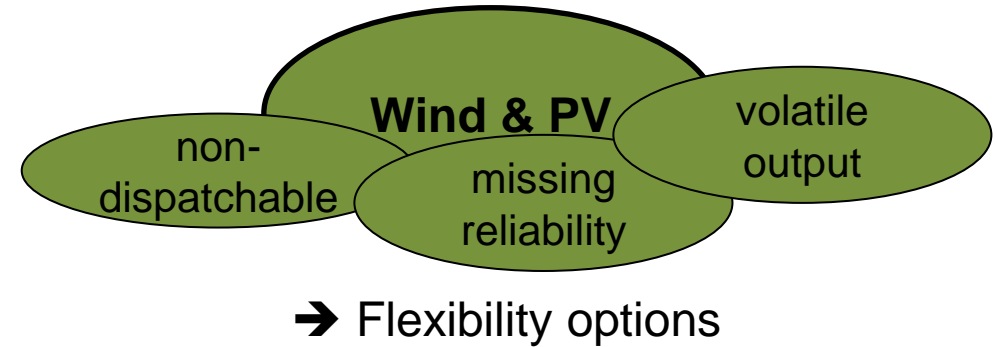
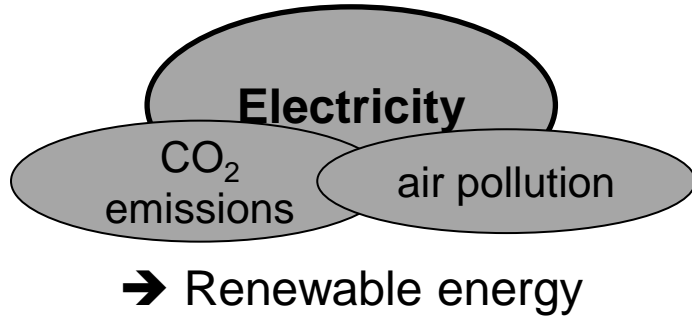
DLR Institute of Engineering Thermodynamics – Energy Systems Analysis



Knowledge for Tomorrow

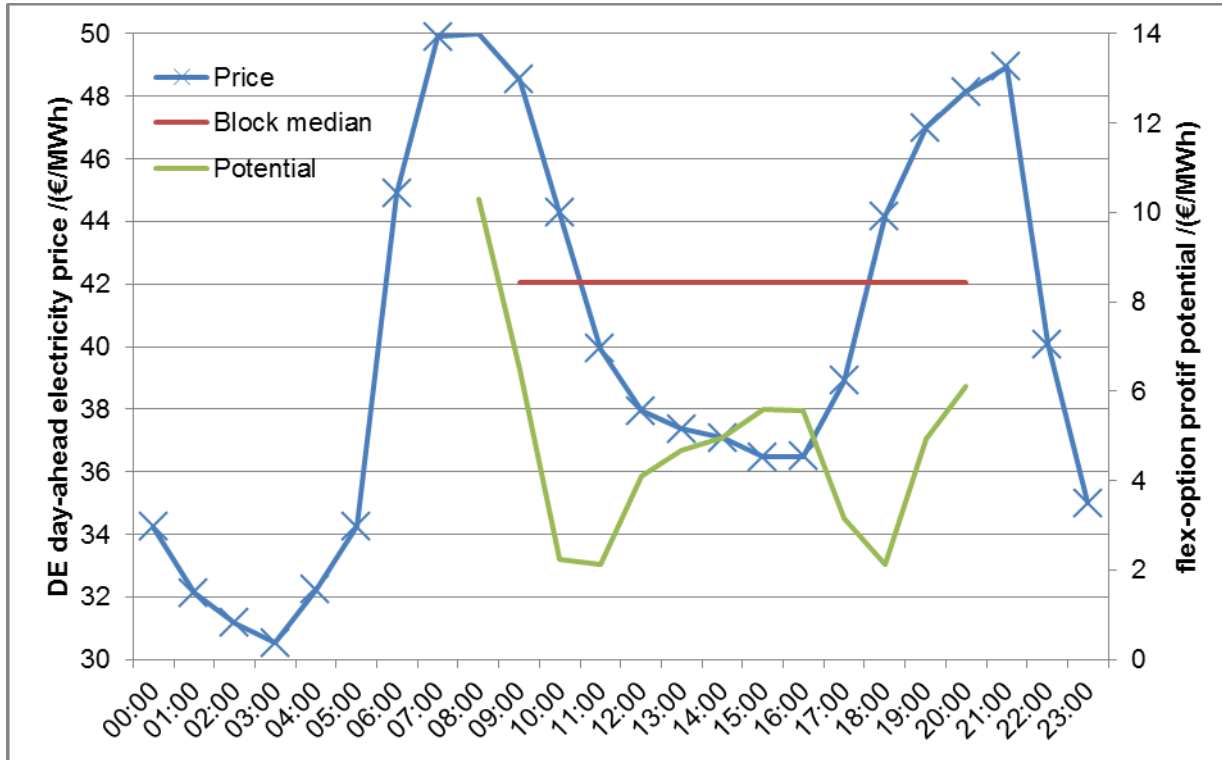


The challenge



The challenge

Profitability of arbitrage



German electricity price – a day in 2018

Storage profitability

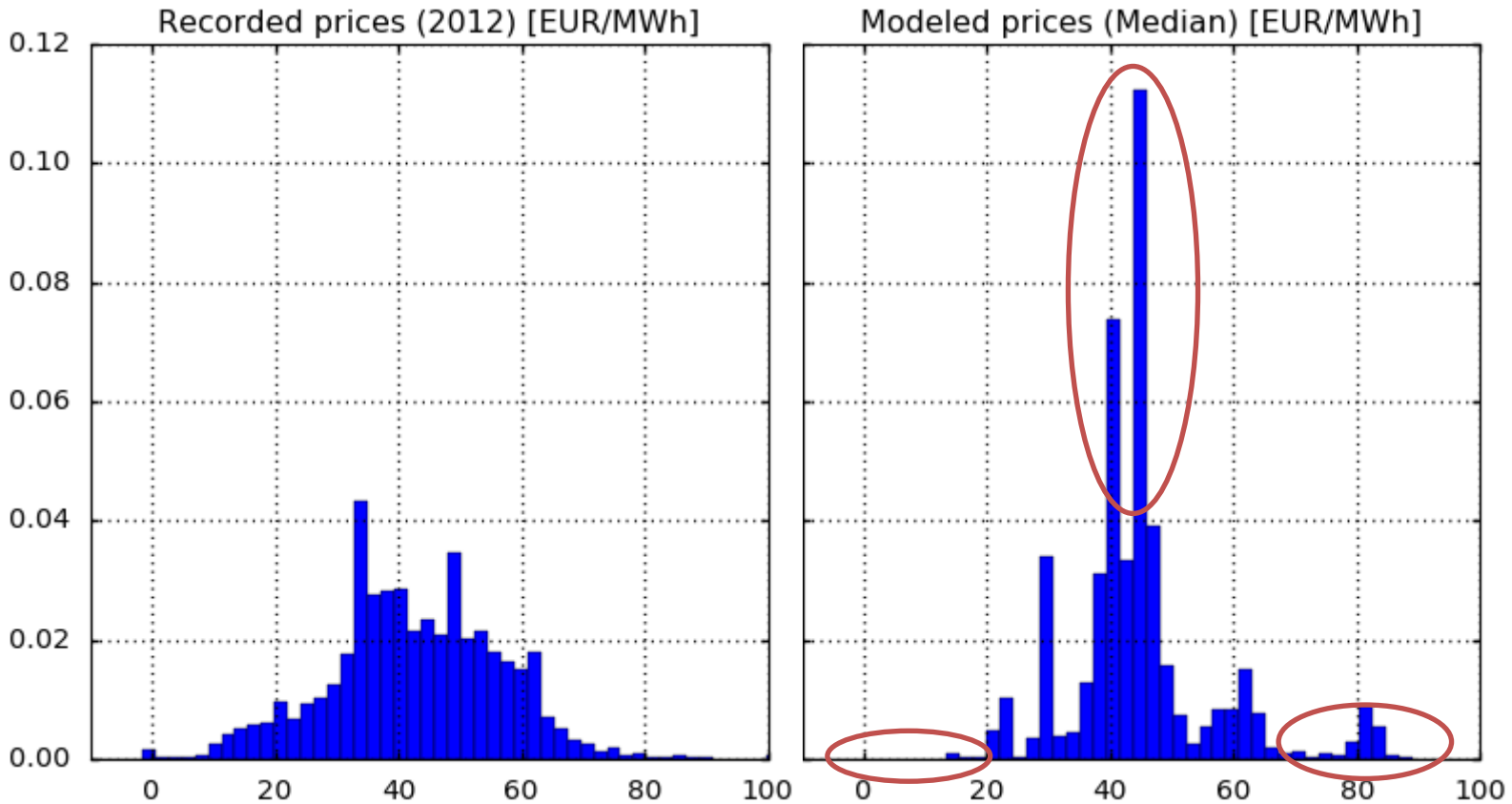
- Block Median: Peak-to-peak
- Block hours ↔ Energy-to-power ratio (E2P)
- Profitability ↔ price fluctuations

➔ Shape of price curve important for storage operators



The challenge

Price modelling



Cao et al., *Sustainability* 2018, 10, 1916, doi:10.3390/su10061916

Fundamental model REMix

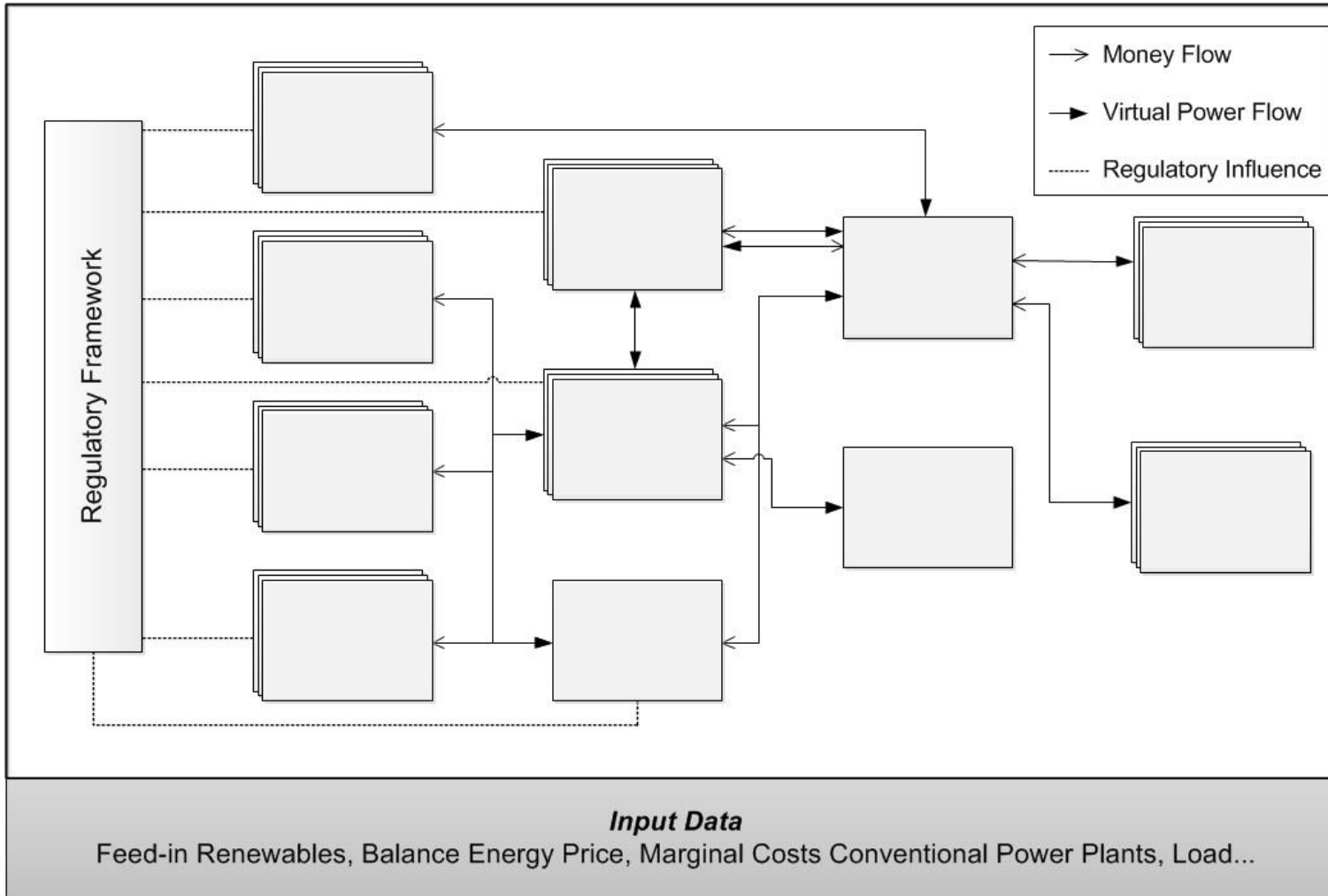
- Linear optimization
- Electricity + sector coupling
- Scope: Europe
- Transport grid restrictions

➔ How to improve price variability modelling?



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Agent-based electricity market simulation



Fundamental modelling

- electricity prices
- actor revenues

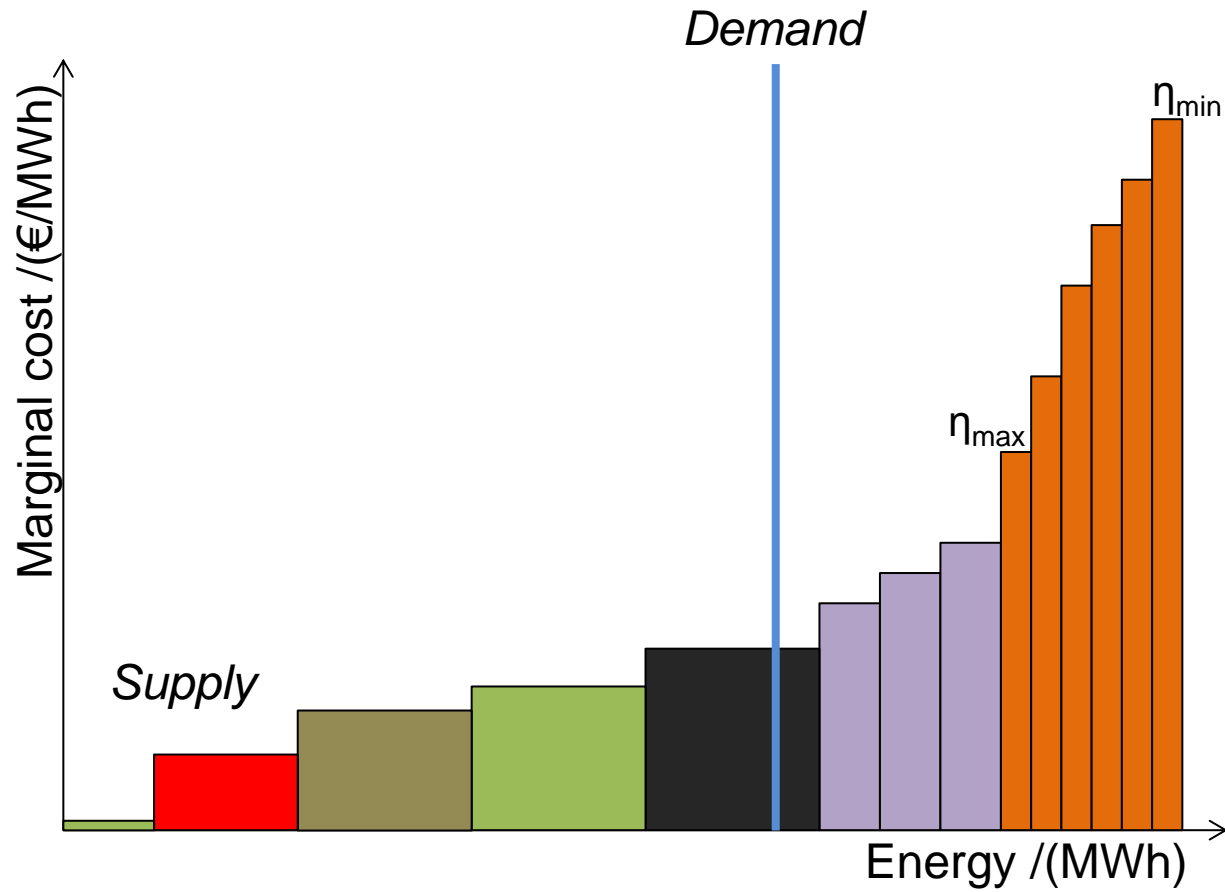
Policy influence

- curtailment
- storage dispatch
- prosumer behaviour



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Price formation



Merit order

- Inflexible demand
- High-res supply bids

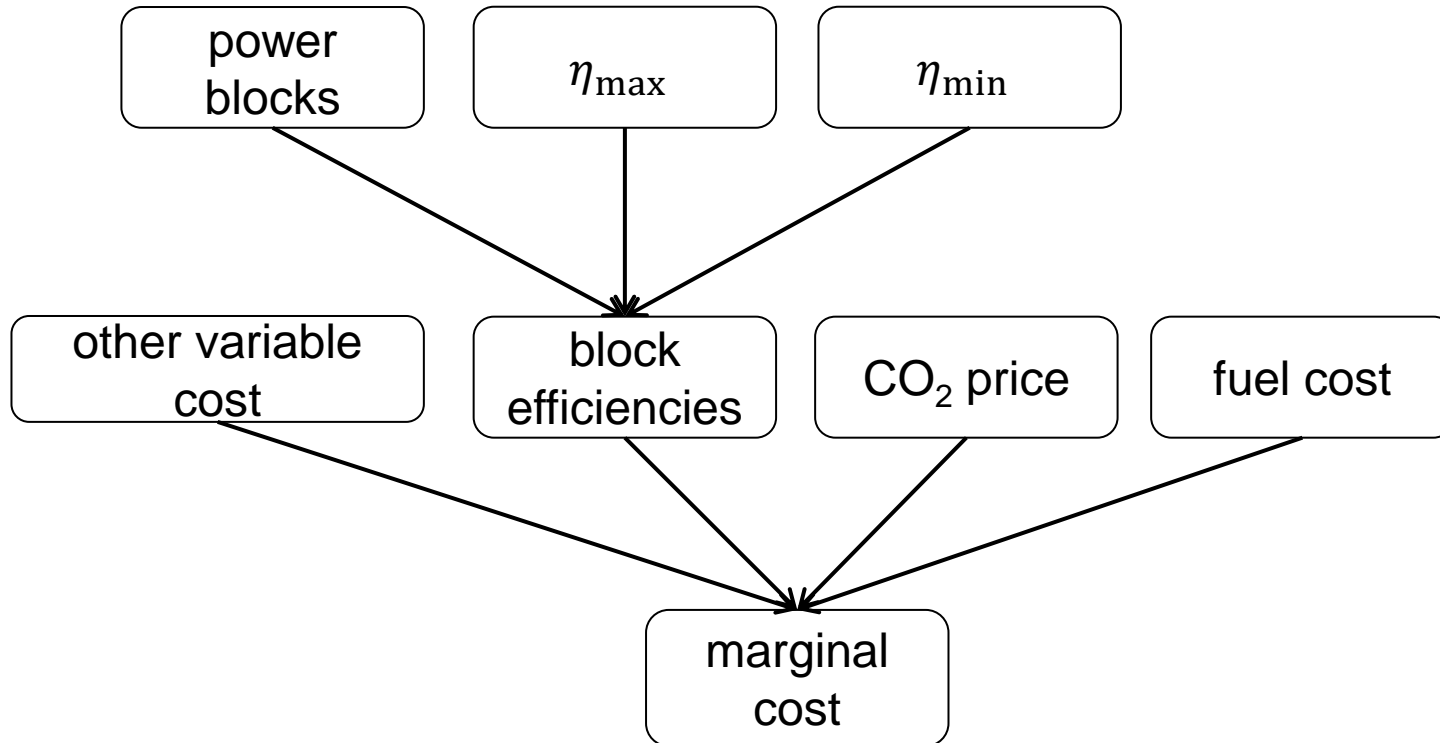
Bids

- Marginal cost = bid price
- Power blocks: type-specific
- Efficiencies interpolated



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Conventionals - marginal costs



Not considered

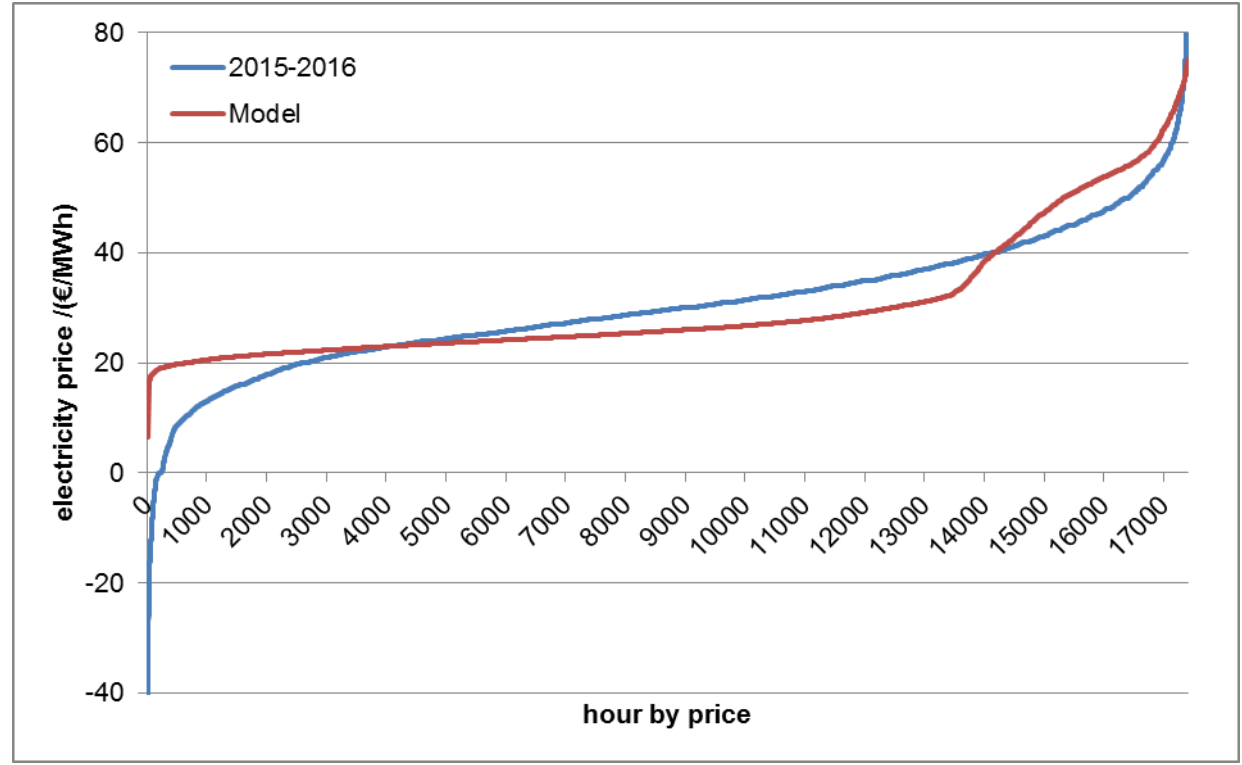
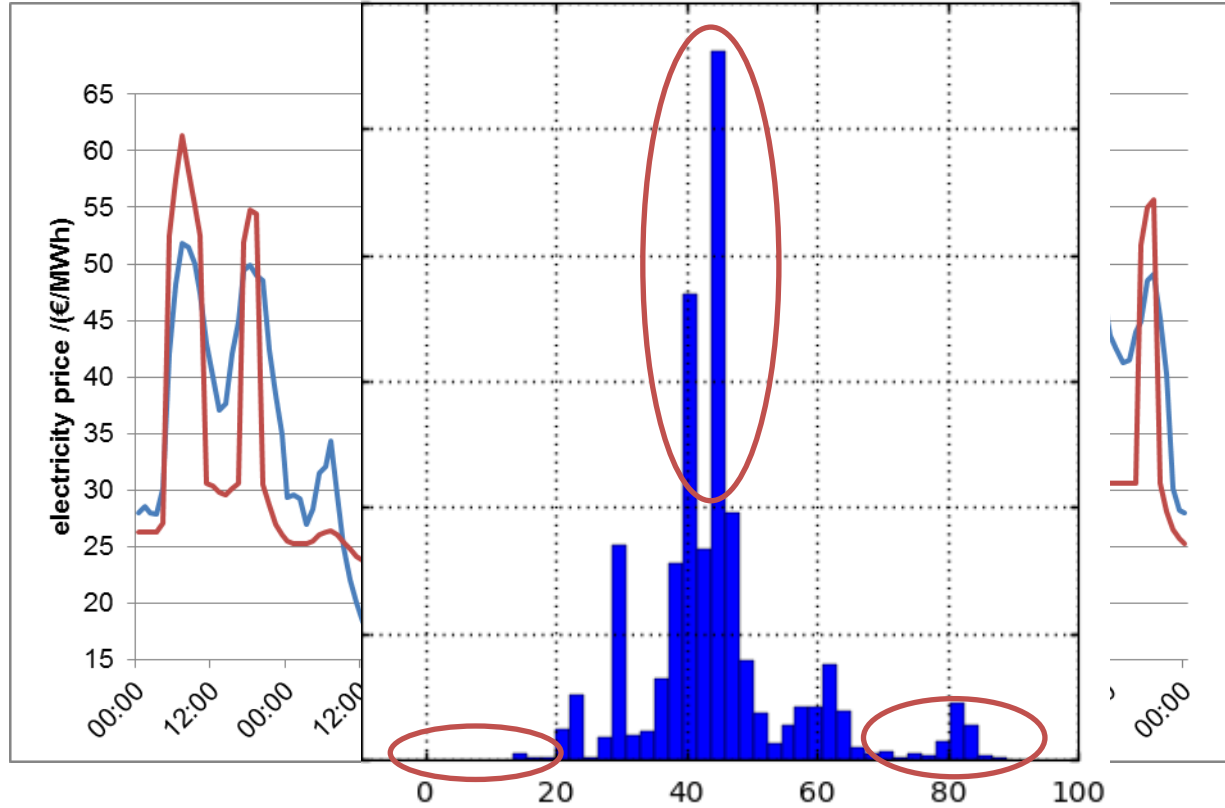
- Control power markets
- Individual power plants
- Start-up cost
- Heat constraints
- ...



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Resulting price

Modeled prices (Median) [EUR/MWh]

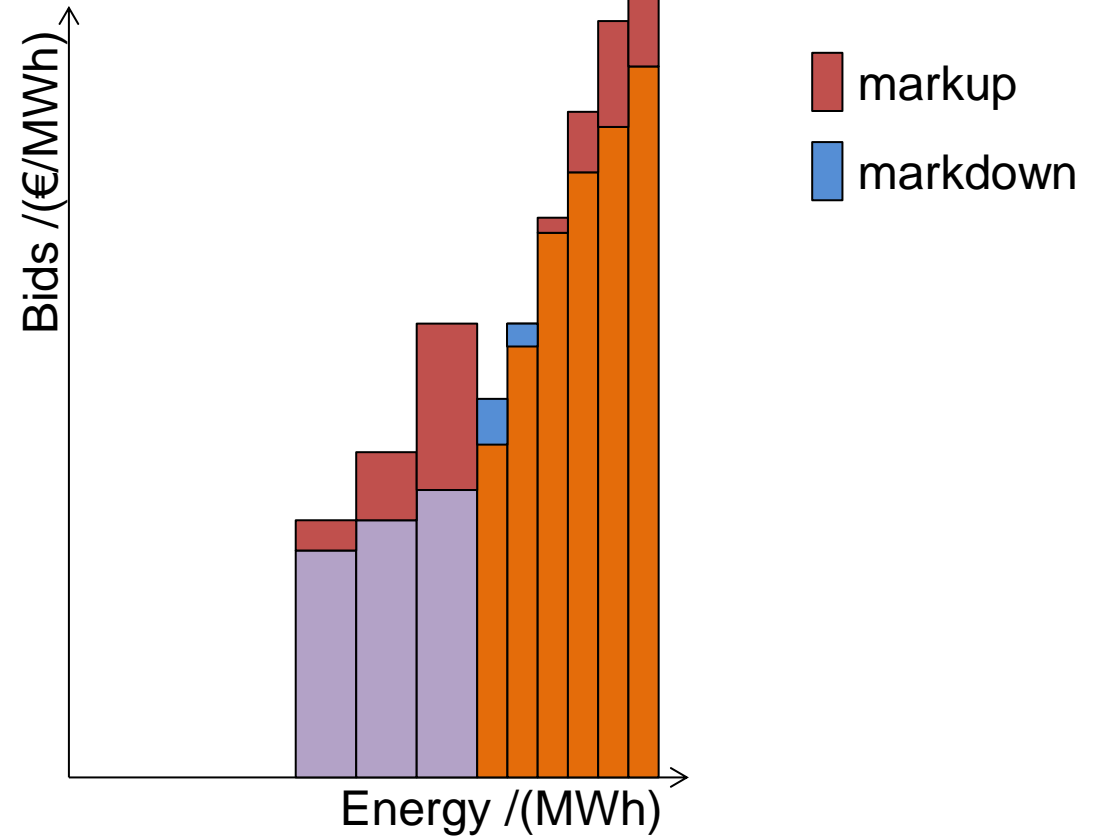
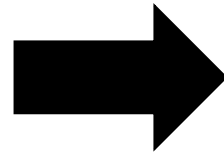
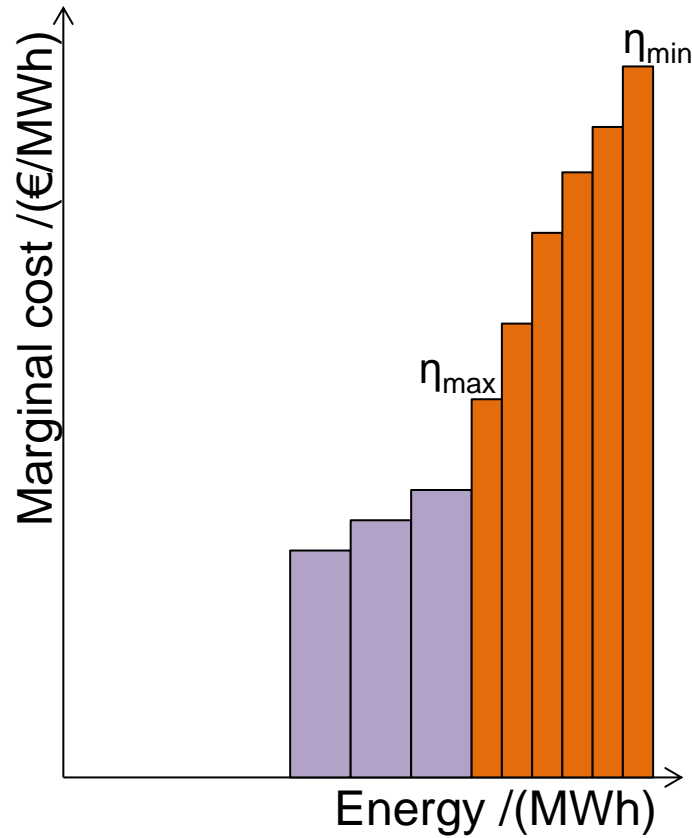


→ Consider missing effects ... but how?



Hybrid approach

Add markups & markdowns

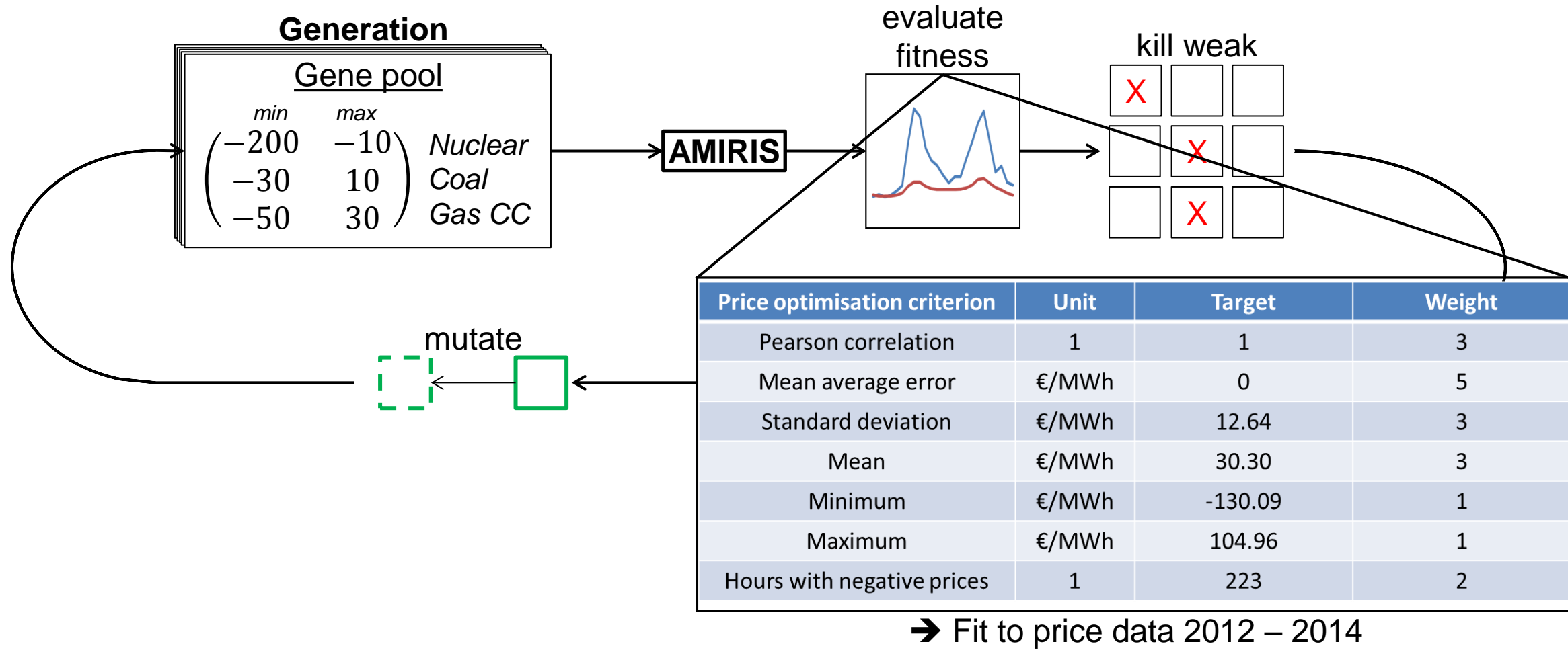


→ Fit markup & markdown values



Markup determination

Genetic algorithm



Markup determination

Validation

Descriptive statistics	Value
Pearson correlation	0.86
Mean average error /€/MWh	4.91
Root mean square error /€/MWh	6.82

Validation with price data 2015 – 2016

- 😊
- 😊 almost forecast level

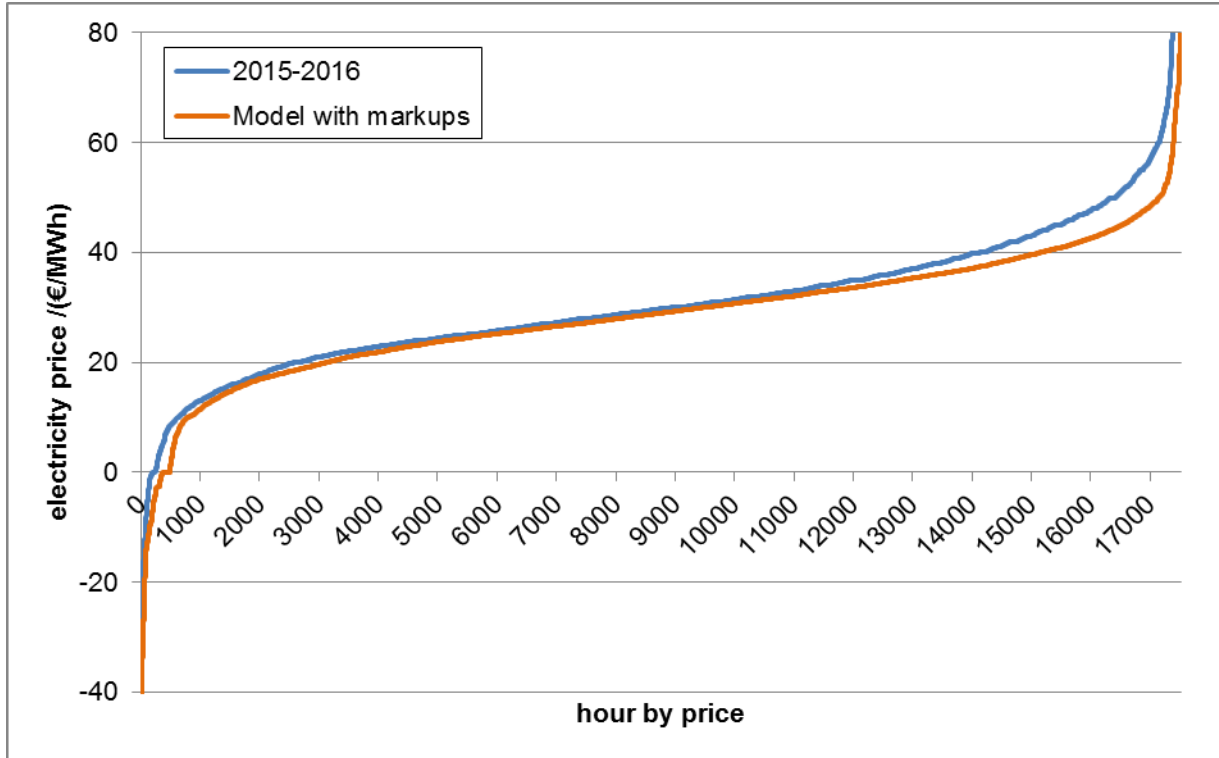
Price optimisation criterion	Target	Model
Standard deviation /€/MWh	12.64	11.68
Mean /€/MWh	30.30	28.37
Minimum /€/MWh	-130.09	-46.78
Maximum /€/MWh	104.96	83.75
Hours with negative prices	223	366

- 😊 good variability
- 😞 slightly too low
- 😞 deep minima
- 😊 high peaks
- 😞 slightly overestimated

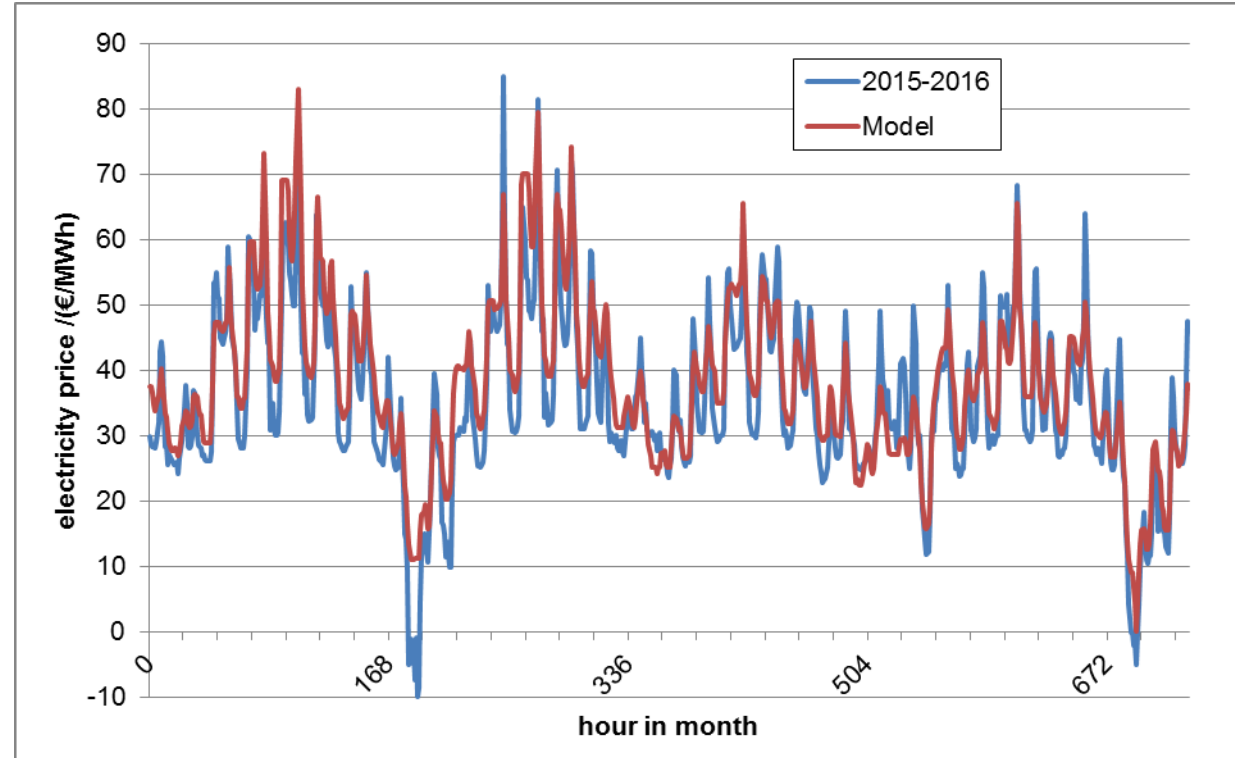


Markups

Results



- Good replication of low prices
- Slightly too low price level



- Good stylized facts replication

→ Consequences for storage?



Impact on storage

Dispatch & Surplus

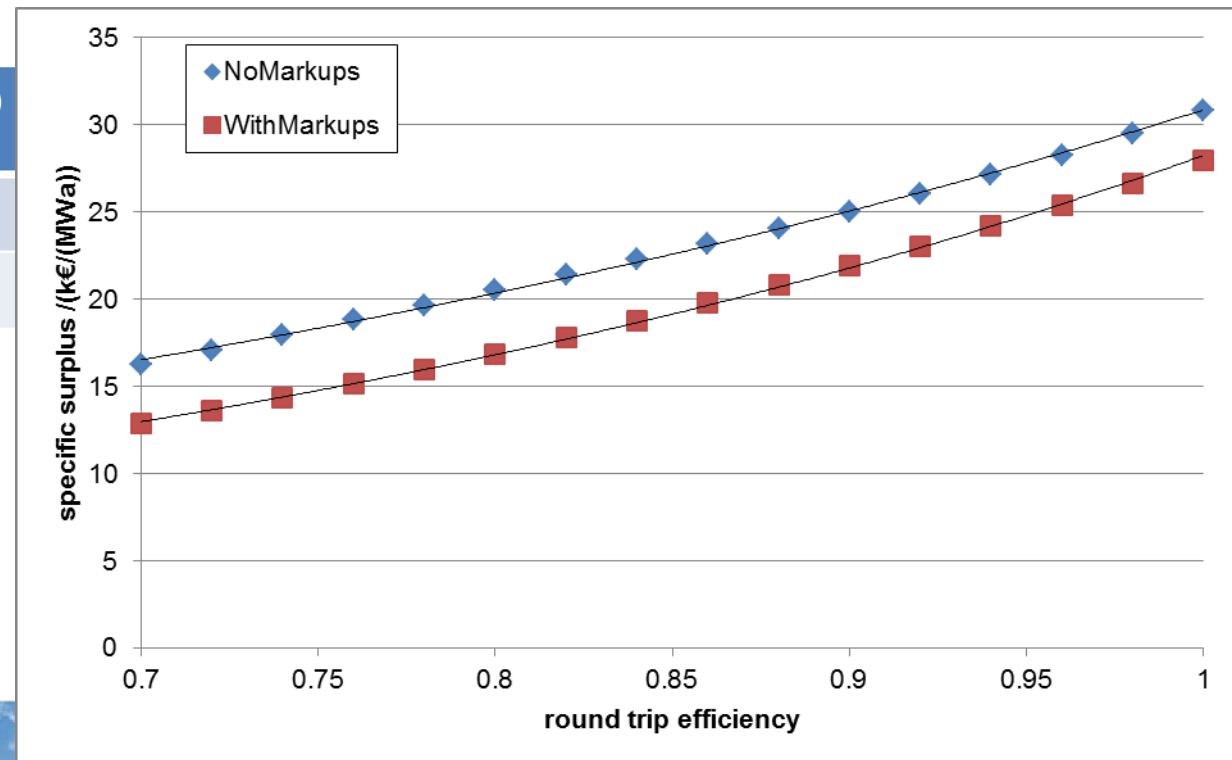
Storage Parameters

- 2.5 GW
- $E2P = 5 \rightarrow 12.5$ GWh
- $\eta = 80\%$

	Discharge hours /(h/a)	Discharged energy /(GWh/a)	Charge hours /(h/a)	Charged energy /(GWh/a)
No markups	1,719	2,438	1,994	3,009
With markups	2,570	3,318	2,628	4,097

	Surplus /(k€/MWa)
No markups	20.5
With markups	16.9

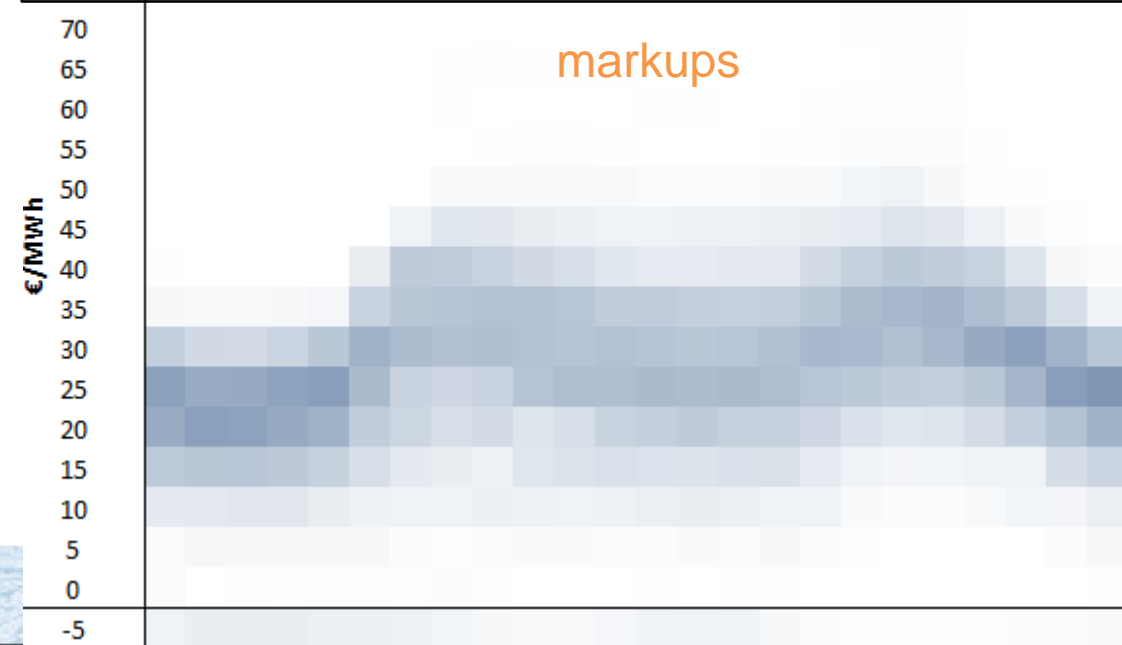
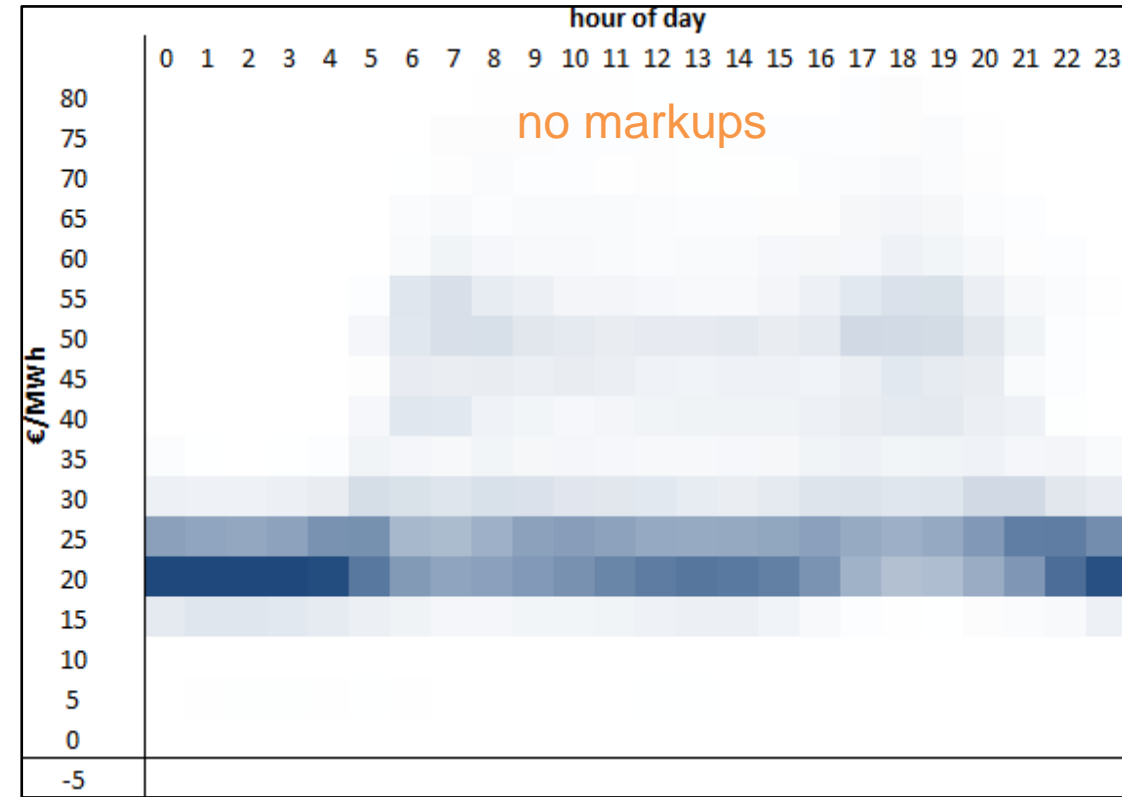
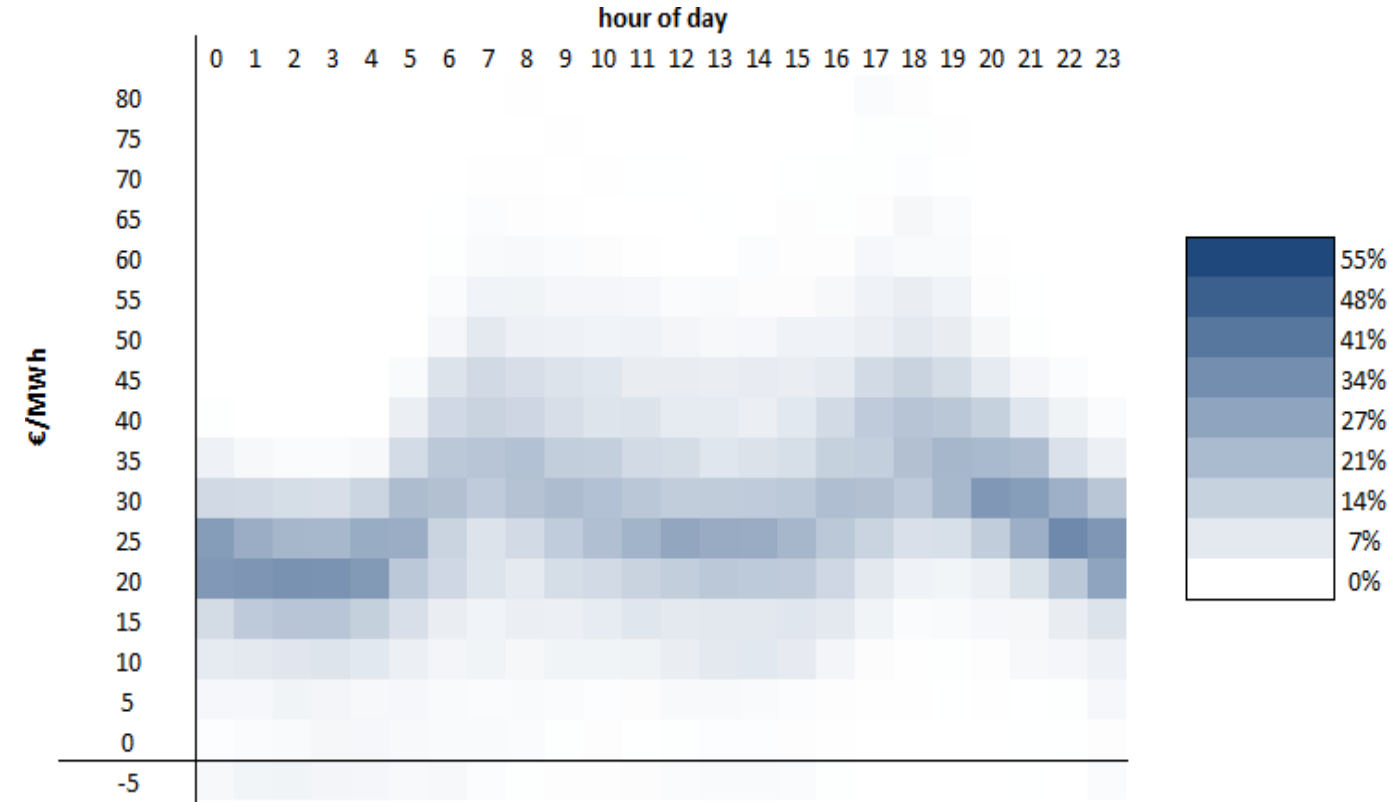
With markups: More dispatch, ok,
but why less surplus?



Markups

Results

Data 2015 – 2016



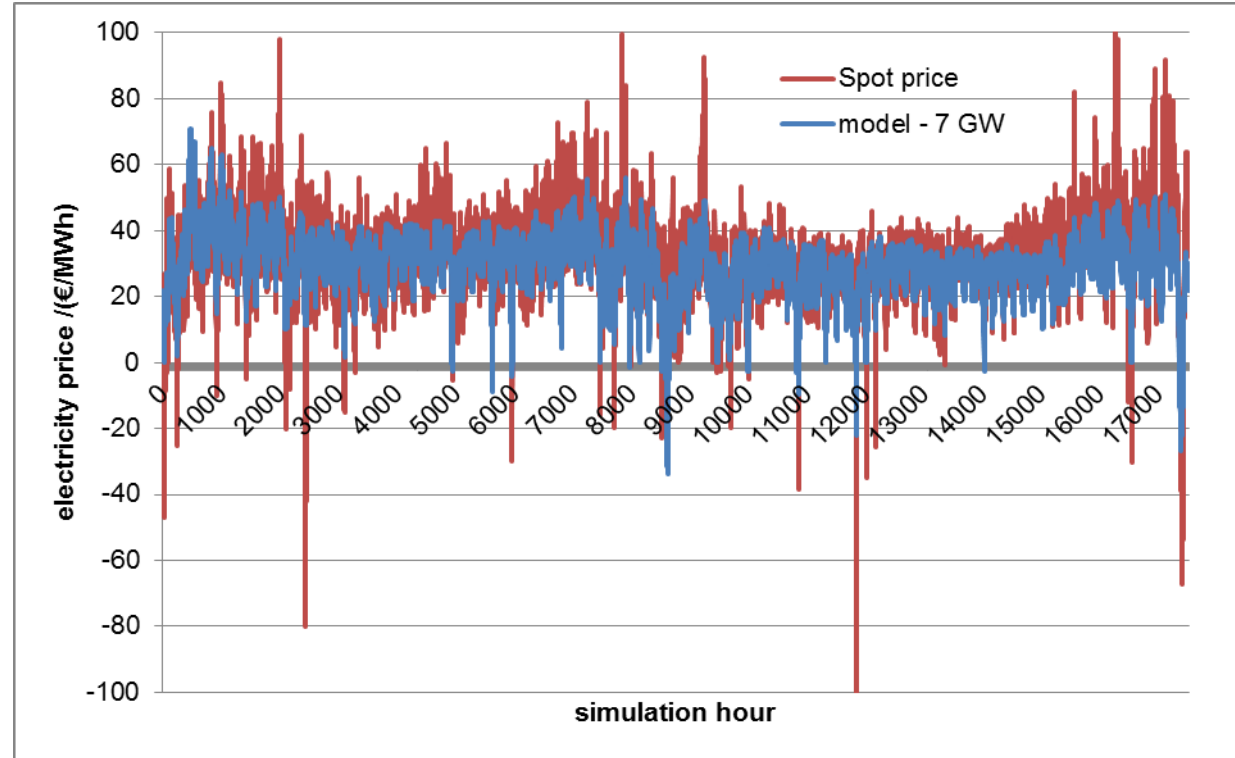
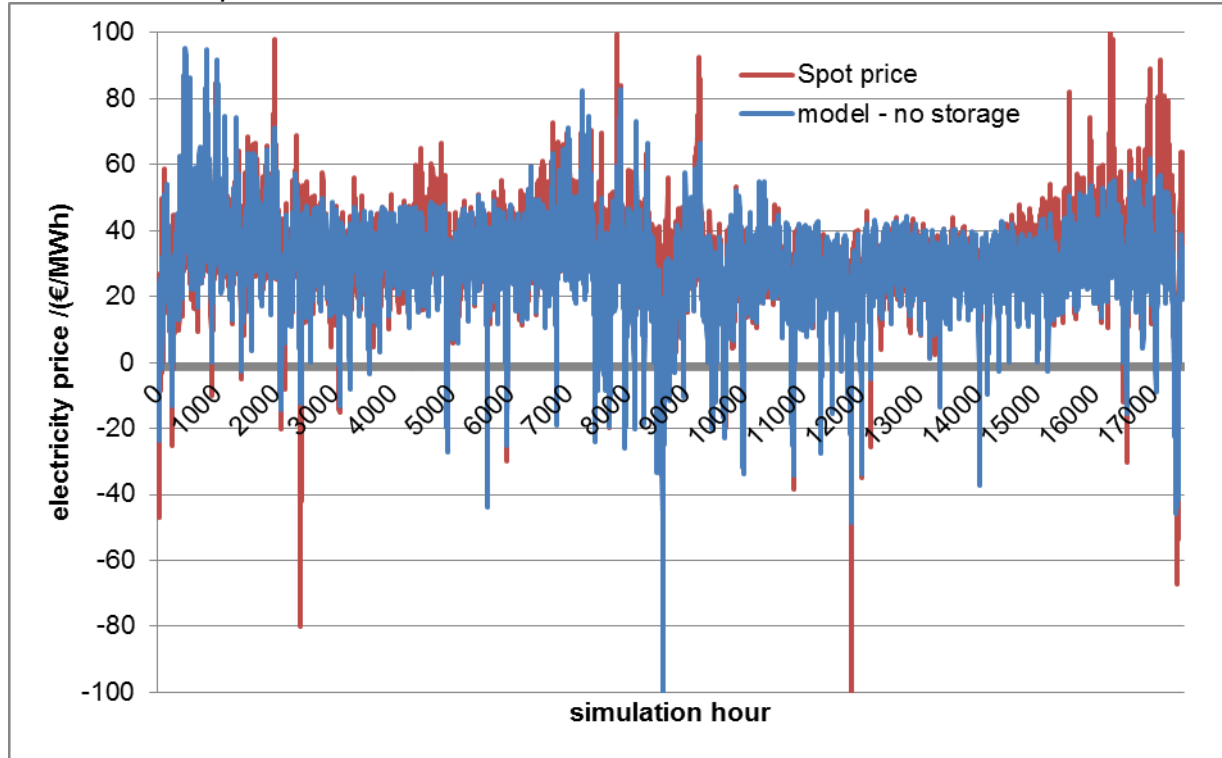
- ➔ Markups improve shape parameters
- ➔ More precise profitability estimates



Impact of storage

Price feedback

E2P = 5 $\eta = 80\%$



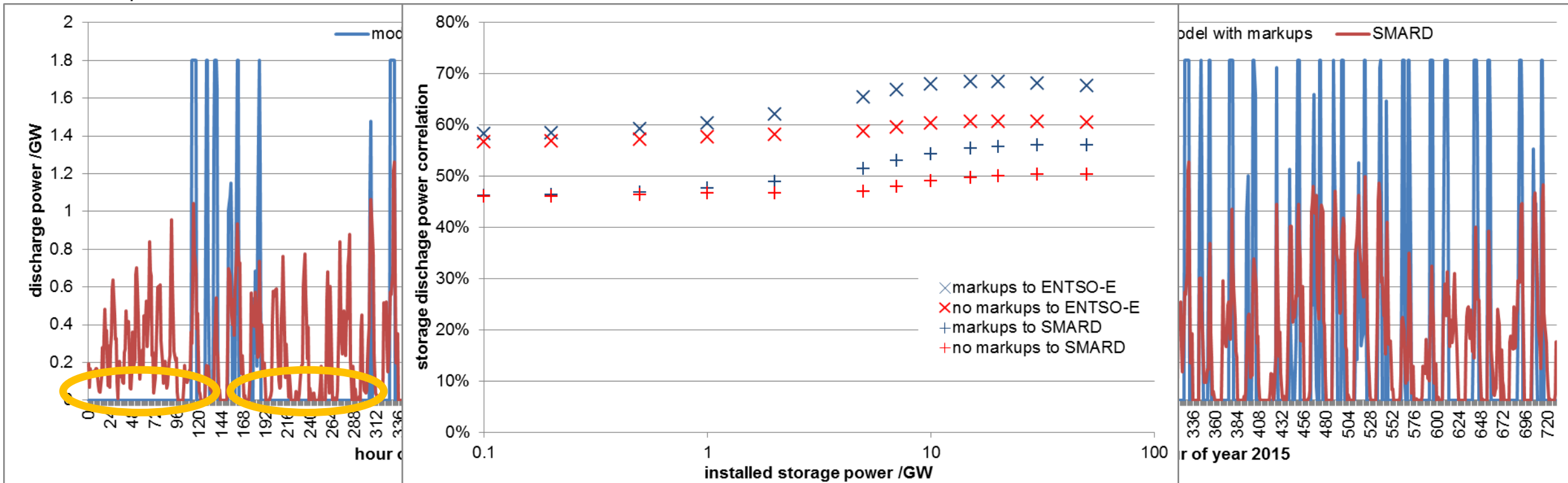
Storage dampens price variability
→ Verify storage dispatch



Storage dispatch

Model vs. data

E2P = 5 $\eta = 80\%$ 2 GW



- ➔ Markups: better stylised facts of dispatch
- ➔ Markups: higher correlation to measured dispatch



Wrap up

Price variability

- good reproduction necessary
- fundamental modelling: complex
- ➔ hybrid approach: markups

Application to storage

- markups: better dispatch correlation
- more precise surplus assessment

Markups

- fitted via genetic algorithm
- price: better reproduction of stylised facts
- room for improvement

Future work

- include AT & LU
- connect neighbouring market zones
- improve storage dispatch algorithm
- fundamental markup / bid modelling?

