Electricity Price Forecasting using Sale and Purchase Curves: The X- Model

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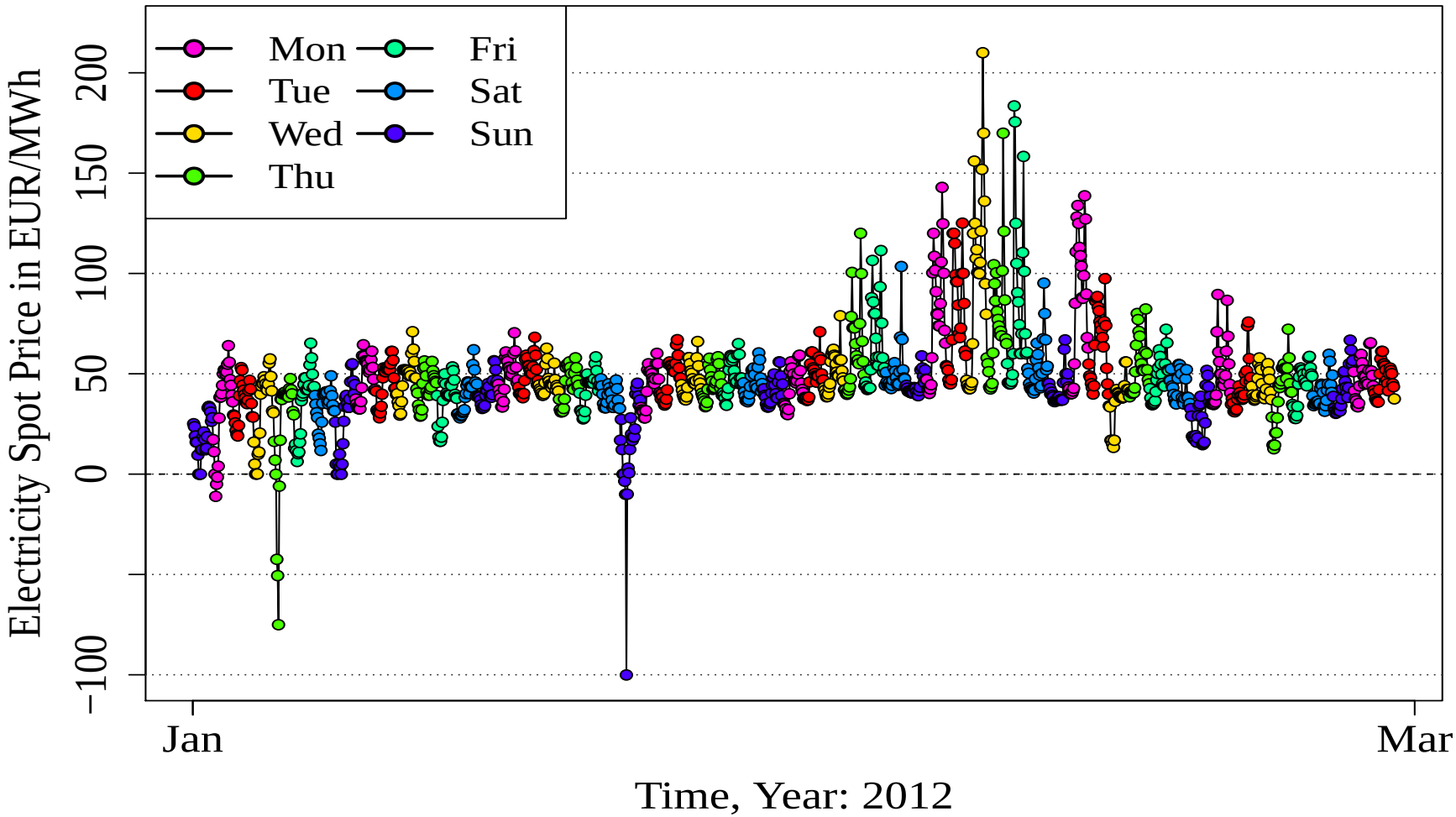
Strommarkttreffen
Berlin, Germany

February 2017

Hourly EPEX electricity spot price Germany&Austria



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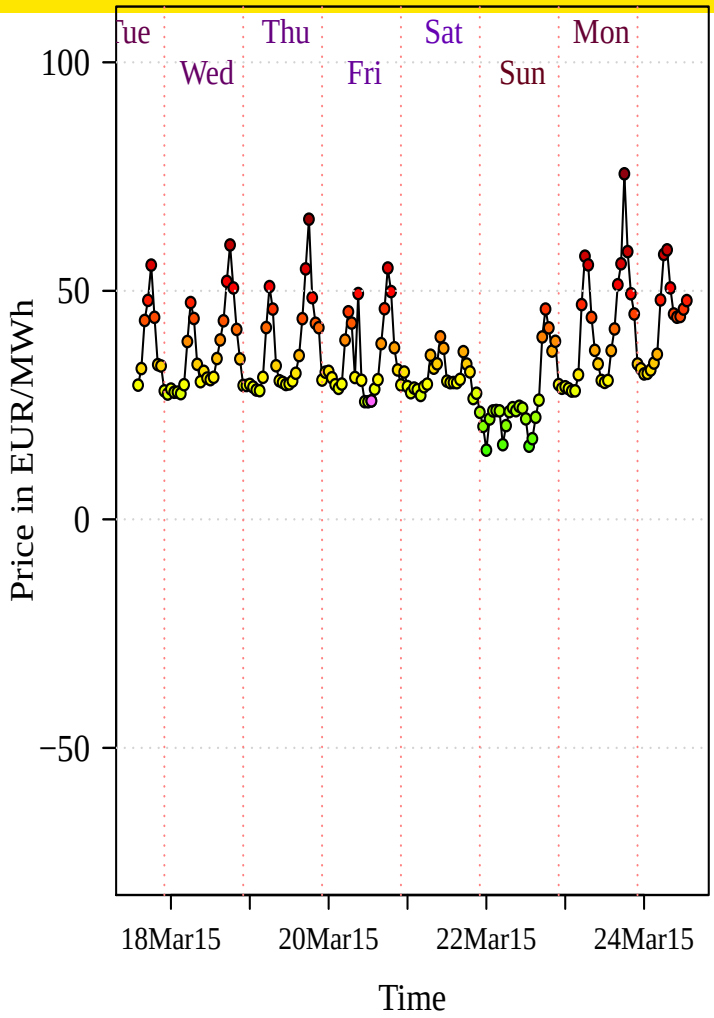

EPEX SPOT SE: Aggregated Curves - Mozilla Firefox

EPEX SPOT SE: Aggre...

www.epexspot.com/en/market-data/dayaheadauction/curve/auction-aggregated-curve/2015-12-19/DE

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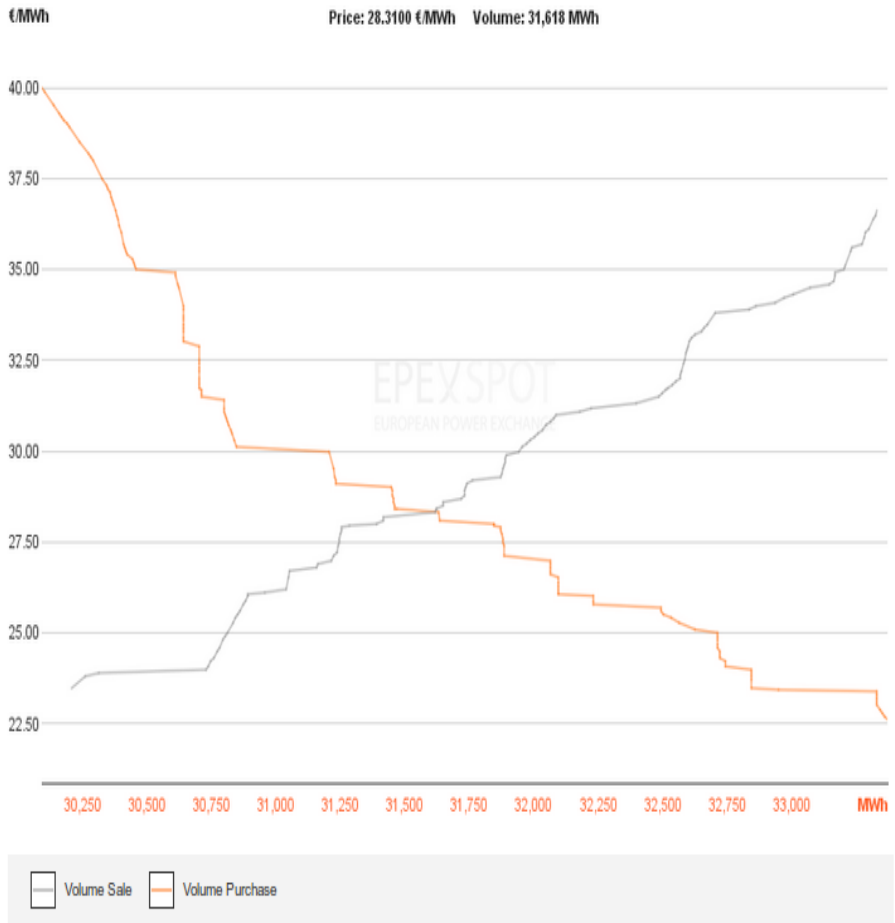
19/12/2015 19/12/2015

13-14



Considered market and auction facts

- two-sided auction at 12:00 for next day hourly prices
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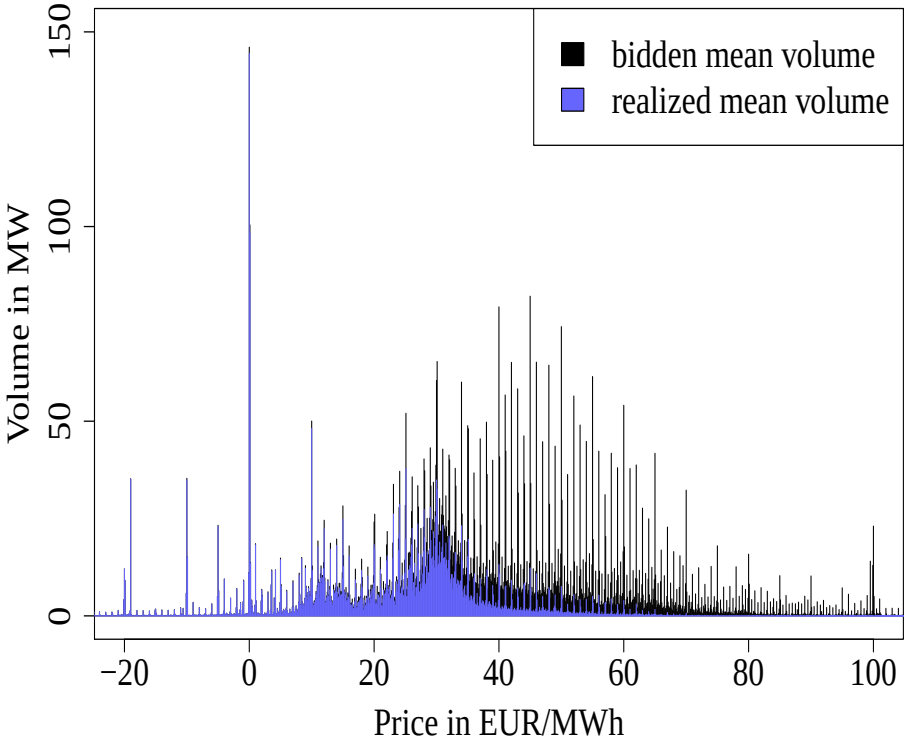
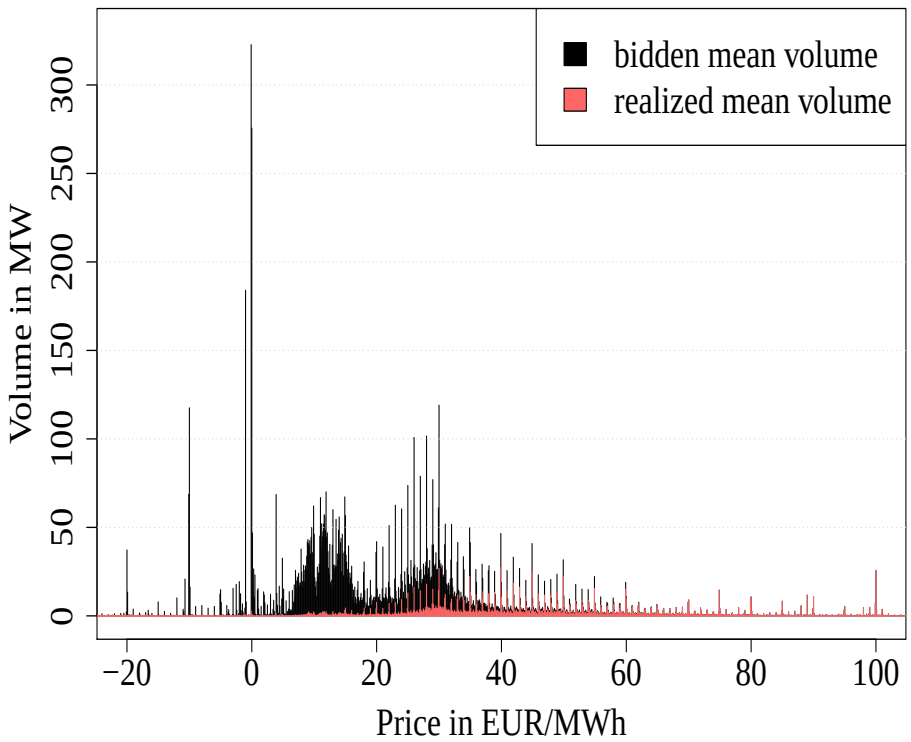
- prices between -500 to 3000 EUR/MWh
- smallest bid volume unit 0.1 MWh
- smallest bid price unit 0.1 EUR/MWh
  $\Rightarrow$ 35001 possible bid prices:
  $\mathbb{P} = \{-500, -499.9, -499.8, \ldots, 2999.9, 3000\}$

Distribution of mean bid volume between -20 and 100 EUR/MWh



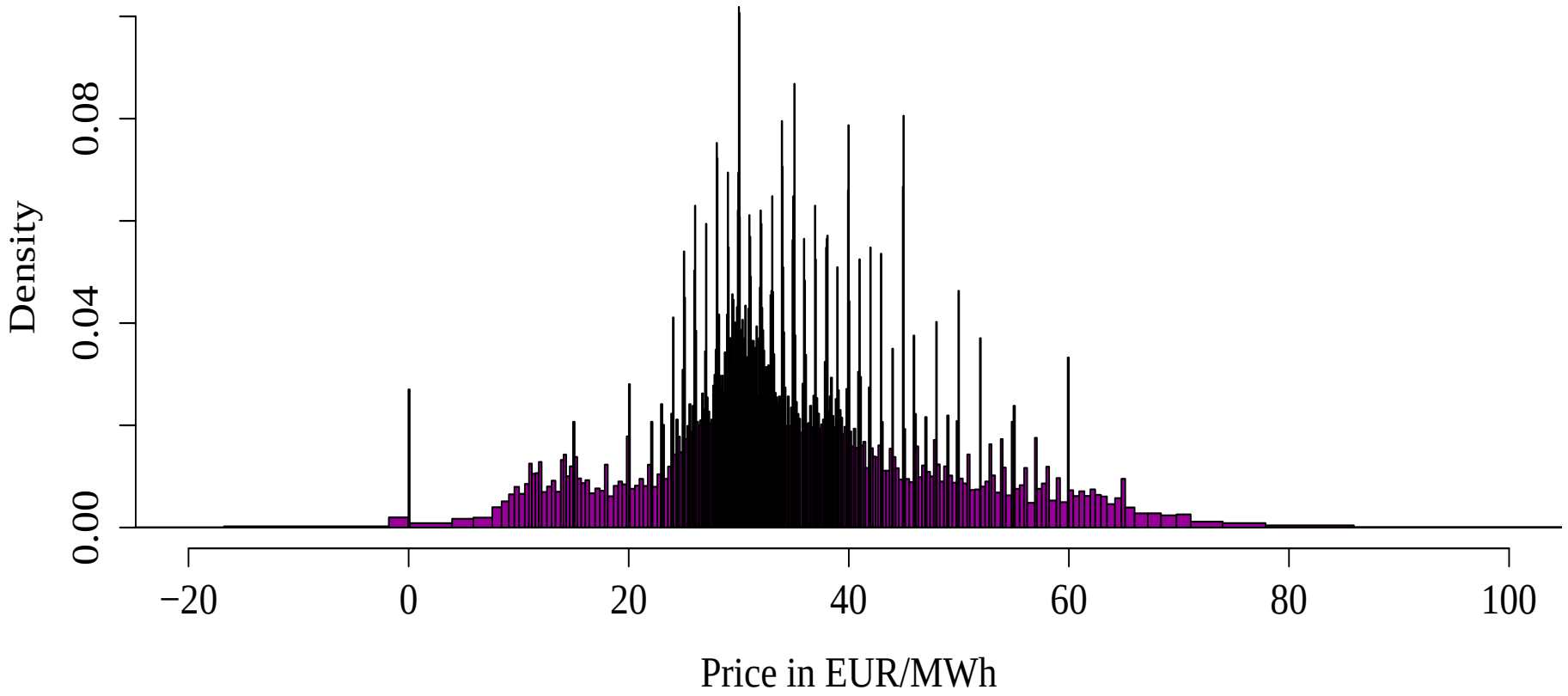
Sale / Supply



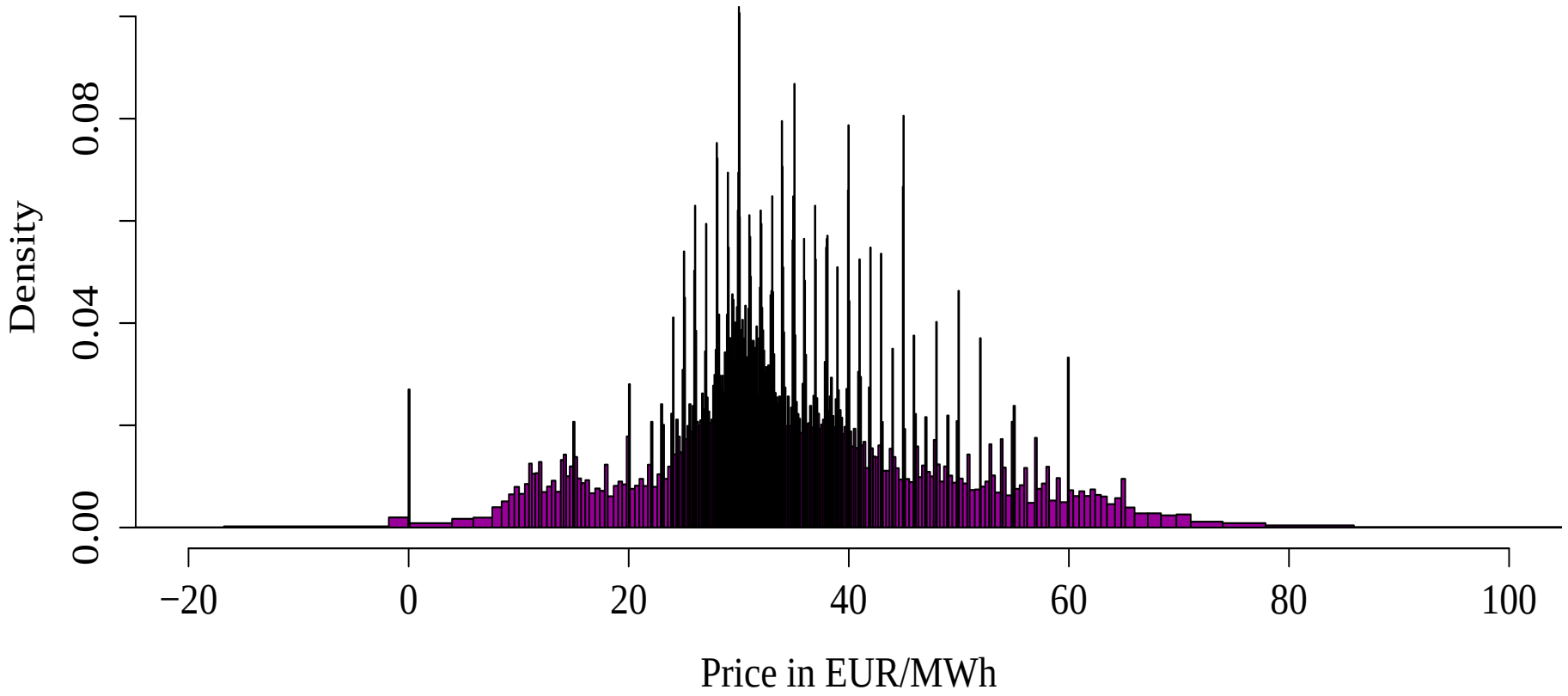
Purchase / Demand

- bid cluster at round prices:
  e.g. 0.0 EUR/MWh, 10.0 EUR/MWh, 70.0 EUR/MWh

Histogram of market clearing prices (-20 to 100 EUR/MWh)



Histogram of market clearing prices (-20 to 100 EUR/MWh)



- price cluster at round prices, e.g. at 0.0 EUR/MWh:
  - between -0.5 and 0.5 EUR/MWh 0.634%
  - between -1.5 and -0.5 EUR/MWh 0.079%
  - between 0.5 and 1.5 EUR/MWh 0.056%

Model approach (in 4 steps)

1. Group the bid data of similar price regions to **price classes** (35001 $\Rightarrow$ reasonable size)

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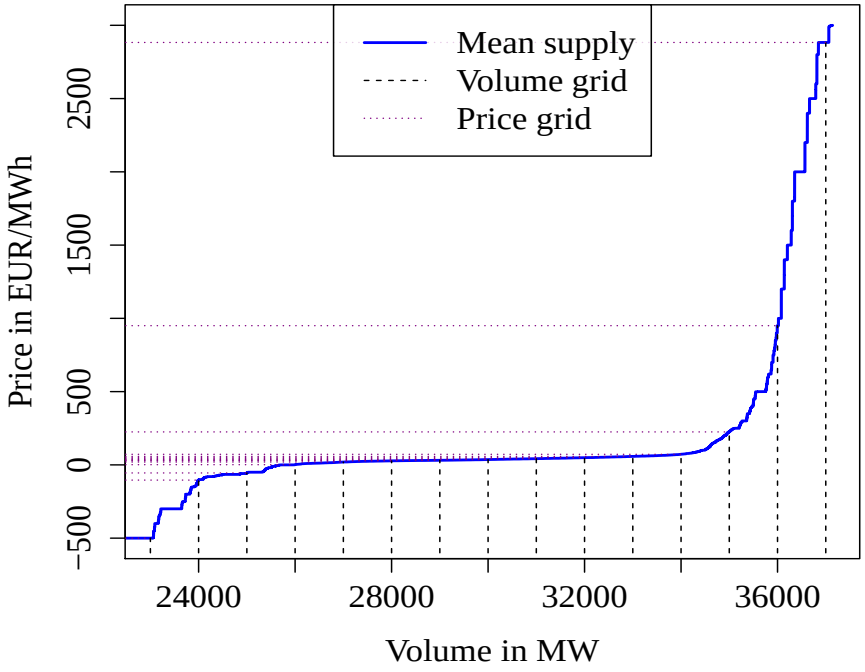
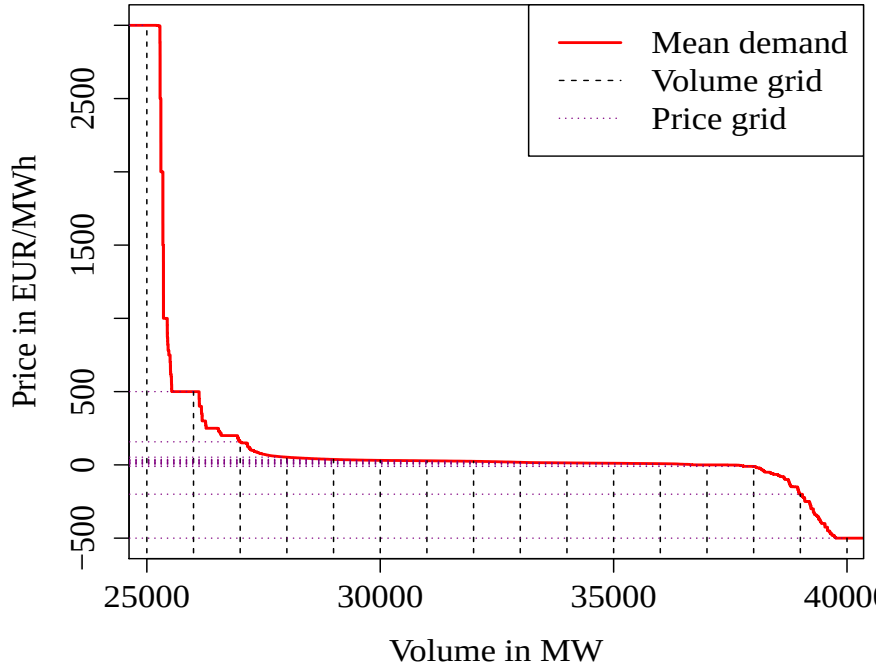
3. Reconstruct the precise bidding structure within each price class
4. Compute supply and demand curves and their intersection $\Rightarrow$ market clearing price

price class grouping:

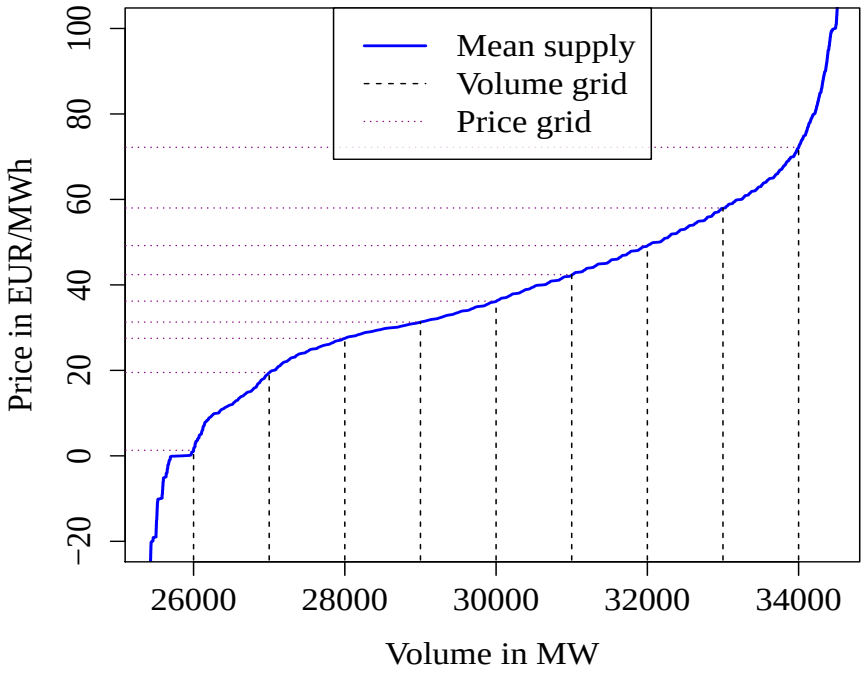
- **bid volume in** each **class** is relatively **equal**ly sized
  $\rightsquigarrow$ about 1000 MWh
- use mean volume $\mathbb{V}(P)$ for each price P
  (for supply and demand)
- price classes: $\mathbb{V}^{-1}(\mathbb{V}_*)$
  with volume grid $\mathbb{V}_* = \{0, 1000, 2000, \ldots\}$



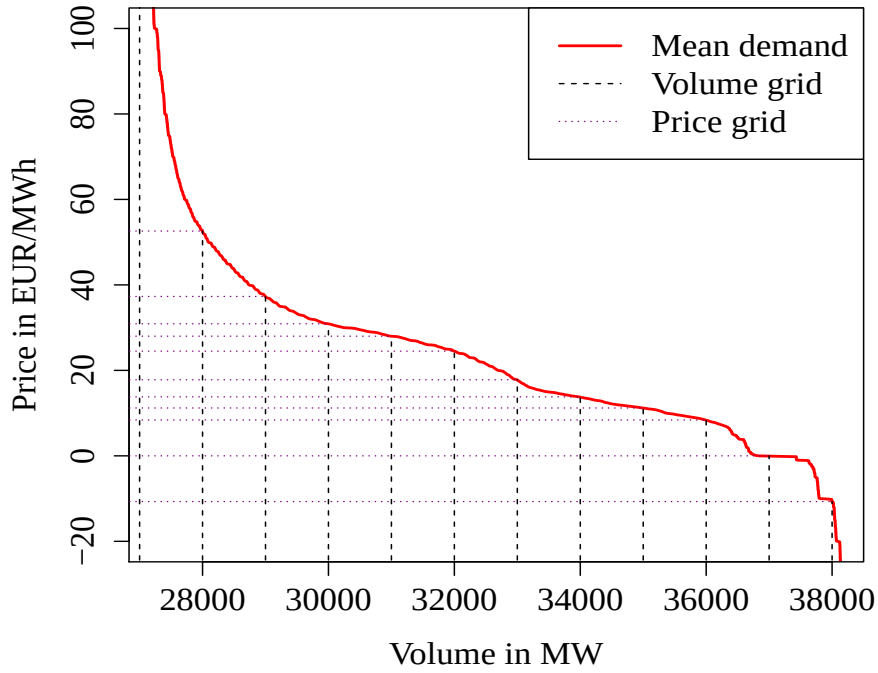
Supply: -500 to 3000 EUR/MWh



Demand: -500 to 3000 EUR/MWh



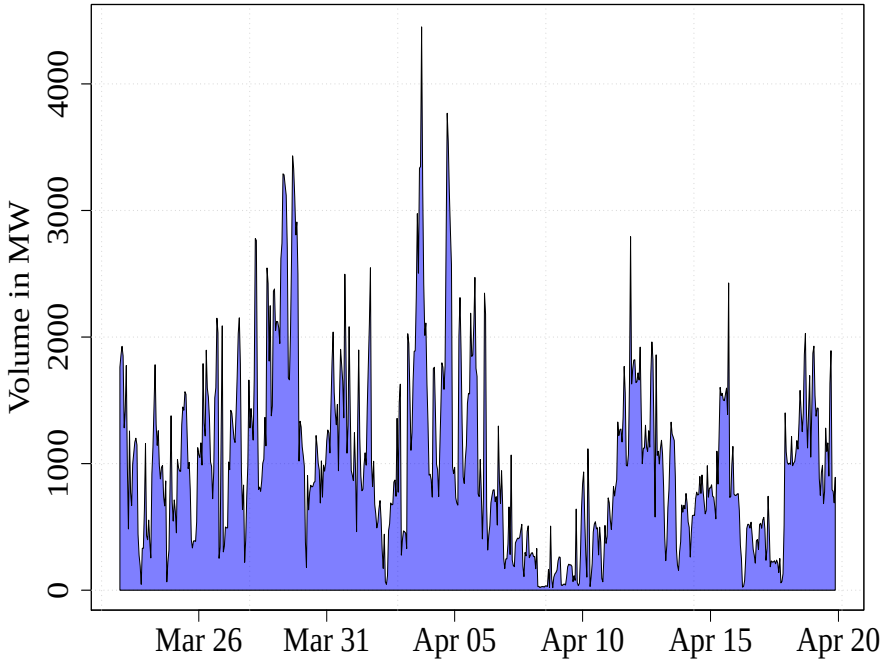
Supply: -20 to 100 EUR/MWh



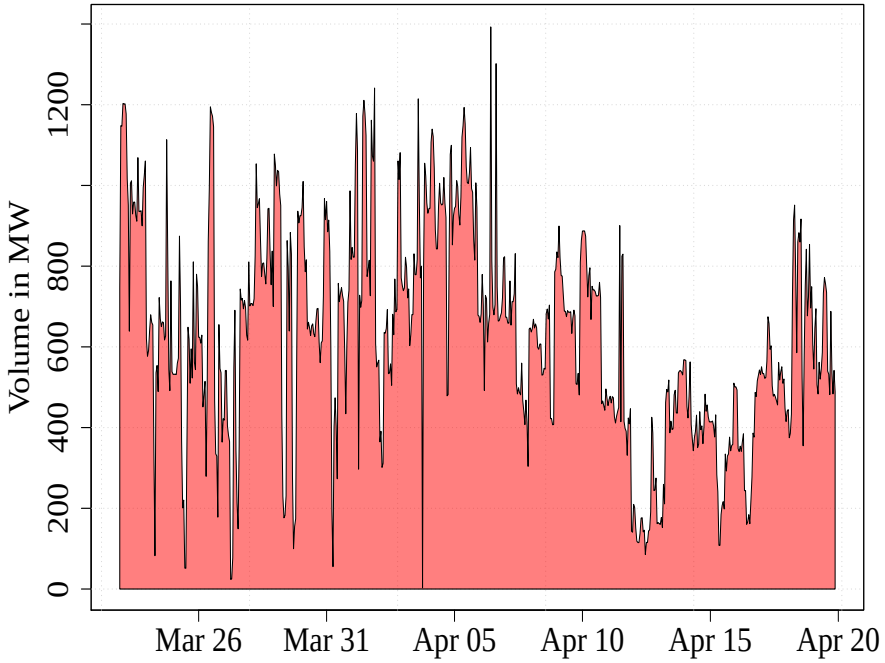
Demand: -20 to 100 EUR/MWh

price classes:

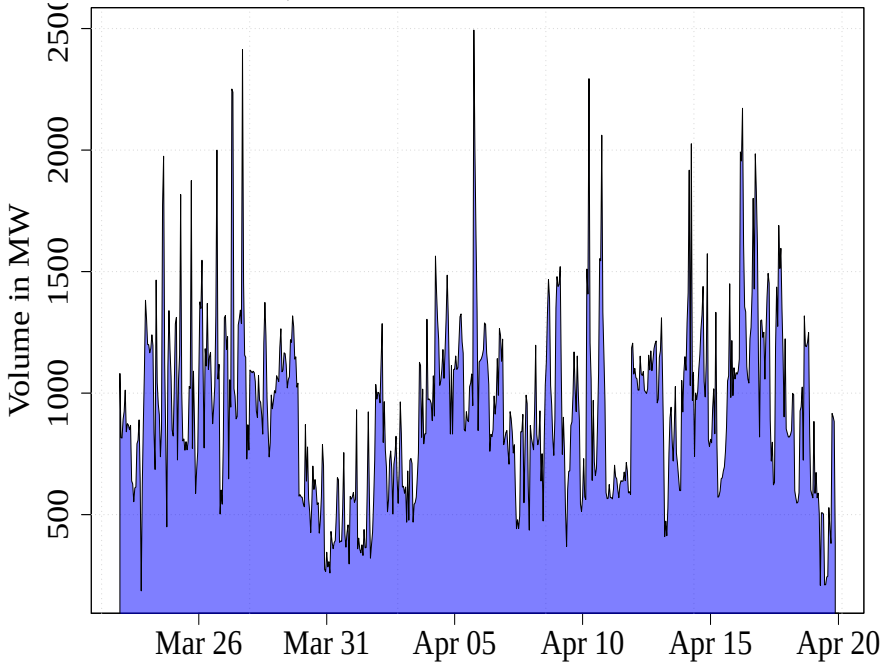
- Supply:
  $\mathbb{C}_S = \{-500.0, -103.9, -55.1, \ldots, 3000.0\}$
  with 16 classes
- Demand:
  $\mathbb{C}_D = \{-500.0, -200.0, -10.7, \ldots, 3000.0\}$
  with 16 classes
- e.g. $X_{d,h}^{S,-55.1}$ contains the sum of volumes bid at prices
  $\{-103.8, -103.7, -103.6, \ldots, -100.0, \ldots, -55.0, -55.1\}$
  at day d and hour h



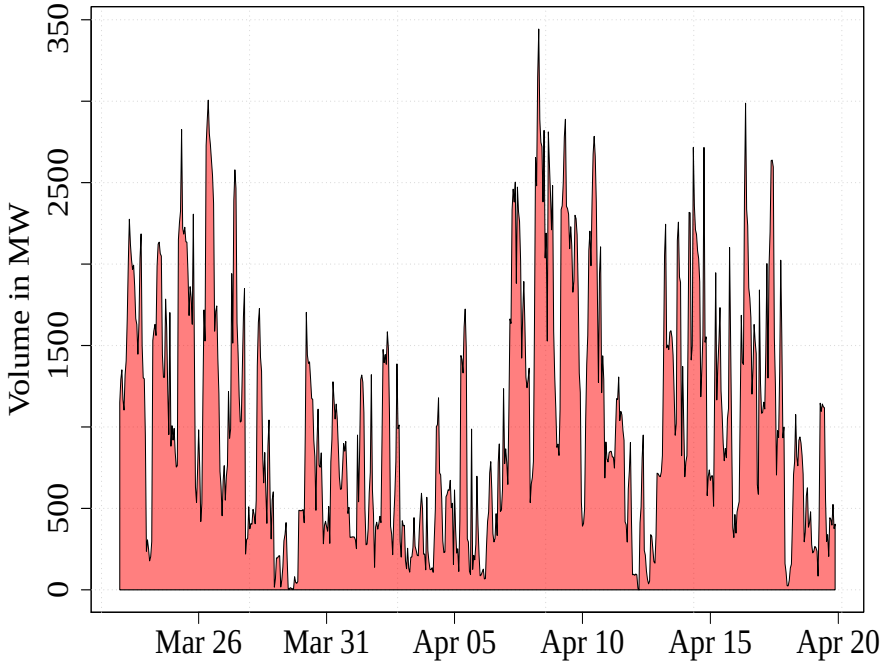
Supply: $X_{d,h}^{S,19.5}$ with bids in $[1.4, 19.5]$



Demand: $X_{d,h}^{D,8.4}$ with bids in $[8.4, 11.1]$

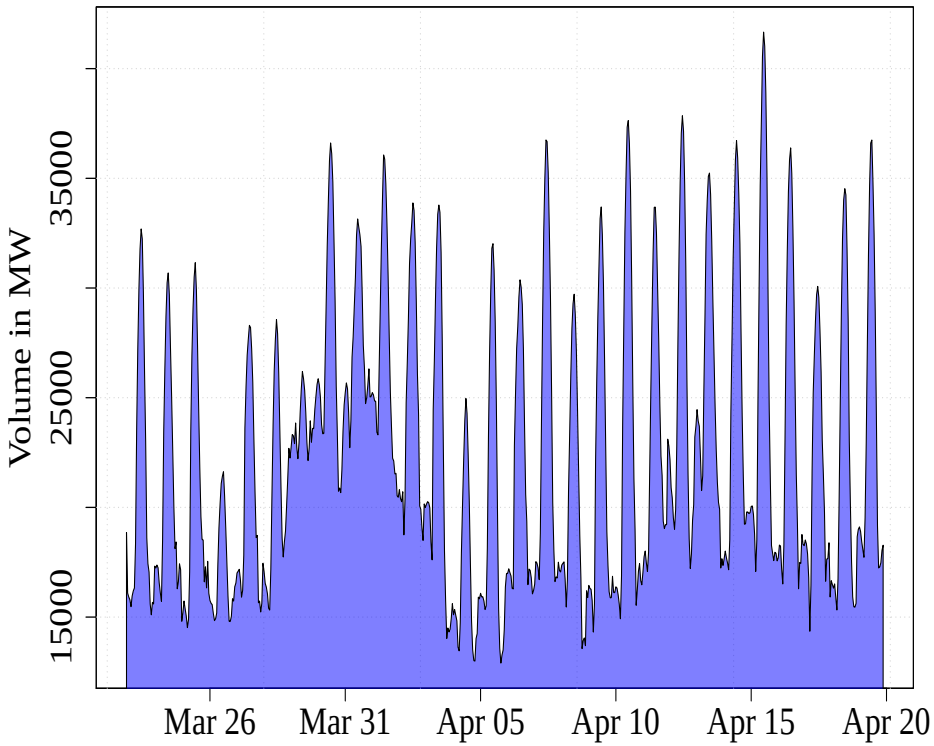


Supply: $X_{d,h}^{S,58.0}$ with bids in $[49.3, 58.0]$

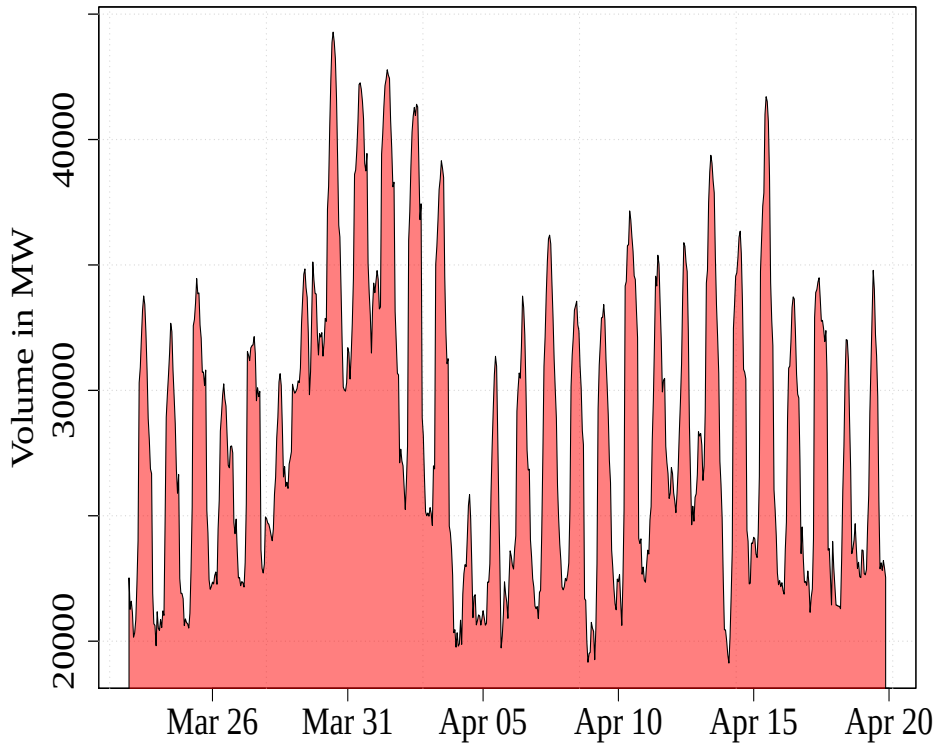


Demand: $X_{d,h}^{D,37.3}$ with bids in $[37.3, 52.5]$

Exception:



Supply: $X_{d,h}^{S,-500}$ with bids at exactly -500



Demand: $X_{d,h}^{D,3000}$ with bids at exactly 3000

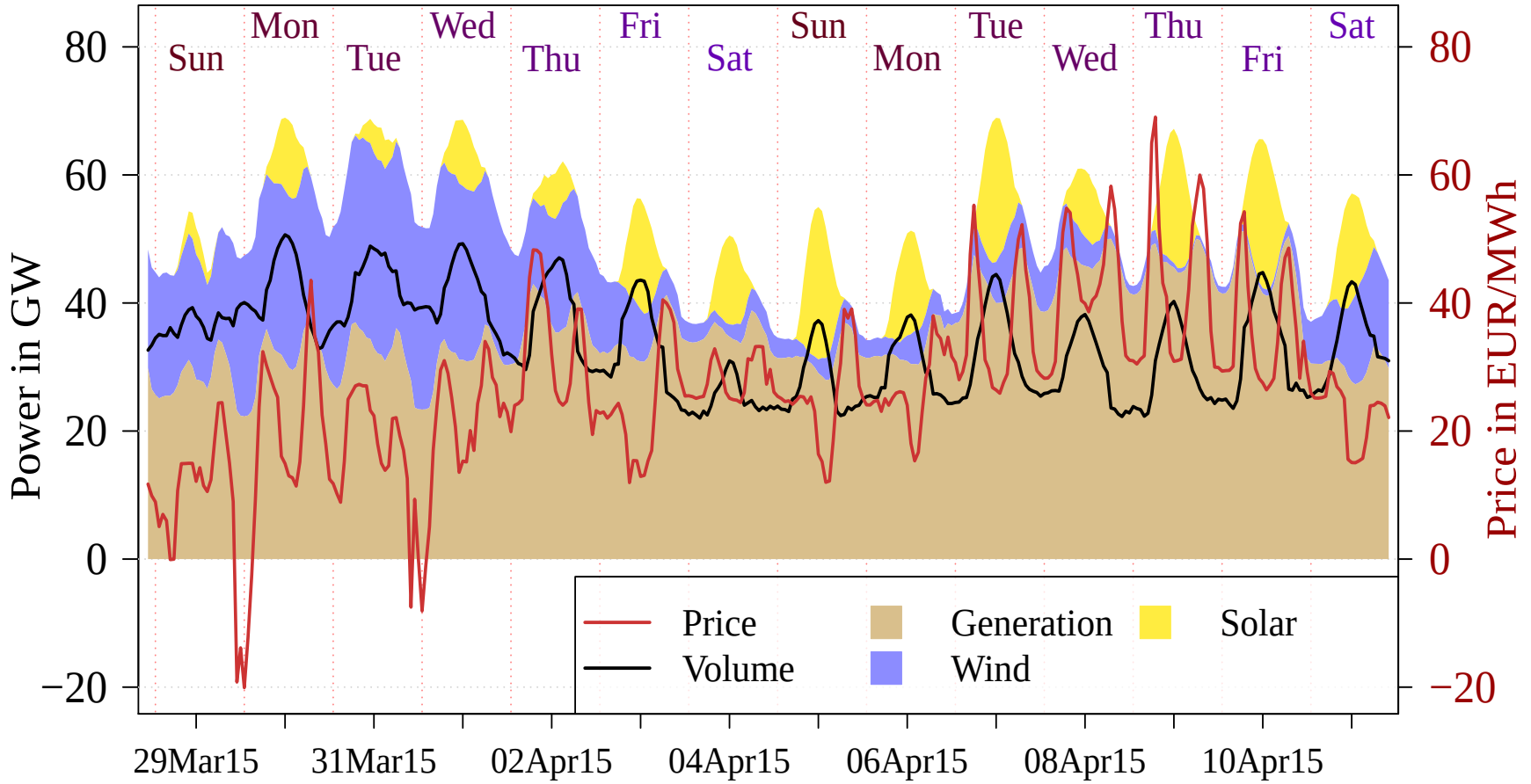
- clear periodic pattern
- large volume $\rightsquigarrow$ important process

Time series model for bid volumes in each price class:

- define $\boldsymbol{X}_{d,h} = (X_{1,d,h}, \ldots, X_{M,d,h})' =$
  $((X^{S,c}_{d,h})_{c\in\mathbb{C}_S}, (X^{D,c}_{d,h})_{c\in\mathbb{C}_D}, X^{\text{price}}_{d,h}, X^{\text{volume}}_{d,h}, X^{\text{generation}}_{d+1,h}, X^{\text{wind}}_{d+1,h}, X^{\text{solar}}_{d+1,h})'$

  planned generation, wind and solar $\rightsquigarrow$ d+1 available

External regressors



- planned generation, wind and solar from *EEX transparency*

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  planned generation, wind and solar $\rightsquigarrow$ d+1 available
- **ARX type process** to $\boldsymbol{X}_{d,h}$:

$$X_{m,d,h} = \sum_{l=1}^{M}\sum_{j=1}^{24}\sum_{k\in\mathcal{I}_{m,h}(l,j)} \phi_{m,h,l,j,k} X_{l,d-k,j} + \sum_{k=2}^{7} \psi_{m,h,k} W_k(d) + \varepsilon_{m,d,h}$$

- index sets of lag with possible impact

$$\mathcal{I}_{m,h}(l,j) = \begin{cases} \{1,2,\ldots,36\} & , m = l \text{ and } h = j \\ \{1,2,\ldots,8\} & , (m = l \text{ and } h \neq j) \text{ or } (m \neq l \text{ and } h = j) \\ \{1\} & , m \neq l \text{ and } h \neq j \end{cases}.$$

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- $W_k(d)$ weekday dummies
- estimation by **lasso** (BIC based)

Reconstruction of price structure:

2 reconstruction assumptions:

- Probability that a price P is traded is constant over time
- Distribution of a volume of a traded price as mean volume

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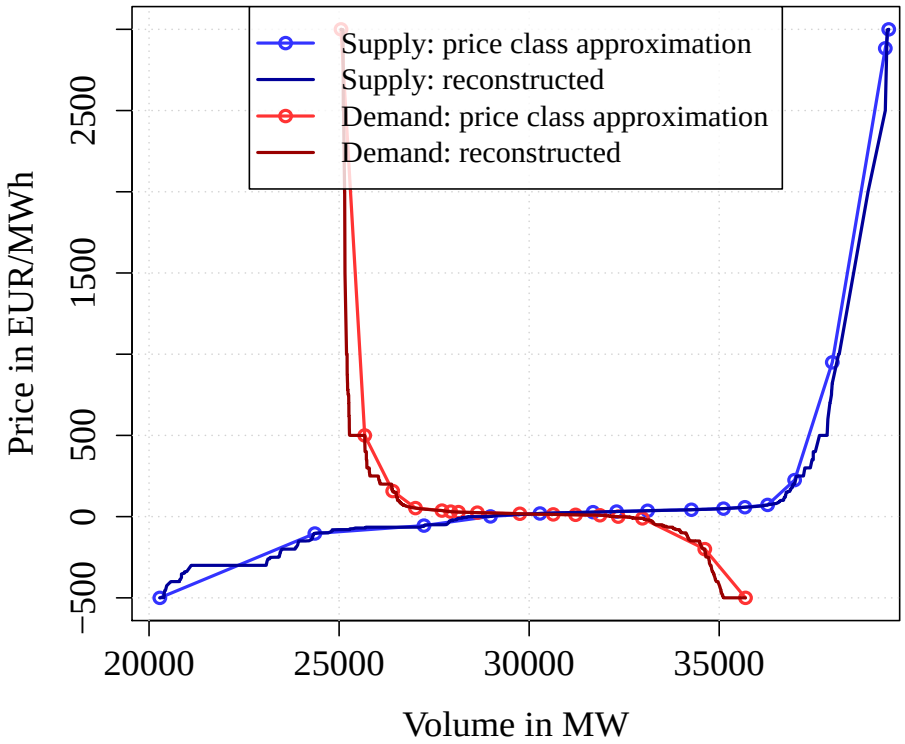
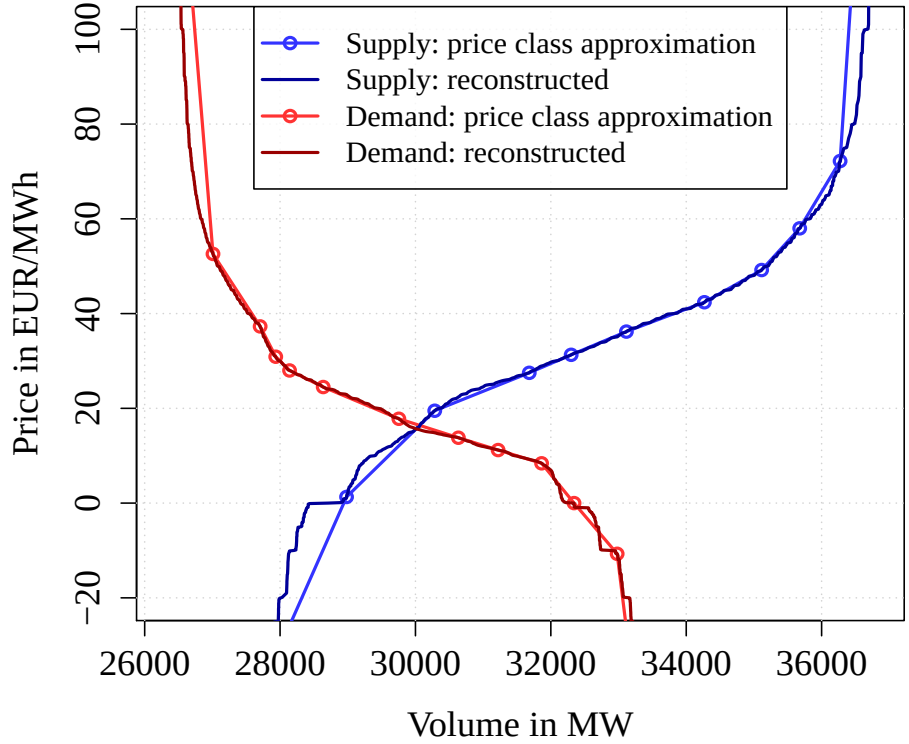


-500 to 3000 EUR/MWh



-20 to 100 EUR/MWh

Forecasting study for X-Model

- Rolling window (with re-estimation of X-Model)
- Two years of in sample data
- Out-of-sample range from 01.11.2014 to 19.04.2015

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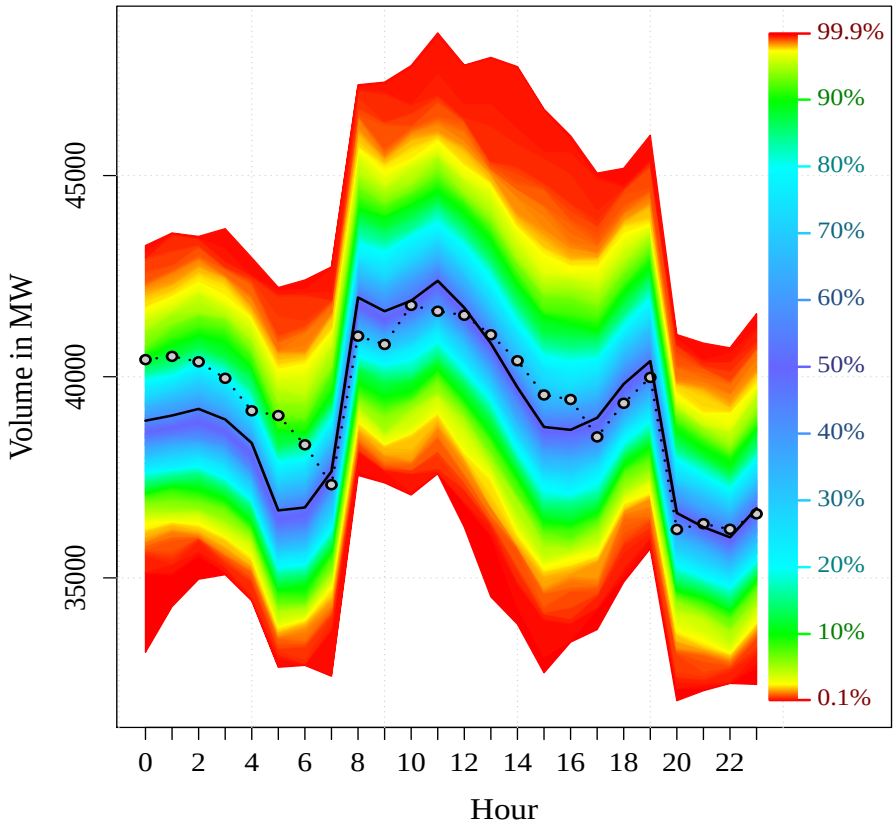
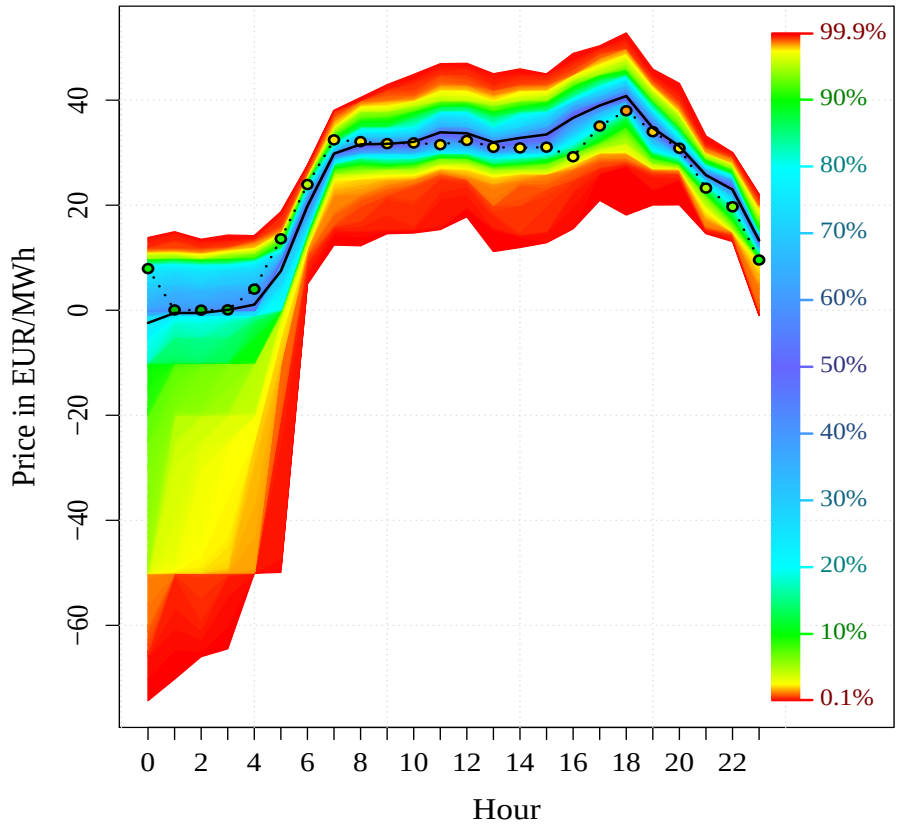
- Two years of in sample data
- Out-of-sample range from 01.11.2014 to 19.04.2015
- Prediction bands by residual based bootstrap
  with bootstrap sample size $B = 5000$
- Relatively fast:
  about 12 minutes for estimation + forecasting
  (on a standard computer)

Forecasting X-Model: 19.12.2014 - price cluster at 0.0

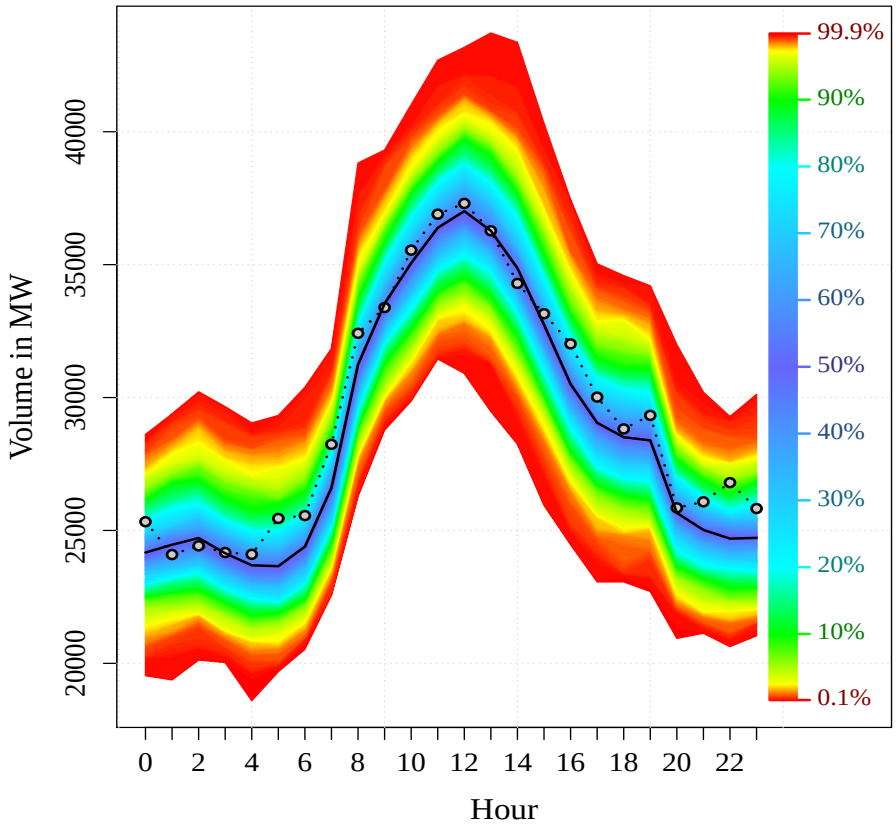


Volume

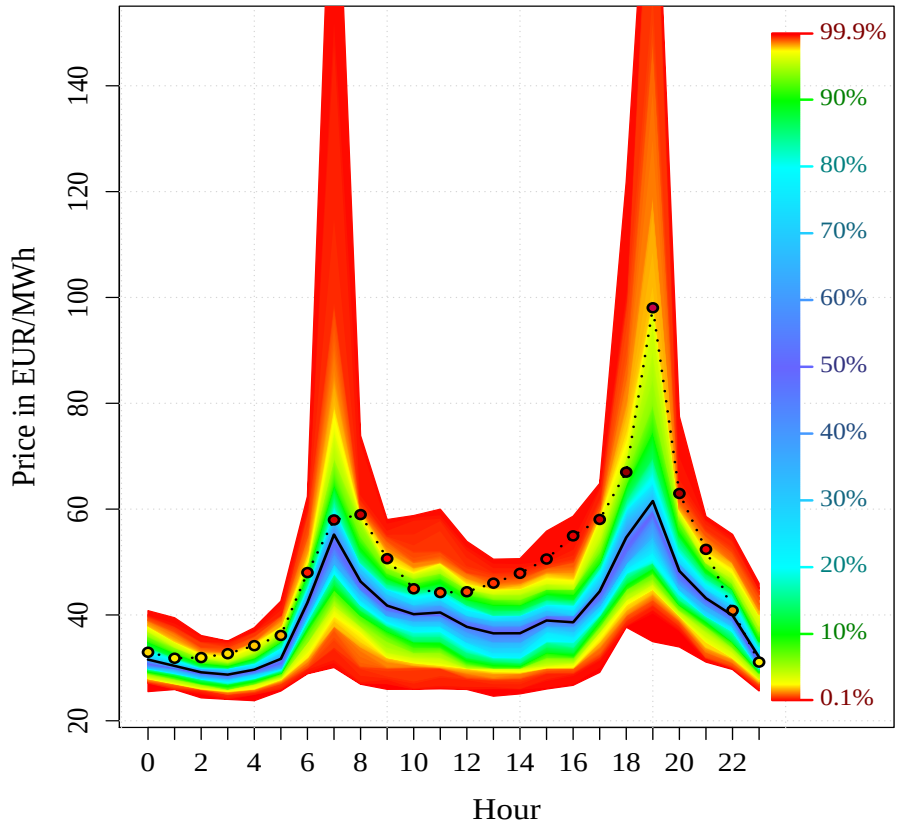


Price

Forecasting X-Model: 24.03.2014 - largest positive price spike

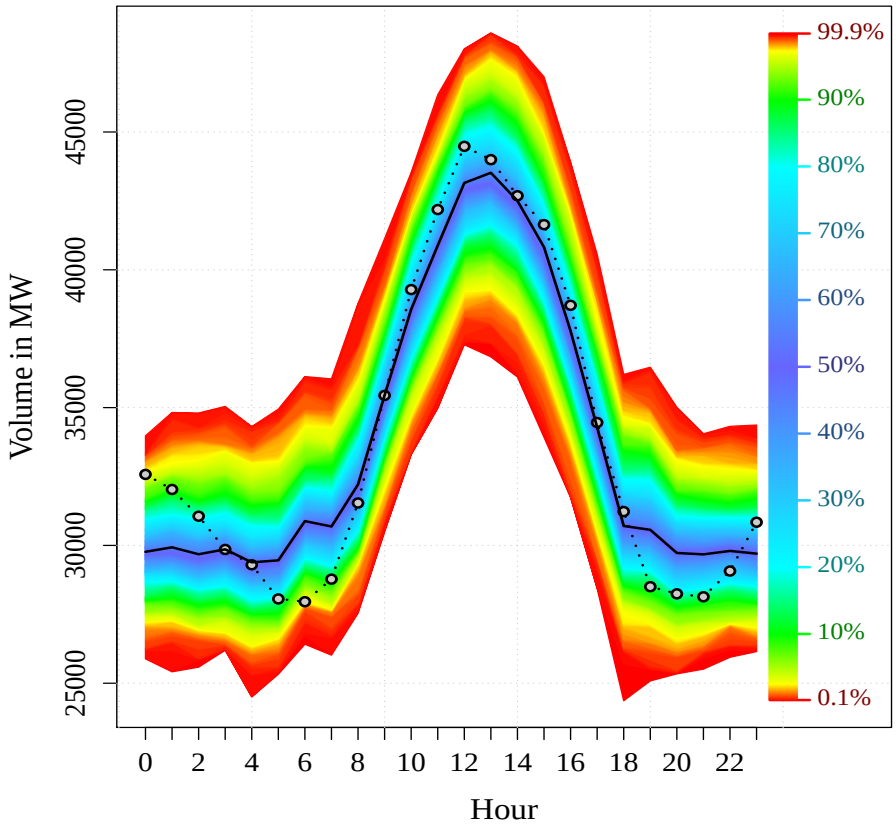


Volume

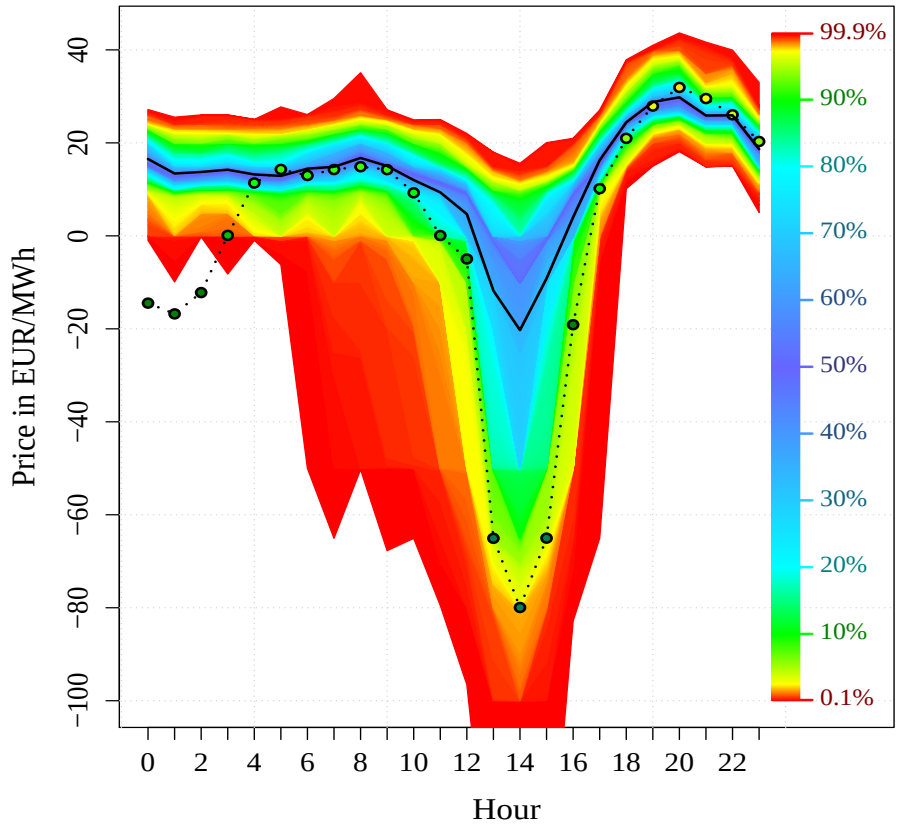


Price

Forecasting X-Model: 12.04.2015 - largest negative price spike

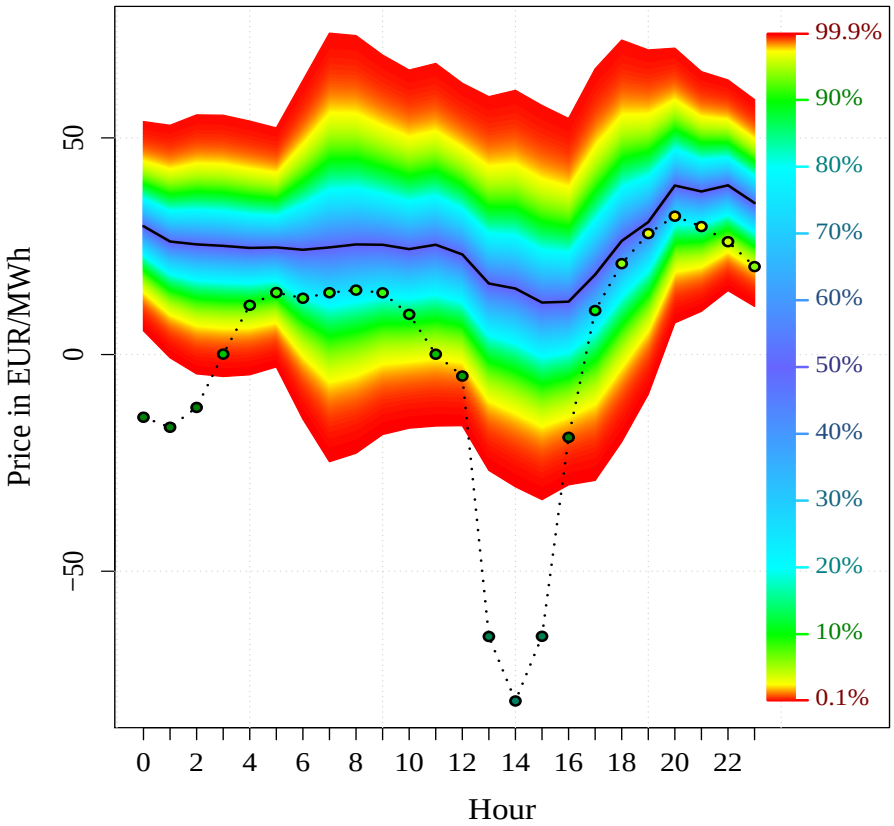


Volume

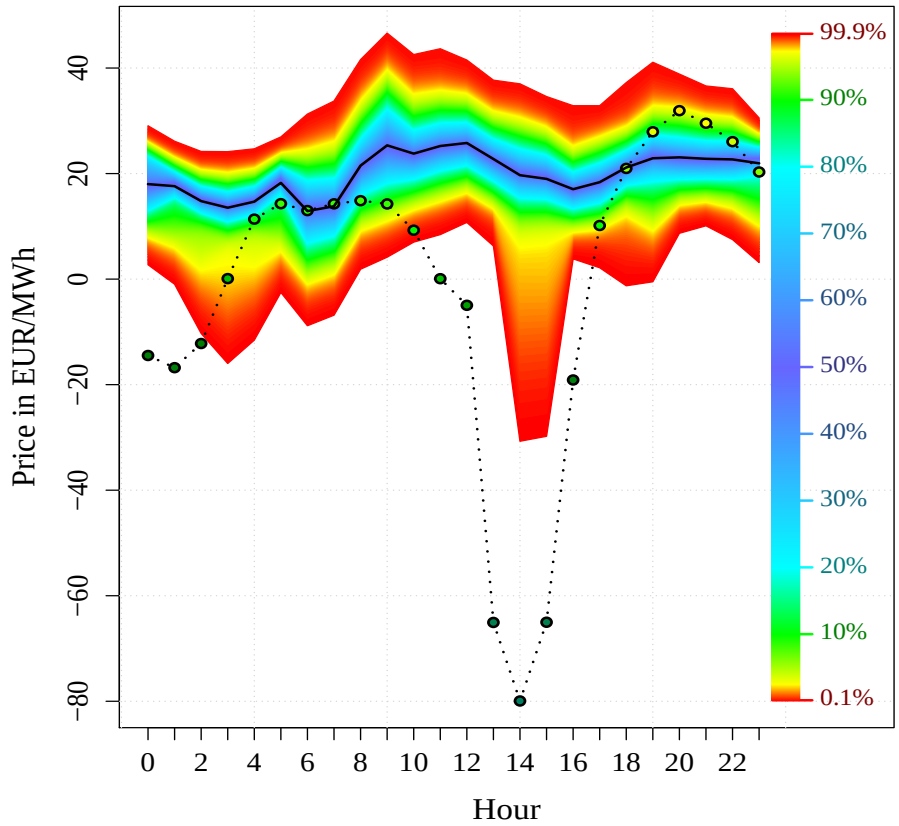


Price

Forecasting Benchmarks: 12.04.2015 - largest negative price spike



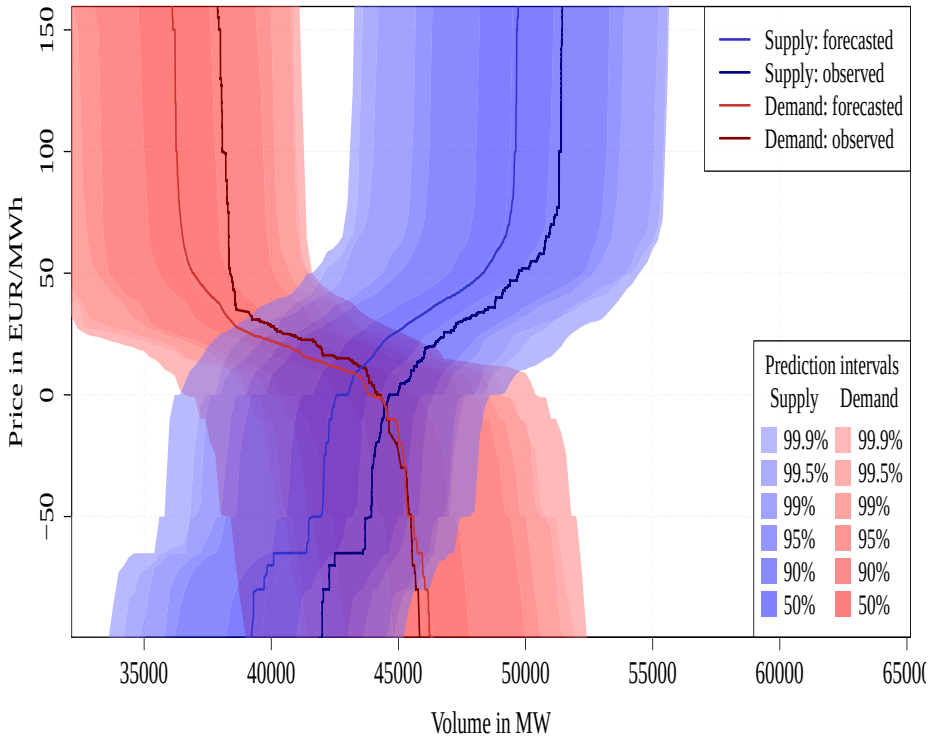
Naiv (168-pesistent)



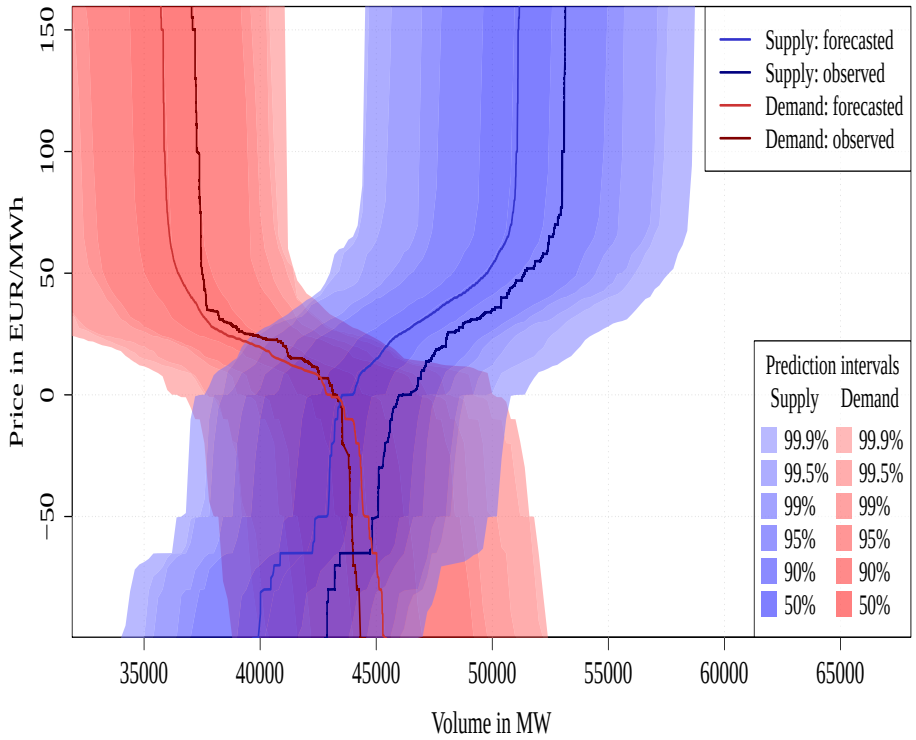
Regime Switching

[Karakatsani and Bunn (2008)]

Prediction bands for supply and demand curves:



12.04.2015 12:00-13:00



12.04.2015 13:00-14:00

Forecasting study for X-Model

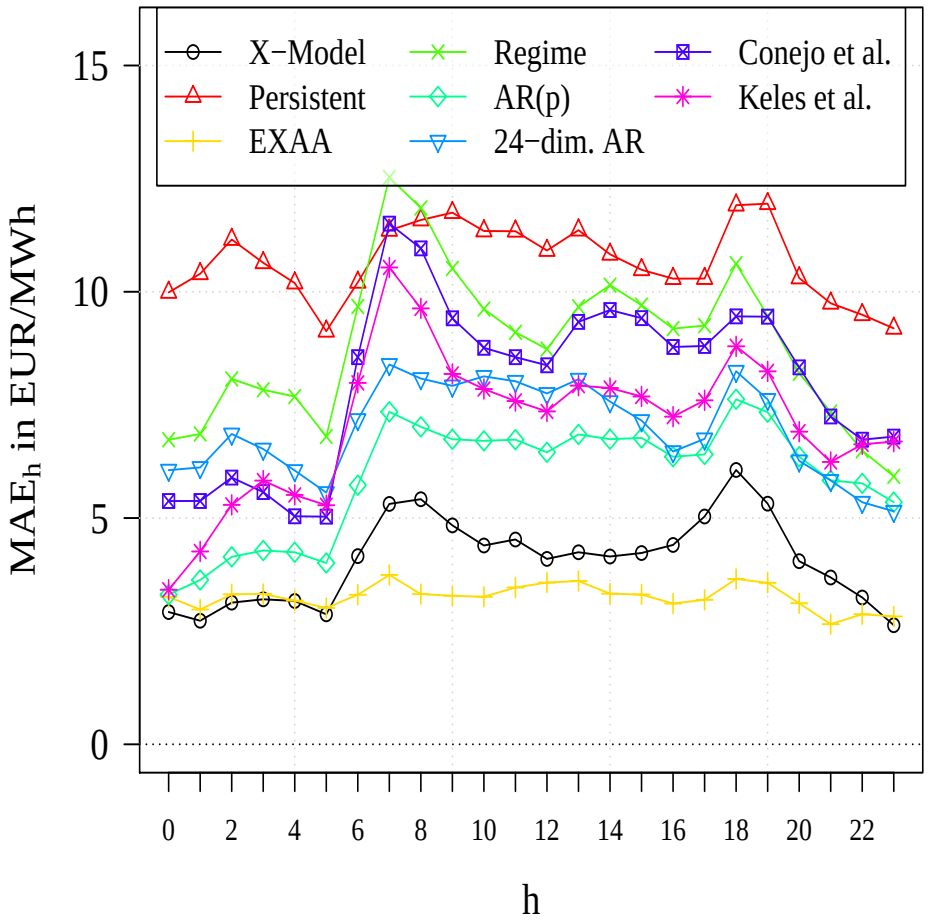
- MAE and RMSE in EUR/MWh:

Forecasting study for X-Model

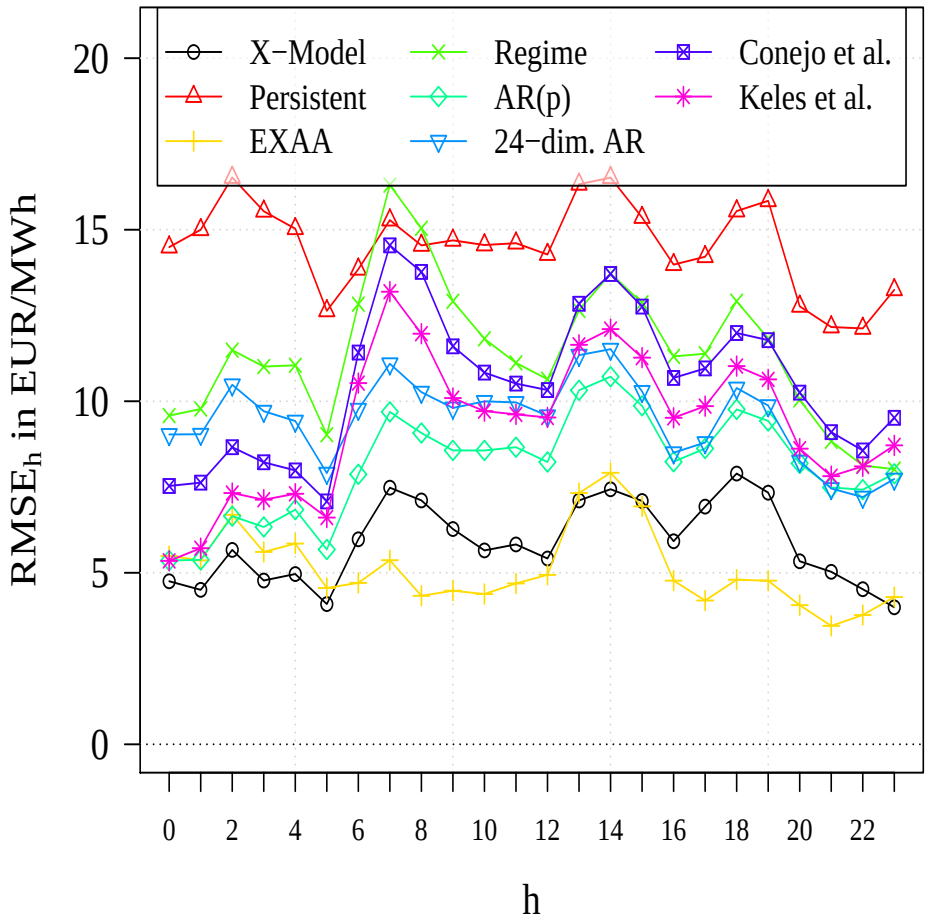
- MAE and RMSE in EUR/MWh:

Models	MAE (std.dev.)	% of Naïve	RMSE (std.dev.)	% of Naïve
Naïve	10.66 (0.159)	100	14.60 (0.240)	100
X-Model	**4.08 (0.068)**	**38.2**	**5.99 (0.185)**	**41.0**
Regime	8.83 (0.117)	82.9	11.60 (0.197)	79.5
AR(p)	6.02 (0.097)	56.5	8.43 (0.238)	57.8
24-dim. AR	6.96 (0.103)	65.3	9.55 (0.219)	65.4
Conejo et al.	8.02 (0.112)	75.3	10.72 (0.213)	73.4
Keles et al.	7.11 (0.099)	66.7	9.53 (0.219)	65.3
EXAA	*3.26 (0.065)*	*30.6*	*5.23 (0.303)*	*35.8*

Forecasting study for X-Model



hourly MAE: MAE_h



hourly RMSE: $RMSE_h$

Summary

- Sale/supply and purchase/demand curves approach applicable
- X-Model can cover all known stylized facts
  e.g. seasonalities, volatility clustering
  but also price clustering
- Great for predicting price spikes
- Remarkable forecasting performance
- A lot of space for improvements

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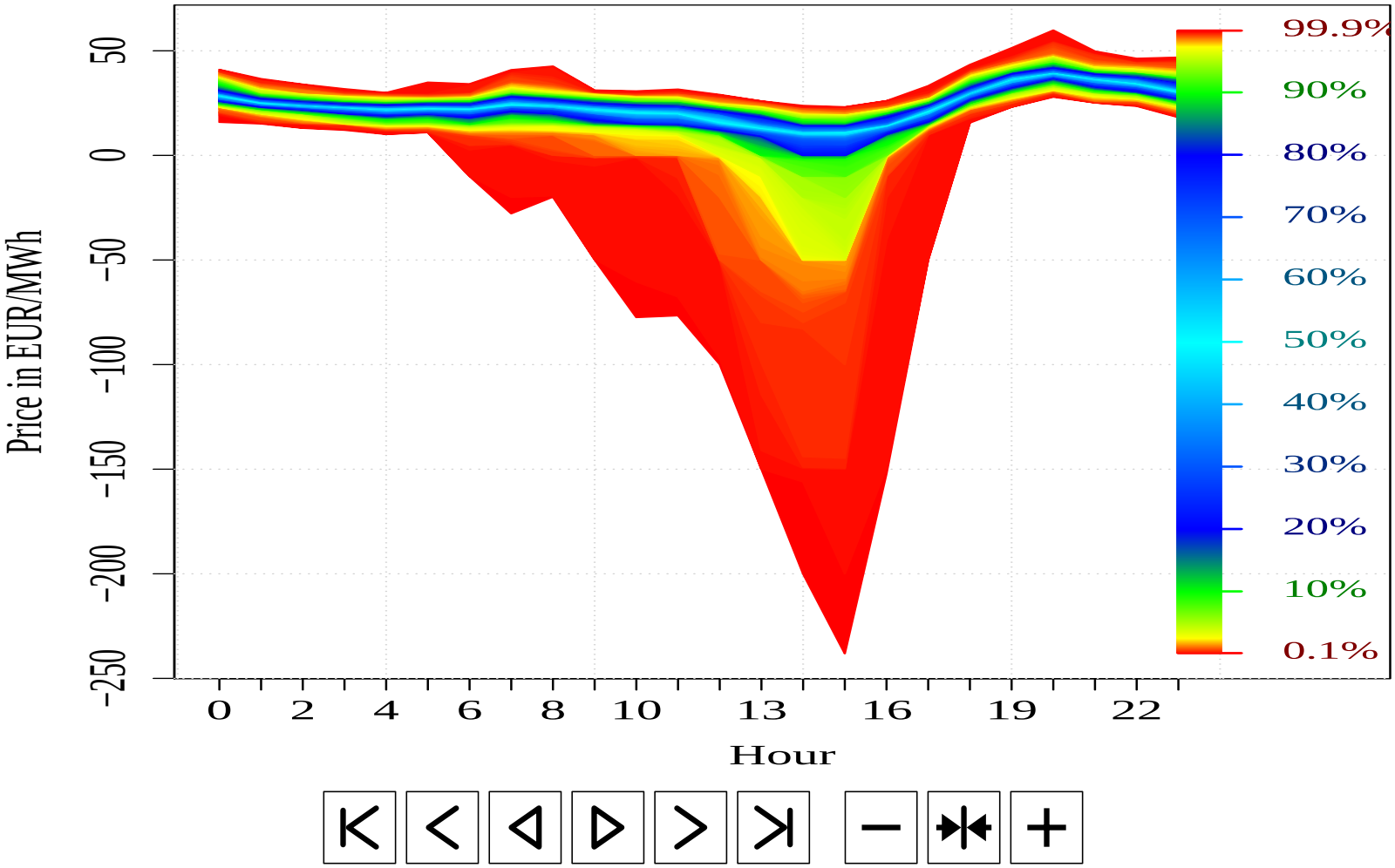
Thank you for your attention!



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