TOOL FOR STATISTICAL ANALYSIS OF ENERGY MARKET DATA WITH THE AIM OF STOCHASTIC MODELLING OF THE DEMAND RESPONSE AGGREGATOR

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Content

Introduction

- Deregulation
- Liberalization
- Ongoing process

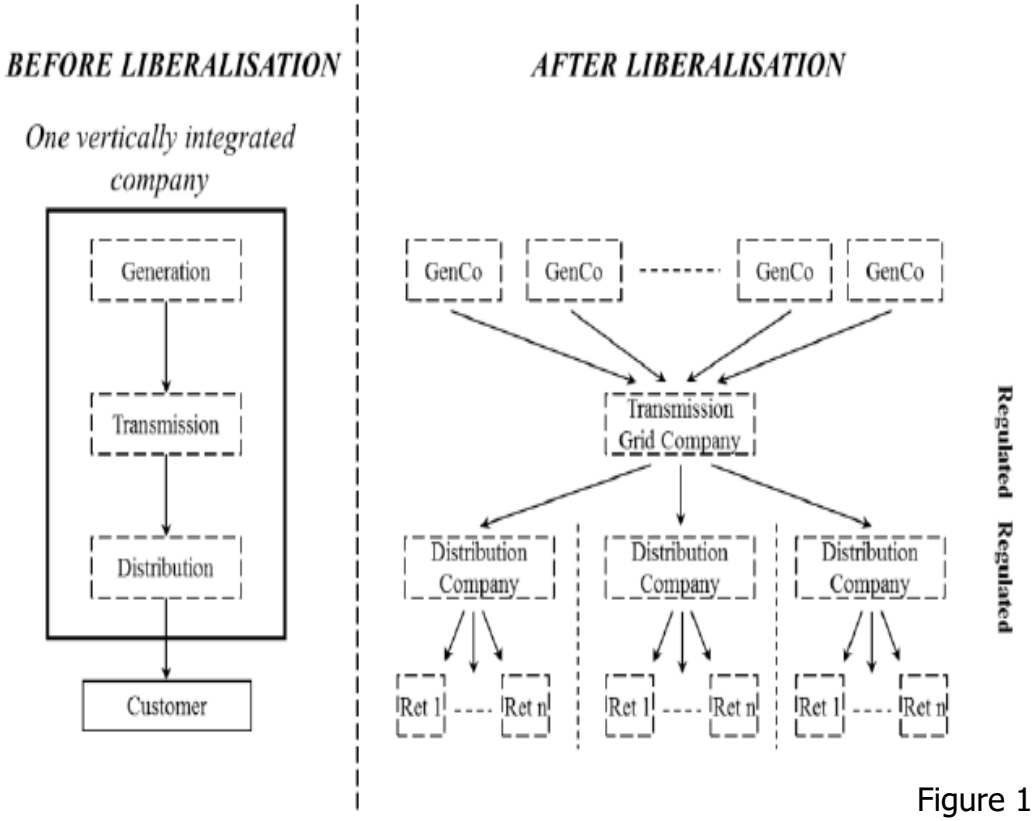

Figure 1

Denmark

- The Danish market consists of two areas
  - Mutually connected with 600 MW DC
- Energinet (TSO)

Table 1

2017 [GWh]	Demand	Supply
Load	34.021	0
Wind	0	14.779
PV	0	789
Central CHP	0	9.156
Local CHP	0	4.373
Export	2.322	0
Import	0	6.886

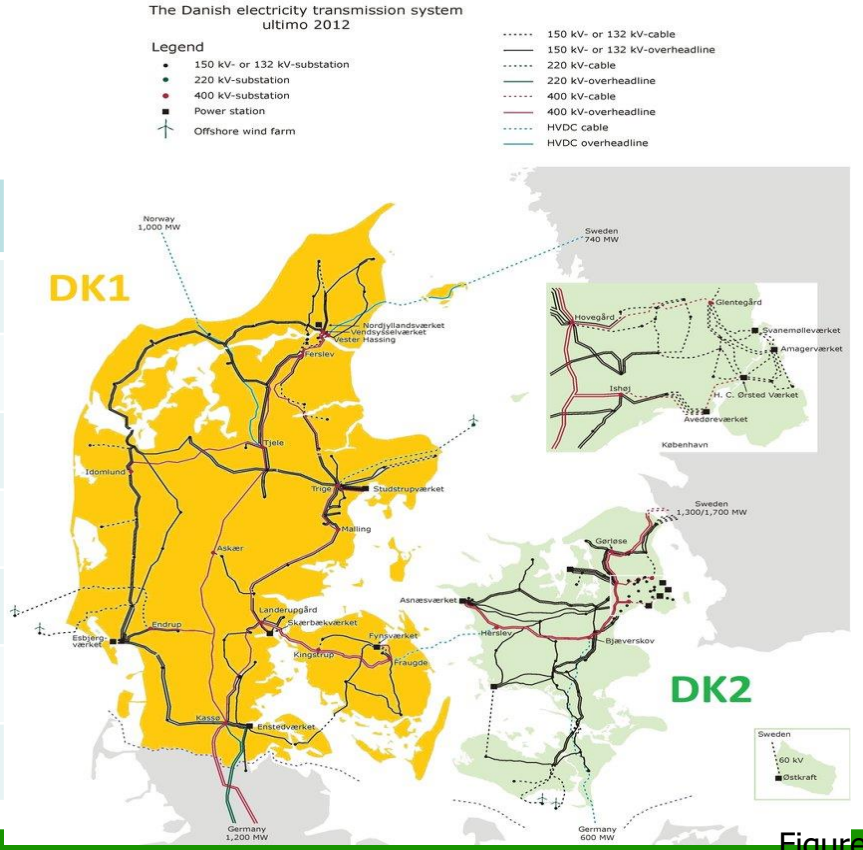

Figure 2

Nord Pool

- Nordic and Baltic region
- Elspot
  - 12 to 36 hours in advance
  - Trading closes at 12:00 CET for the next day physical delivery
- Elbas
  - Trading until one hour before the delivery
  - *First-come, first served*
  - DK1 joined in 2008.

Balancing market

- „Real-time market”
- Balance Responsible Parties (BRPs)
- Down & Up regulation

- Subcategories:
  - Regulating power market (within the delivery hour)
  - Balancing market (after the delivery hour)

Ancillary services

- Primary reserve (FCR)
  - Activation half of the required output power up to 15s after the signal
  - Up i Down regulation (+/- 20 MW)
  - Capacity auctions day before the delivery for 4-hours blocks
- Secondary reserve (aFRR)
  - Activation not longer than 15 min after the signal
  - Pay-as-bid
- Tertiary reserve (mFRR)
  - Auction for the next day

Data collection

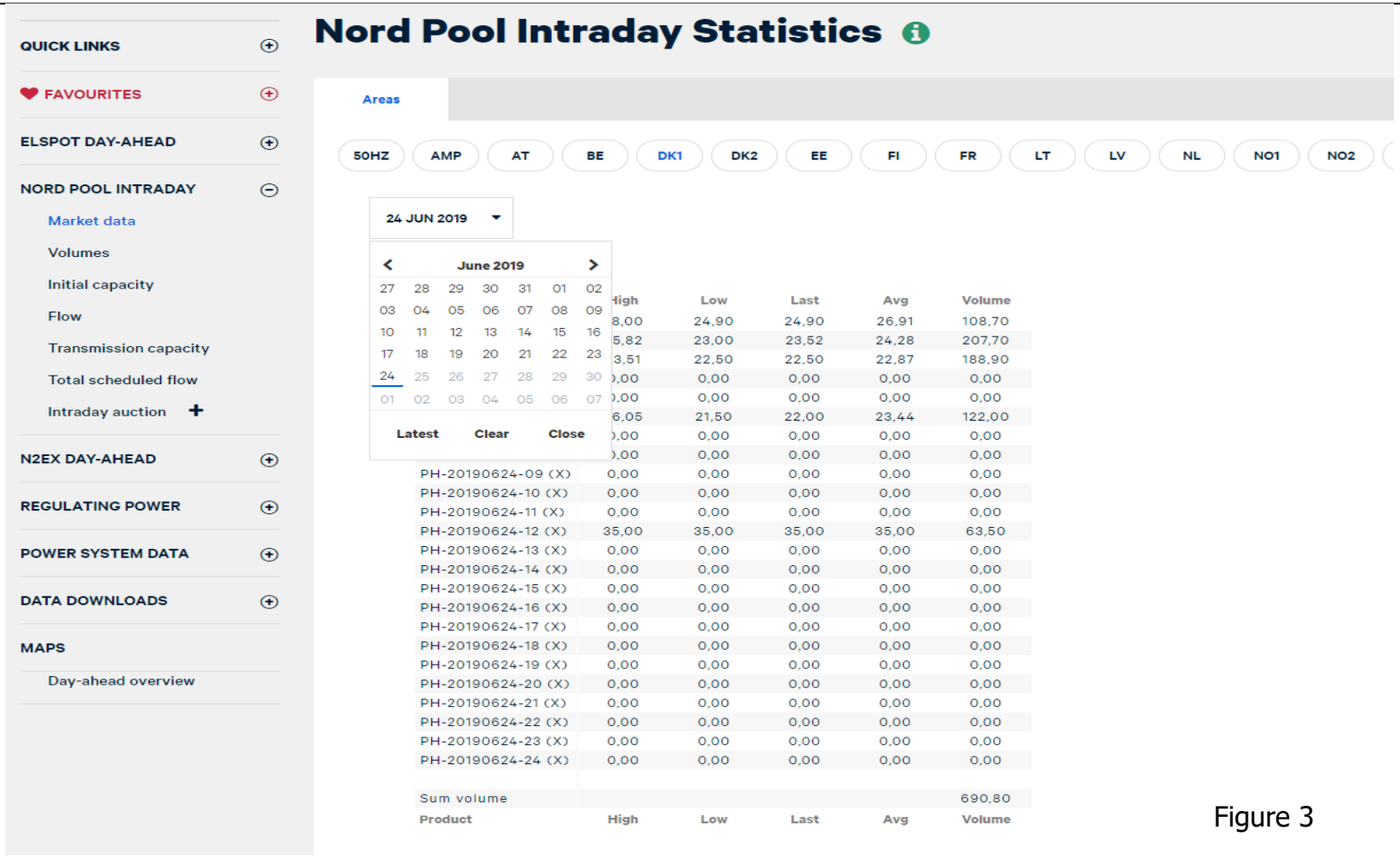

Figure 3

Data preprocessing

- Inconsistency
- Incompleteness
- Filtering data by:
  - Season of the year
  - Day category
- Outliers

2018-03-25 01:00	DK1	0.0	-82.541	PH-20180325-01	38.0
2018-03-25 03:00	DK1	0.0	-370.386	PH-20180325-02	43.0
				PH-20180325-03	43.8

Figure 4

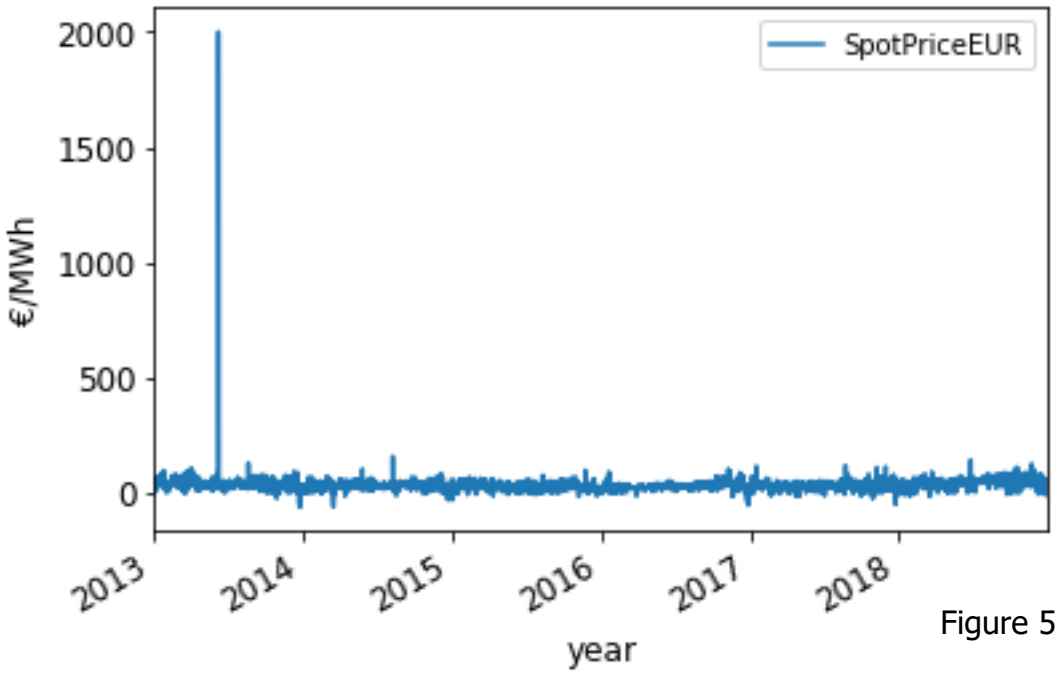

Figure 5

Table 2

Date and time	Spot price [€]	Season
2013-06-07 07:00:00	1901.32	Spring
2013-06-07 08:00:00	1901.40	Spring
2013-06-07 09:00:00	2000.00	Spring
2013-06-07 10:00:00	2000.00	Spring
2013-06-07 11:00:00	1901.36	Spring

Distribution?

Table 3

Day	Season	Mean	Mode	Median
Saturday	Fall	30.7415	28.00	29.590
	Winter	27.458429	31.00	28.230
	Spring	27.145237	24.00	25.005
	Summer	33.197245	29.00	30.690
Sunday	Fall	29.992727	29.00	29.69
	Winter	22.400837	29.00	24.90
	Spring	31.820660	24.00	24.02
	Summer	31.125641	30.00	28.07
Working day	Fall	42.305921	31.00	37.980
	Winter	34.217380	31.00	31.755
	Spring	31.820660	25.00	29.850
	Summer	40.577369	32.00	38.835
Working night	Fall	32.910165	30.00	30.840
	Winter	26.869131	30.00	28.070
	Spring	27.606823	24.00	25.520
	Summer	33.519283	30.00	31.145

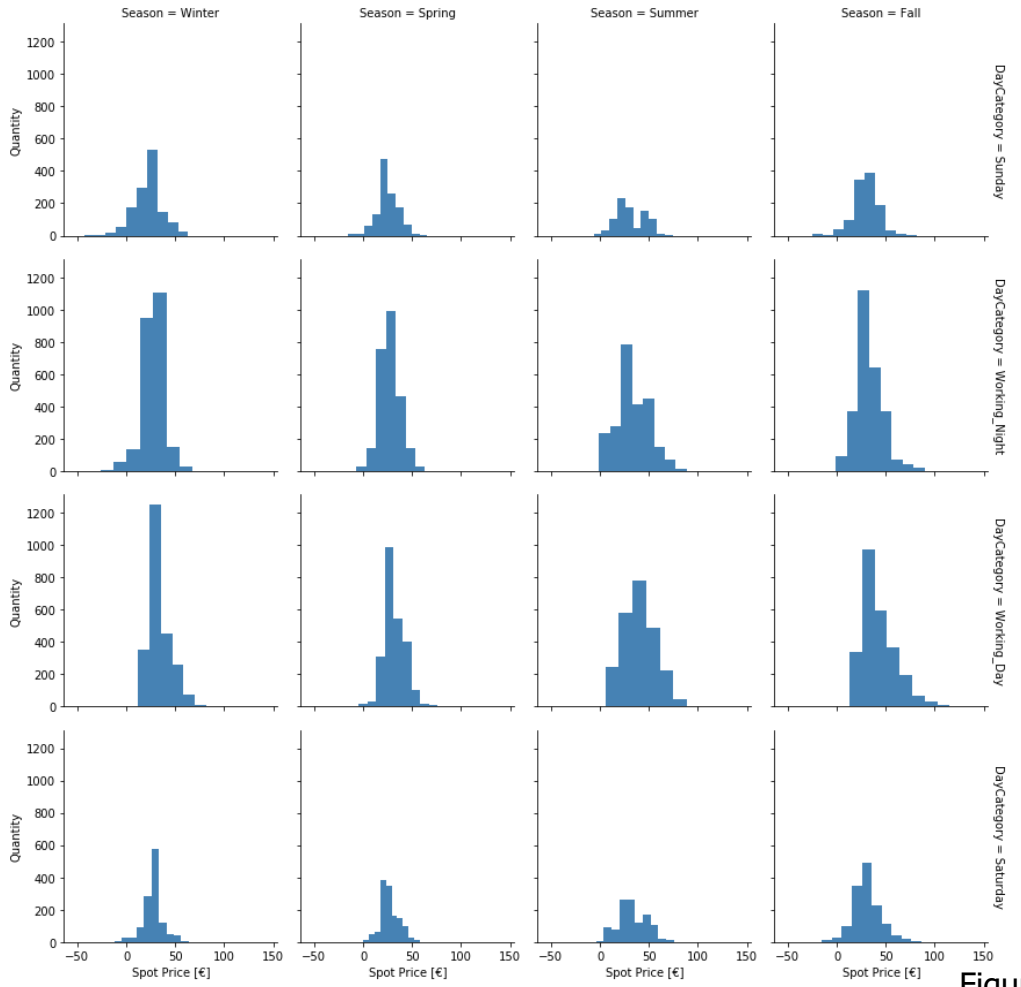

Figure 6

Gaussian (normal) distribution

- Quantile-quantile graph

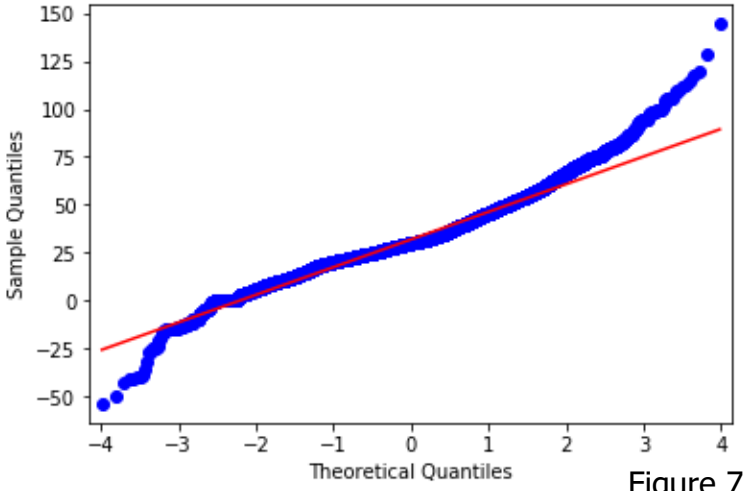

Figure 7

- Standard deviation

Table 4

Season\Day	Saturday	Sunday	Working Day	Working night
Fall	13.654943	13.165629	16.732335	13.879095
Winter	9.770308	14.548433	11.475817	10.901245
Spring	9.591344	10.963596	10.328153	10.169072
Summer	14.605685	14.823140	16.934345	16.973459

Correlations

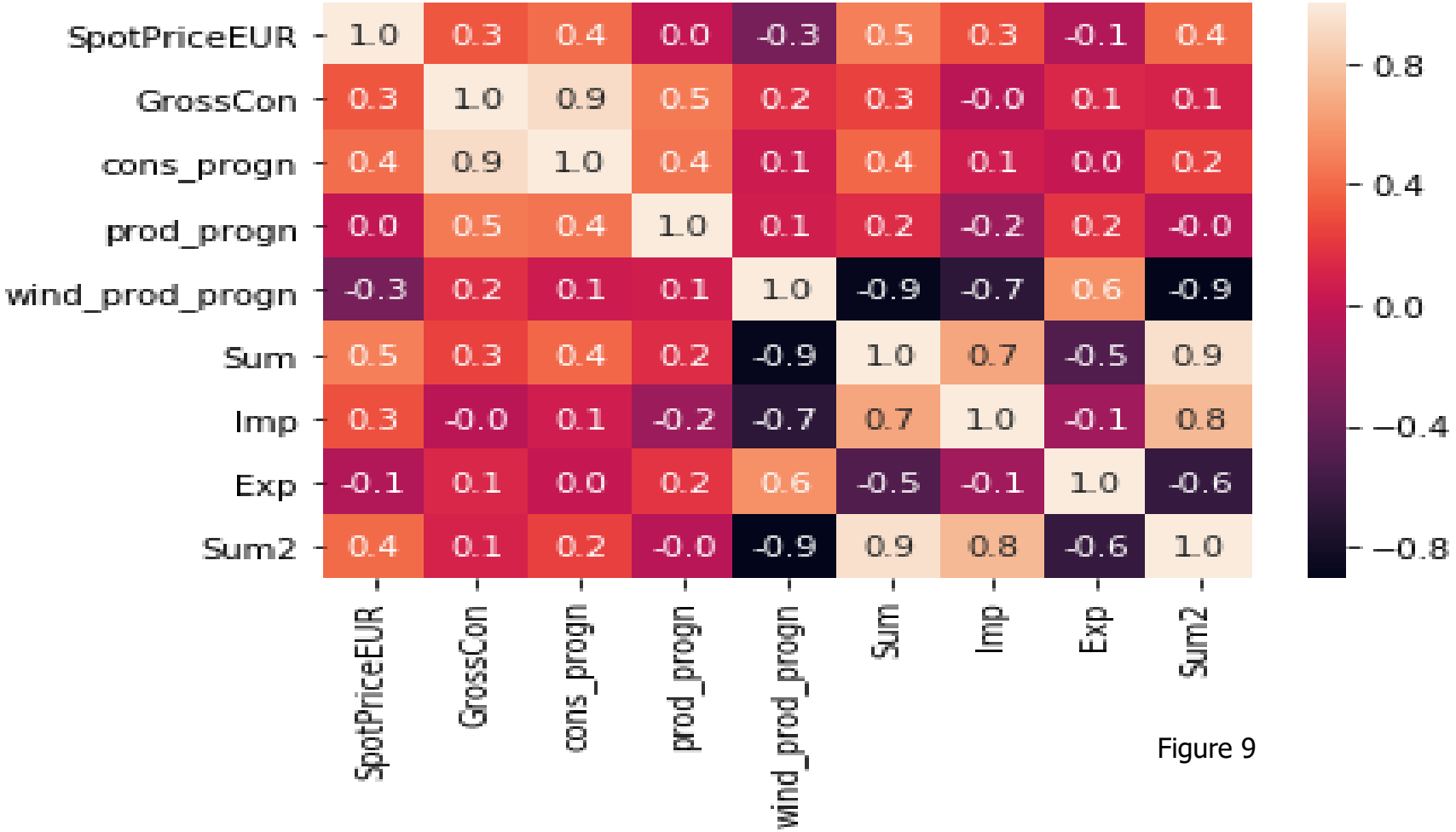

Figure 9

Spread

- Between day-ahead and intraday prices

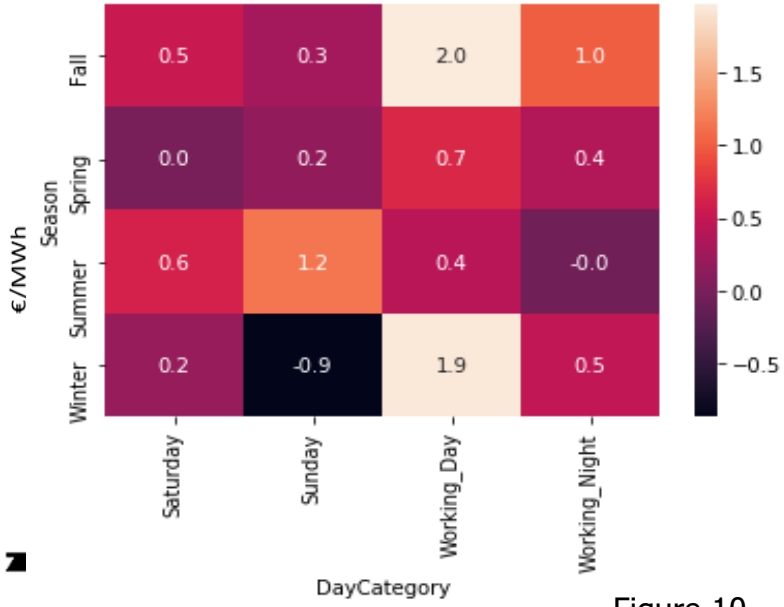

Figure 10

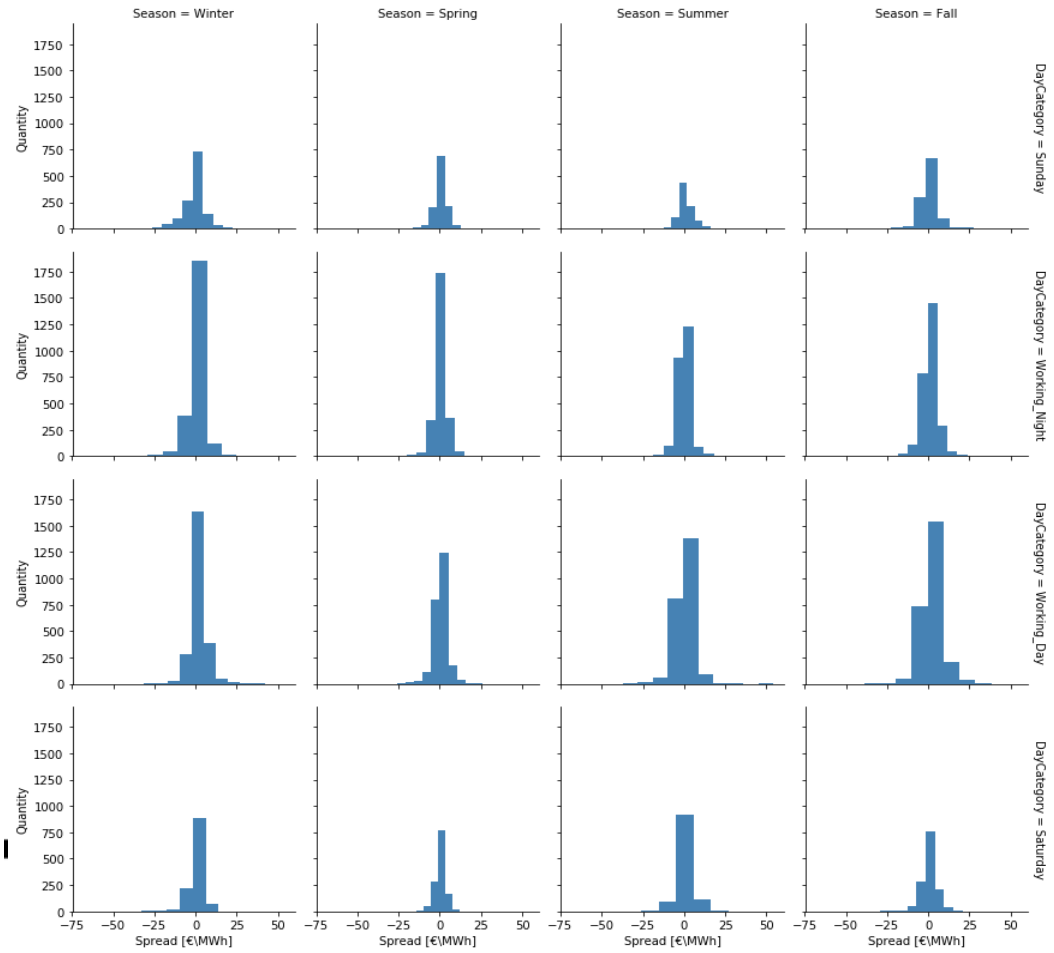

Figure 11

Spread cont.

- Standard deviation: 5.2 €/MWh
- More than 6000 occurrences of spread higher than +/- 5.2€/MWh in the observed period (8k theoretically)
- Chosen as significant spread: 10 €/MWh

Significant spread occurrence

POSITIVE SPREAD

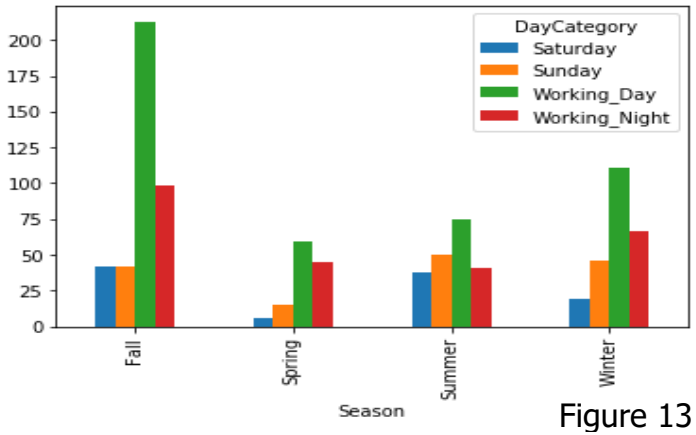

Figure 13

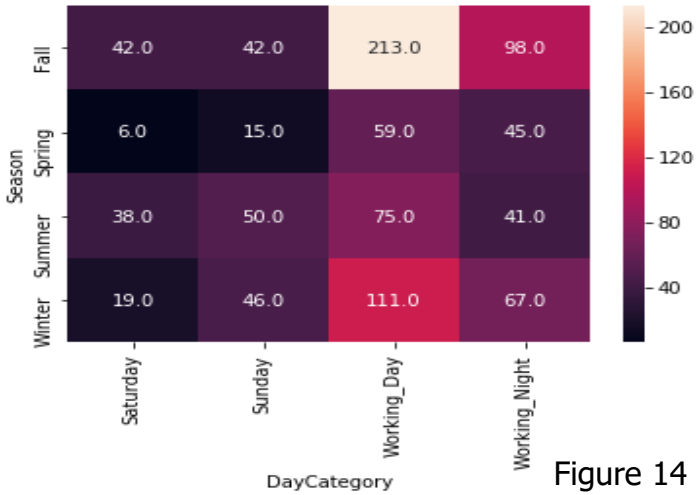

Figure 14

NEGATIVE SPREAD

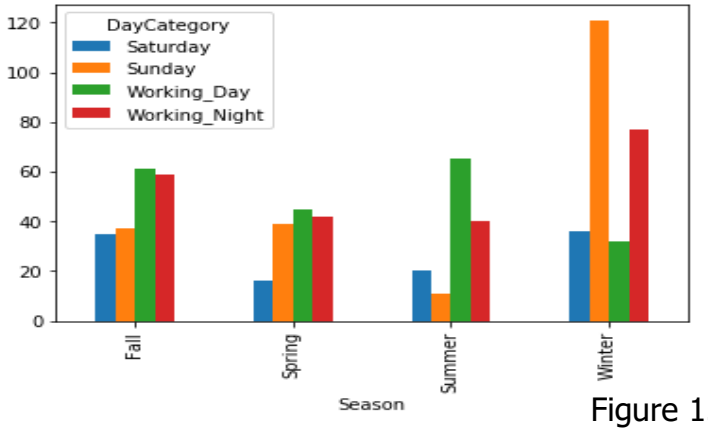

Figure 15

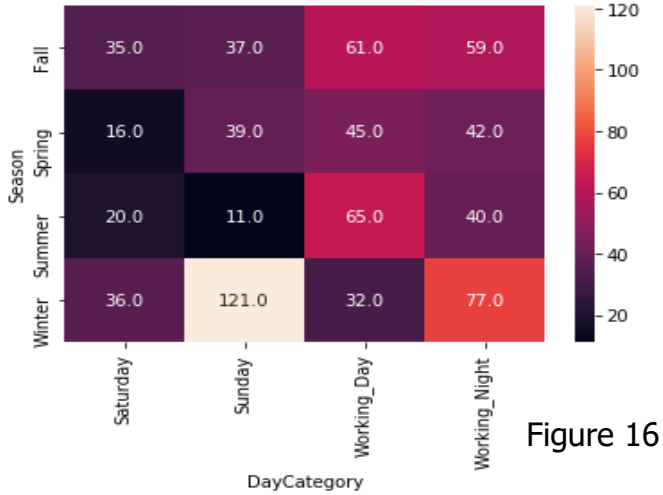

Figure 16

Machine learning

- Subset of AI
- Algorithms and statistical models
- Supervised
  - Trening set formed from known input and output data
  - Regression
  - Classification
- Unsupervised
  - Trening set without known output
  - Somehow tries to cluster the data

Data used for the regression model

- Spot prices (Elspot)
- Average intraday prices (Elbas)
- Balancing prices – up regulation
- Balancing prices – down regulation
- For the purpose of this presentation, it is assumed that prices for various submarkets are known at the same time

High correlation index

Estimators

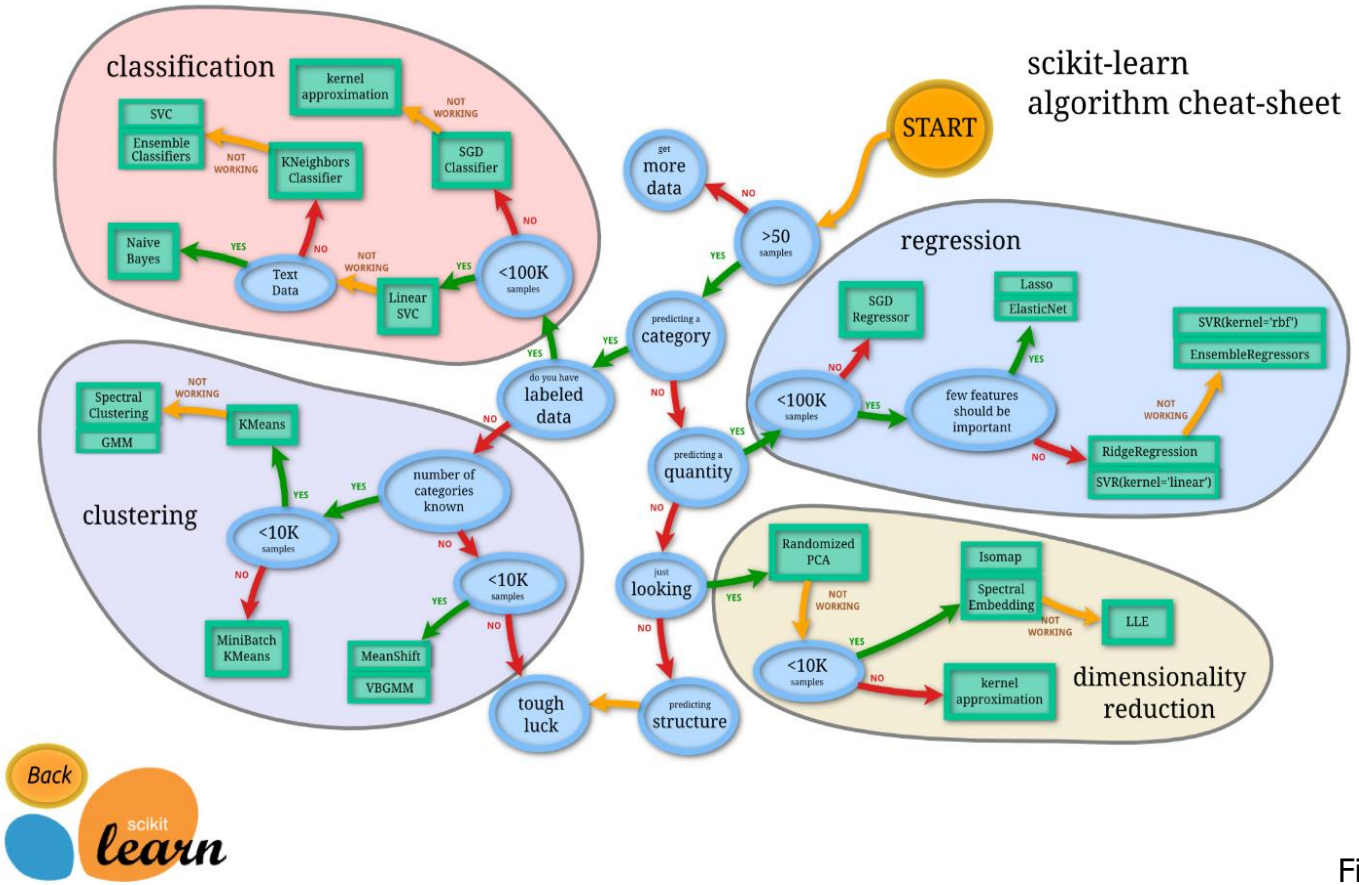

Figure 17

Used algorithms

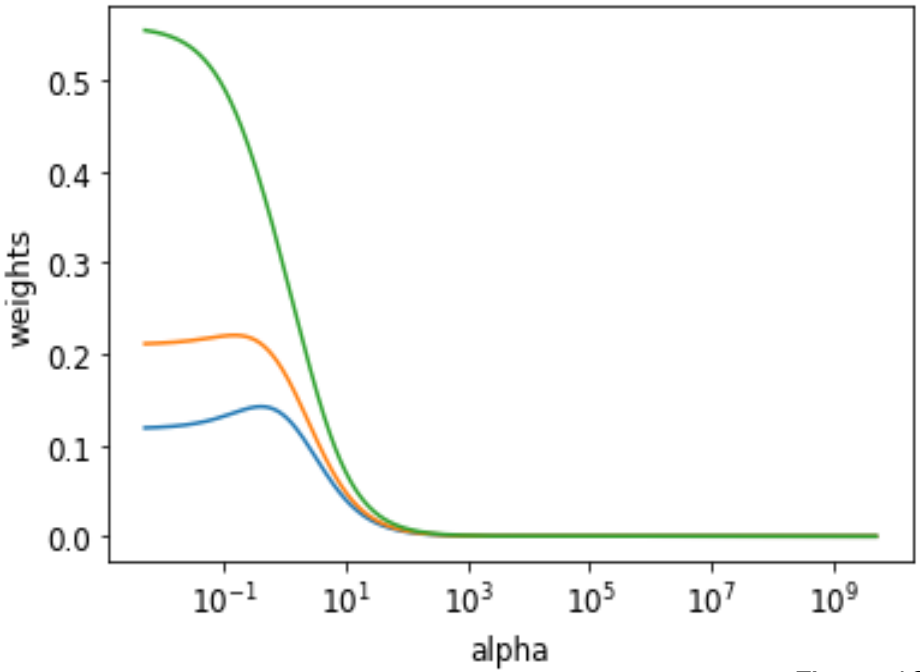

Figure 18

Ridge regression

- Doesn't force coefficients to be equal to zero
- $\min_w \|Xw - y\|_2^2 + \alpha\|w\|_2^2$

$\alpha\|w\|_1$

α parameters i cross-validation

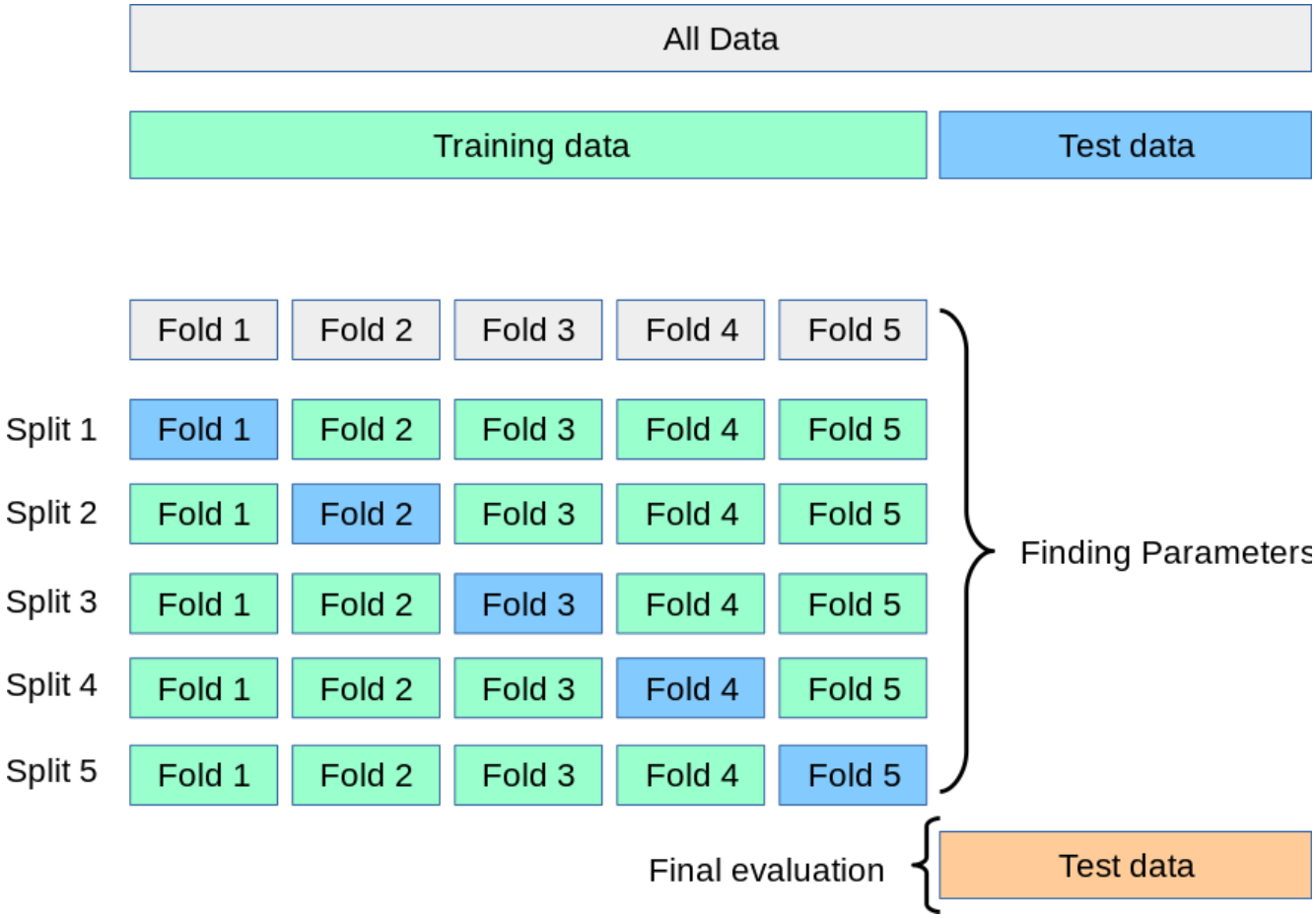

Figure 19

Spot price prediction

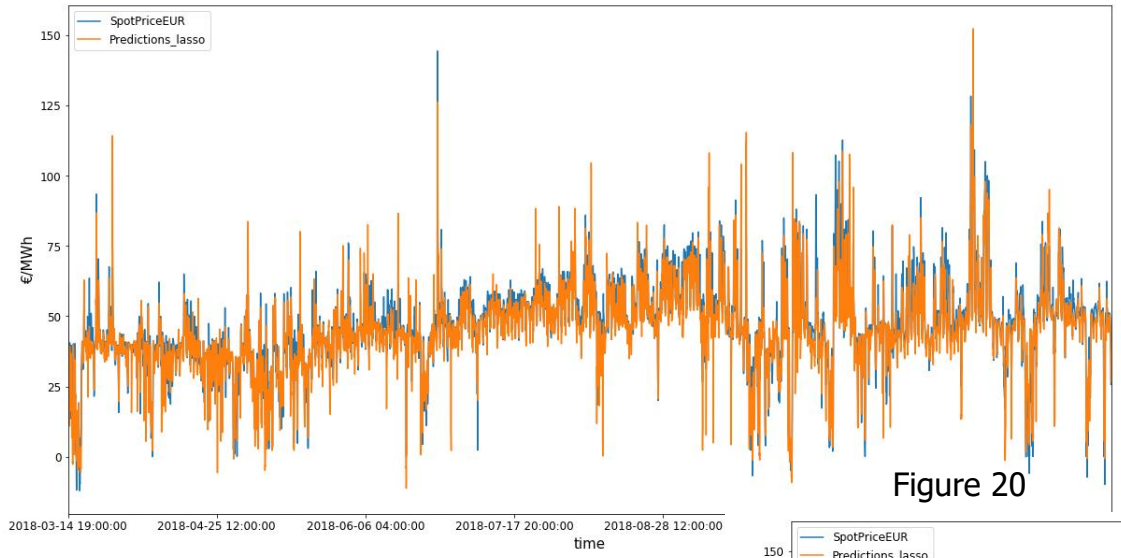

Figure 20

Results (built-in metrics)
Lasso: 0.82795
Ridge: 0.82820

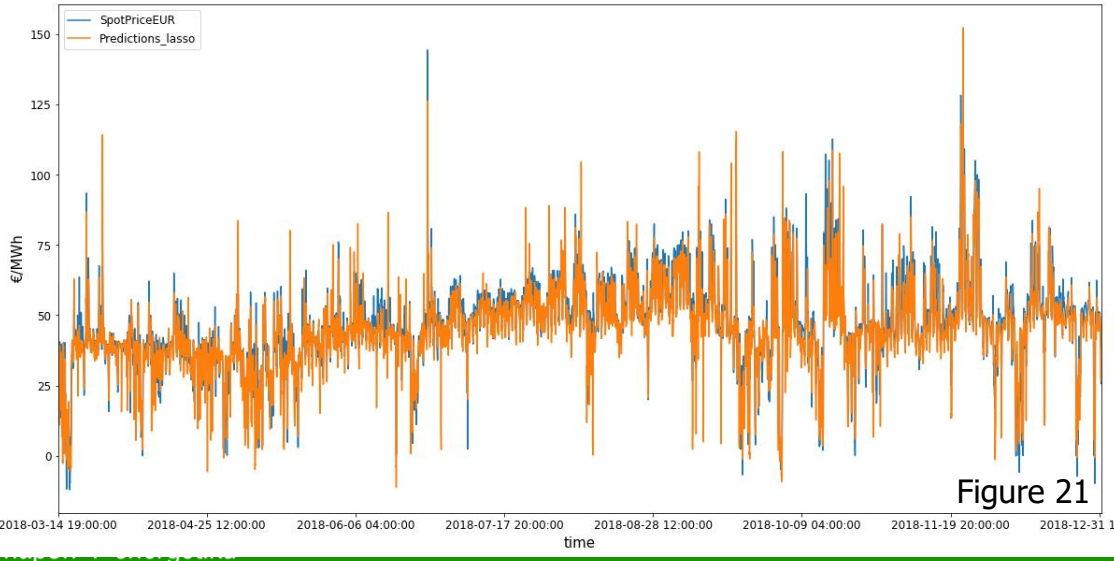

Figure 21

Significant spread classification

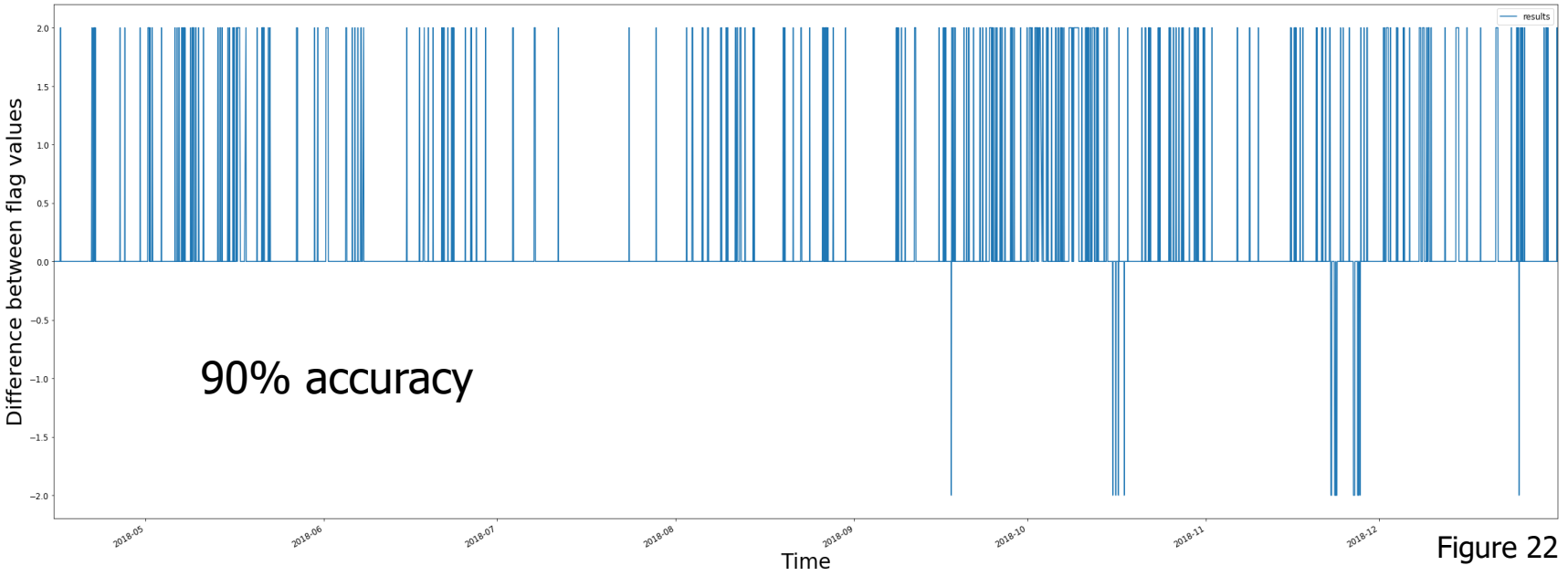

Figure 22

- Predicted and real outputs comparison:
  - „2" i „-2" => missmatch
  - „0" => match

Conclusion

- Importance of thorough data collection and preprocessing
- Correlation
- Big potential for future optimization models
- Further research needed

Acknowledgments

- Project has been supported by the China-Croatian Science and Technology Exchange Program Basic Research on Urban Flexible Multi-Energy System under project FUTURE – Flexible Urban Systems in Multi-Energy Environment and by project IRES-8 – Instigation of Research and Innovation Partnership on Renewable Energy, Energy Efficiency and Sustainable Energy Solutions for Cities