User-Centric Sensor Data Mining for Smart Energy Systems

Eindhoven

Majid Khoshrou Eric J. Pauwels

Centrum Wiskunde & Informatica (CWI)

28 June 2018

Approach for Data Mining

Observation

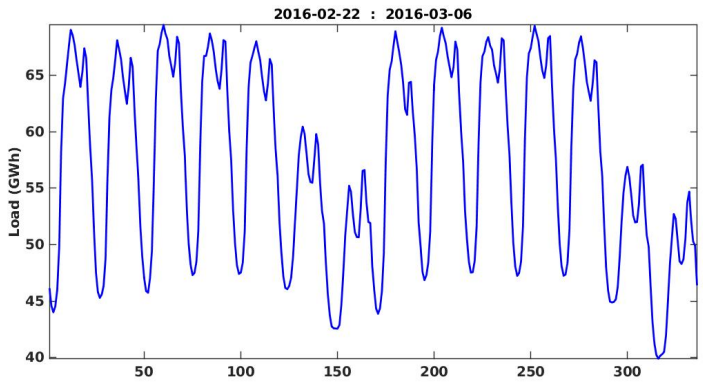
Time series related to use of infrastructures often show significant diurnal patterns!

Methodology

Recast time series as matrix:

- Visualisation as image;
- Powerful matrix decomposition theorems

Example:



An example of timeseries

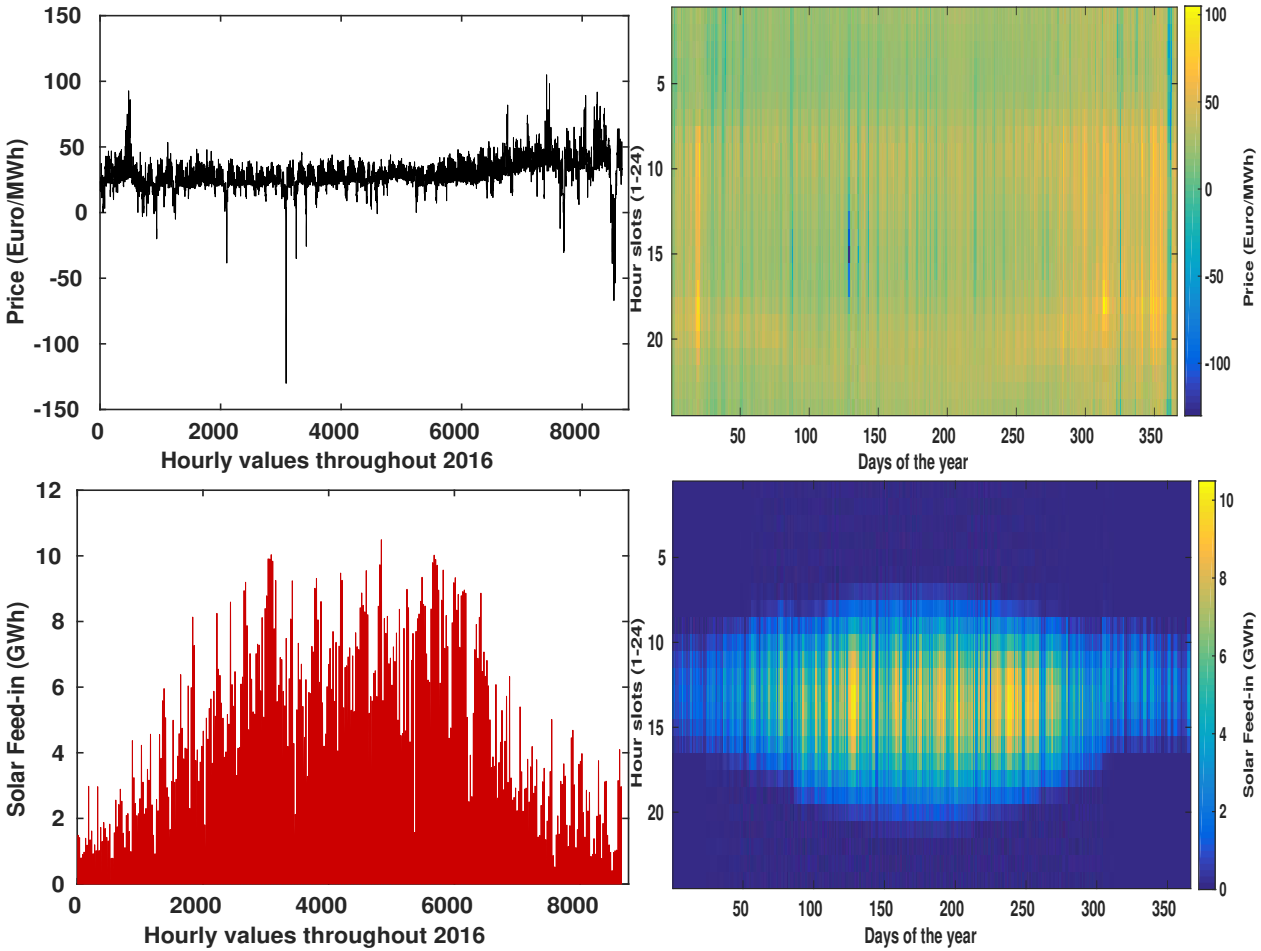
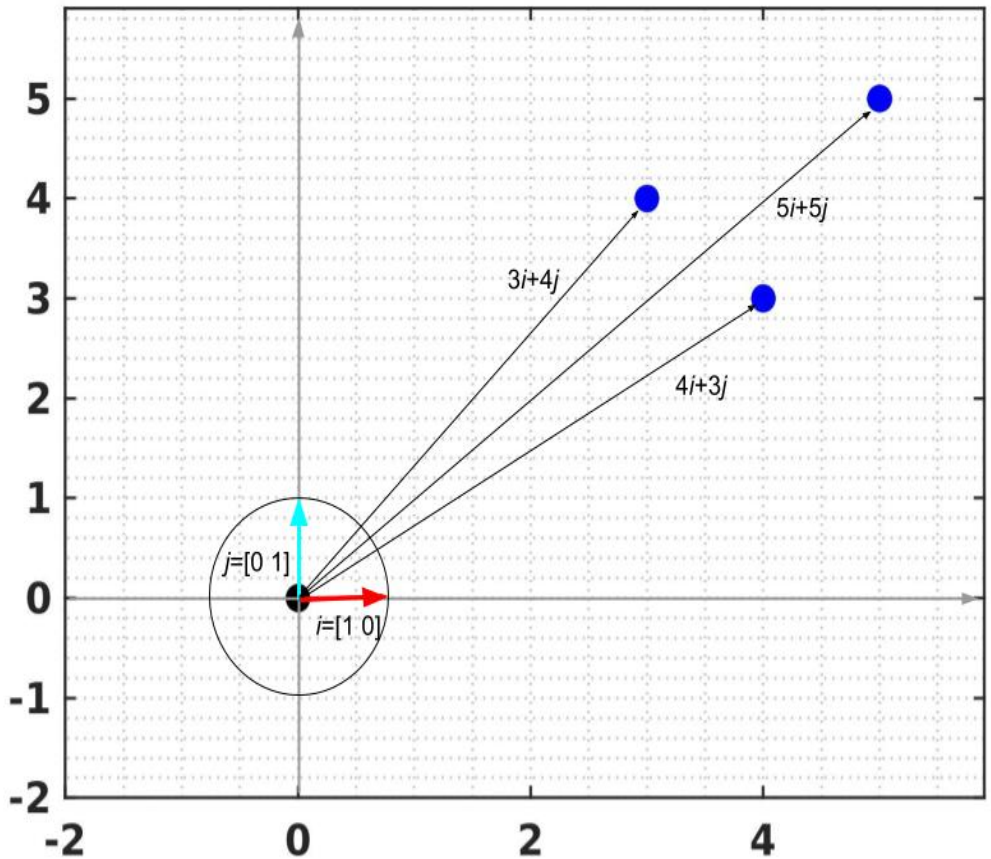


Figure: An overview of the German day-ahead market in 2016; each data point represents one hour slot.

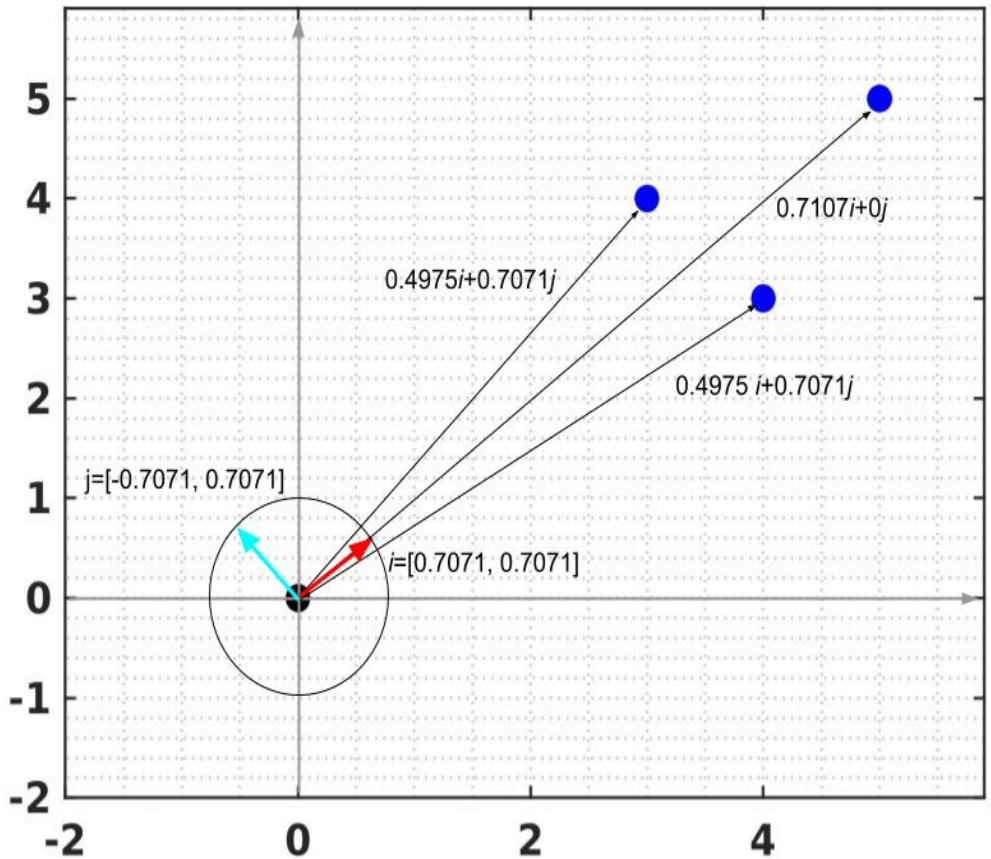
Methodology: Matrix Decomposition

SVD: $$A_{h\times d} = U_{h\times h} S_{h\times d} V^T_{d\times d} = \sum_k \sigma_k U_k V_k^T$$



Methodology: Matrix Decomposition

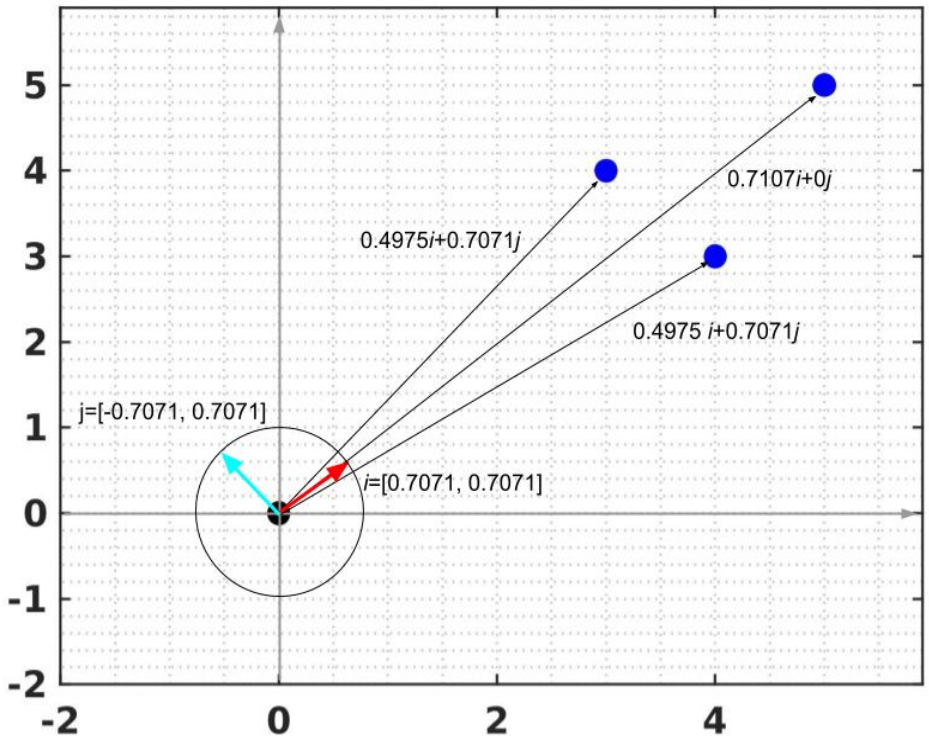
SVD: $$A_{h\times d} = U_{h\times h} S_{h\times d} V^T_{d\times d} = \sum_k \sigma_k U_k V_k^T$$



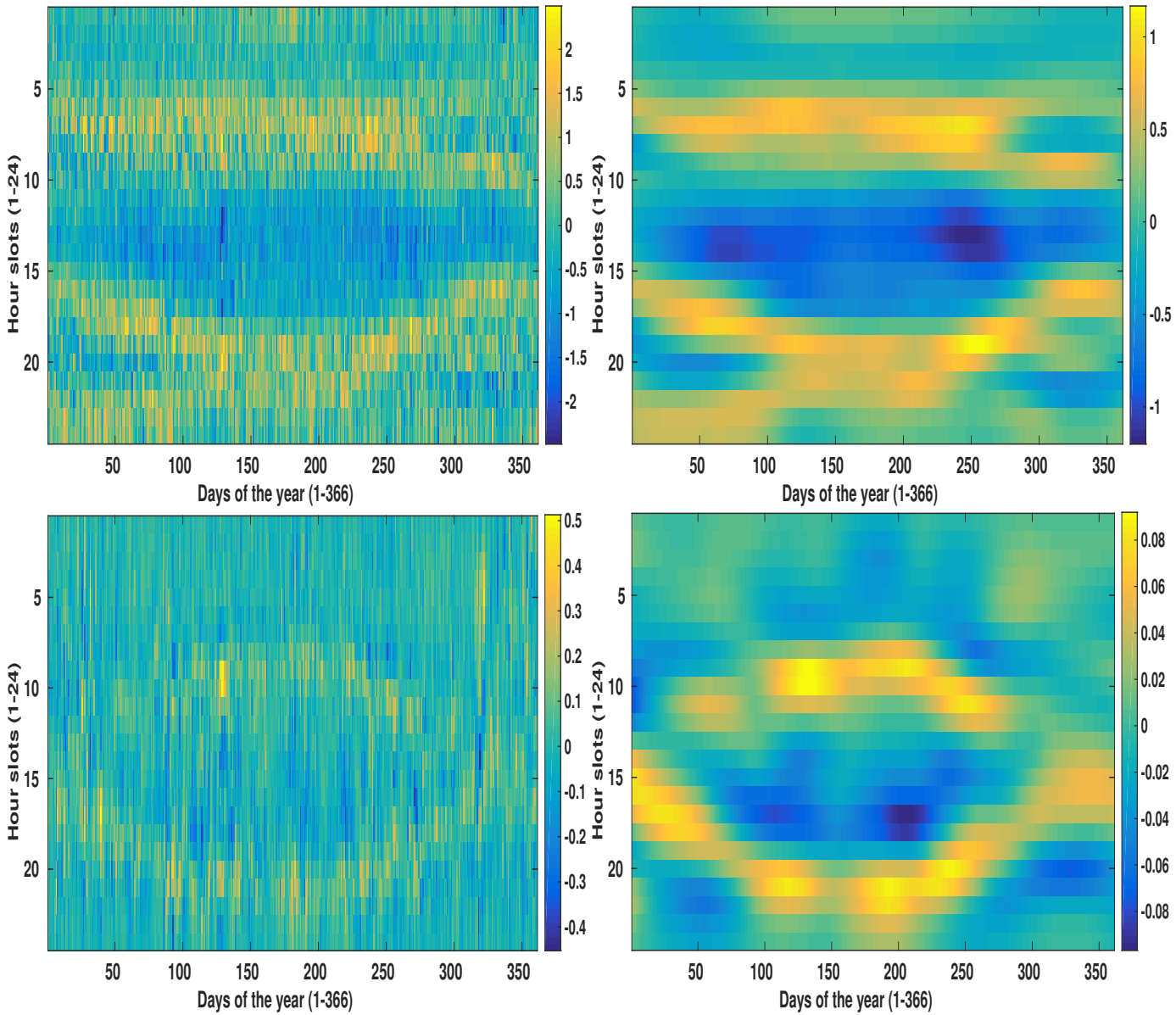
Methodology: Matrix Decomposition

$$A = \begin{bmatrix} 3 & 4 & 5 \\ 4 & 3 & 5 \end{bmatrix}$$

$$= 9.95 \begin{bmatrix} 0.71 \\ 0.71 \end{bmatrix} \begin{bmatrix} 0.50 & 0.50 & 0.71 \end{bmatrix} + 1 \begin{bmatrix} -0.71 \\ 0.71 \end{bmatrix} \begin{bmatrix} 0.71 & 0.71 & 0 \end{bmatrix}$$

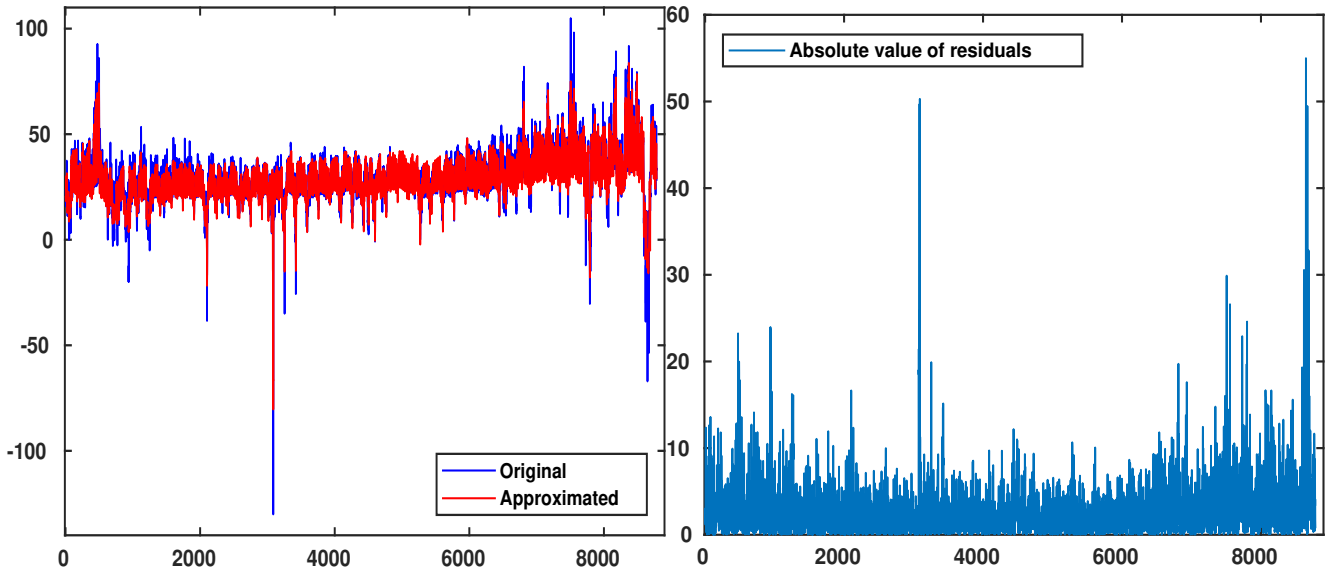


Enhancing the underlying trends

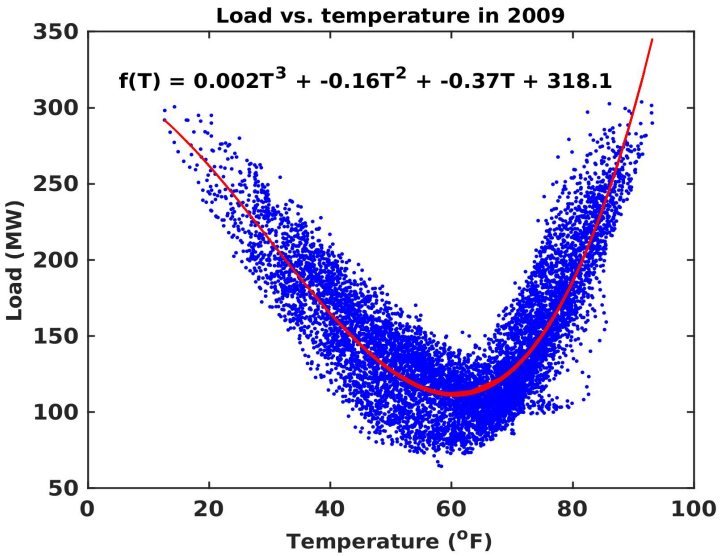


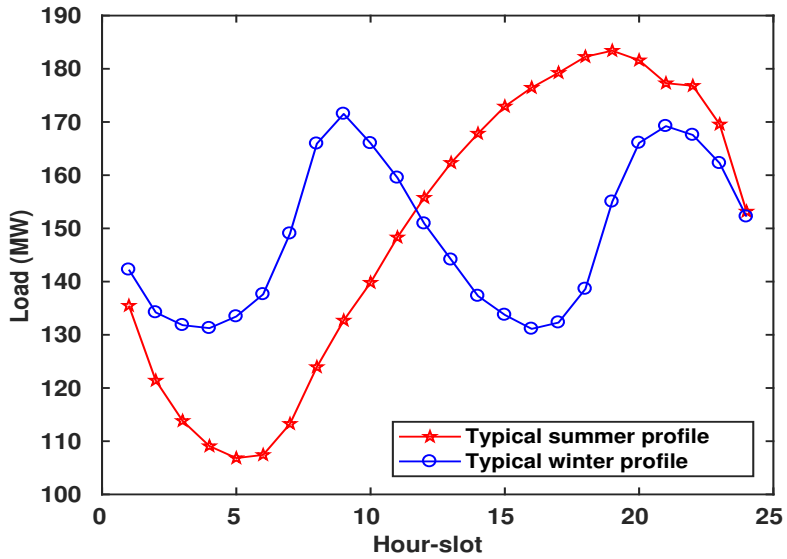
Volatility quantification

Use matrix decomposition methods for residual extraction



Day-ahead (next cycle) forecasting





Day-ahead (next cycle) forecasting

Mn	Lsso	Vnlla	Rcncy	Md 1	Md 2	Md 3	**Md 4**
1	9.88	11.94	12.13	8.54	3.71	3.50	**3.37**
2	9.54	10.95	10.57	9.46	3.29	3.14	**2.95**
3	7.79	8.57	8.38	7.68	2.96	2.79	**2.61**
4	4.89	5.05	4.80	3.35	2.03	1.91	**1.88**
5	5.96	7.37	7.11	3.84	2.43	2.35	**2.23**
6	5.86	6.75	7.35	5.46	3.98	3.76	**3.72**
7	7.66	9.60	9.38	6.59	3.23	2.94	**2.82**
8	10.70	11.21	11.30	7.28	5.94	5.78	**5.78**
9	6.28	5.81	5.65	4.26	3.02	2.94	**2.78**
10	5.20	3.53	3.40	2.77	1.85	1.78	**1.72**
11	6.38	6.06	5.93	5.43	2.61	2.52	**2.31**
12	8.99	9.74	9.45	7.66	2.99	2.77	**2.58**

Publications

- "Quantifying volatility reduction in German day-ahead spot market in the period 2006 through 2016", **IEEE Power & Energy Society General Meeting** (August 2018), Portland, Oregon, USA
- "Data-driven pattern identification and outlier detection in time series", **IEEE Computing Conference** (July 2018), London, UK
- "Propagating uncertainty in tree-based load forecasts", **IEEE ELECO 2017** 10th International Conference on Electrical and Electronics Engineering (November 2017), Bursa, Turkey
- "SVD-based visualisation and approximation for time series data in smart energy systems", **IEEE PES Conference on Innovative Smart Grid Technologies** (September 2017), Torino, Italy

Submitted works

- "Short Term Load Forecasting using Ensembles of Regression Trees", **International Forecasting Journal, Elsevier**
- "The evolution of electricity price on the German day-ahead market before and after the energy switch", **Renewable Energy Journal, Elsevier**
- "An Alternative Approach to Electricity Market Volatility Representation and Quantification", **Energy Policy Journal, Elsevier**

Ongoing works . . .

- Detecting periodicity
- Non-stationary data
- Apply to larger and more diverse data sets