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Leveraging Asynchronous Cross-Border Data and Ensemble Forecasting for Improved Day-Ahead and Imbalance Price Prediction

Energy Finance Christmas Workshop

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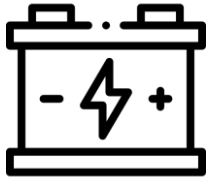
Prof. Hussain Kazmi

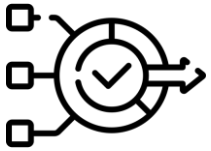
The Cost of Forecasting Errors in Power Systems

- Market volatility and renewables make prices unpredictable

- Forecast errors drive imbalance volumes and costs

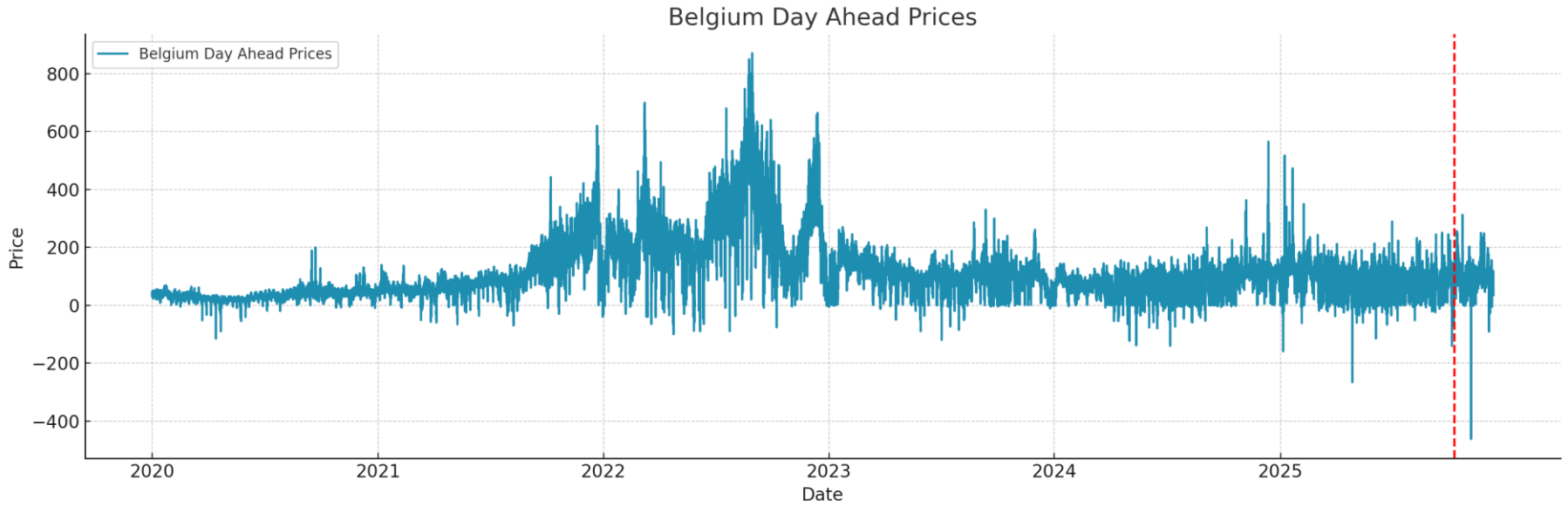


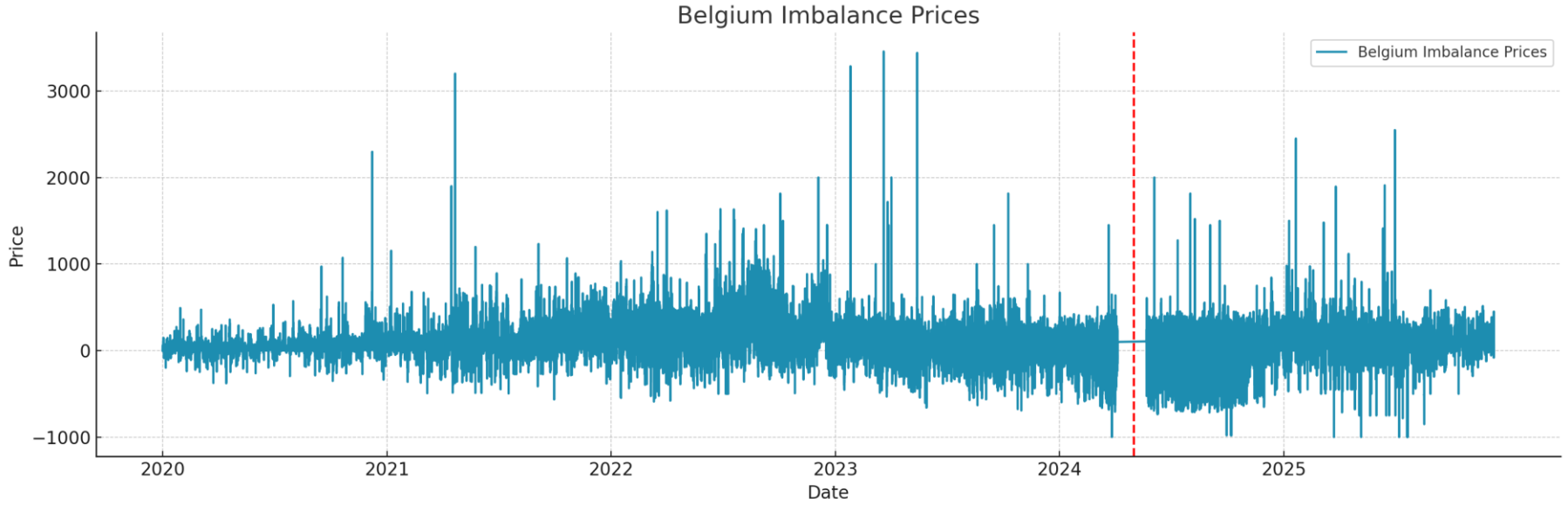
- Flexible assets can mitigate risk



- Value is created when predictions lead to better actions

Two Time Horizons, Two Forecasting Needs





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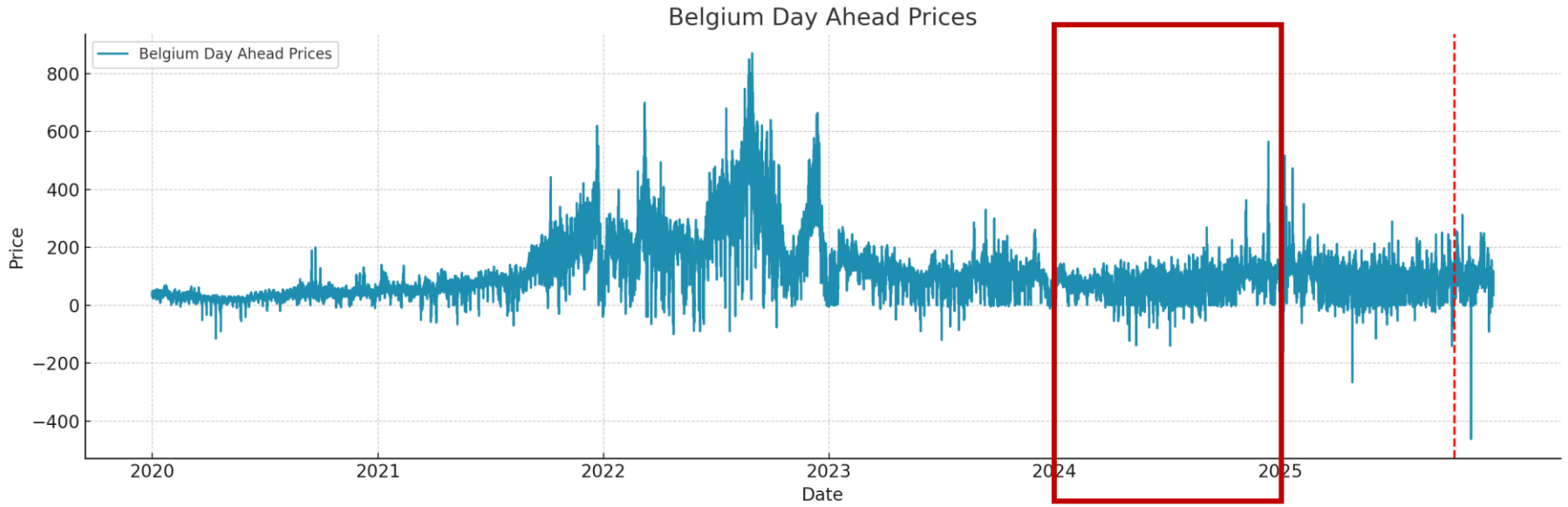
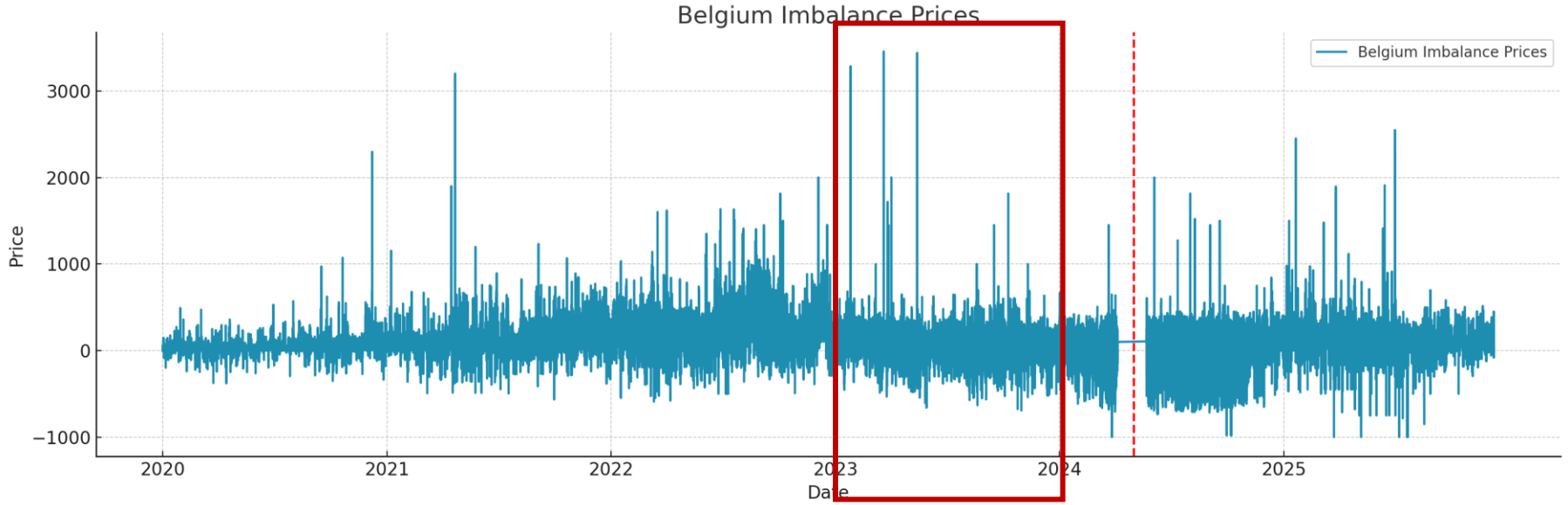
Two Time Horizons, Two Forecasting Needs





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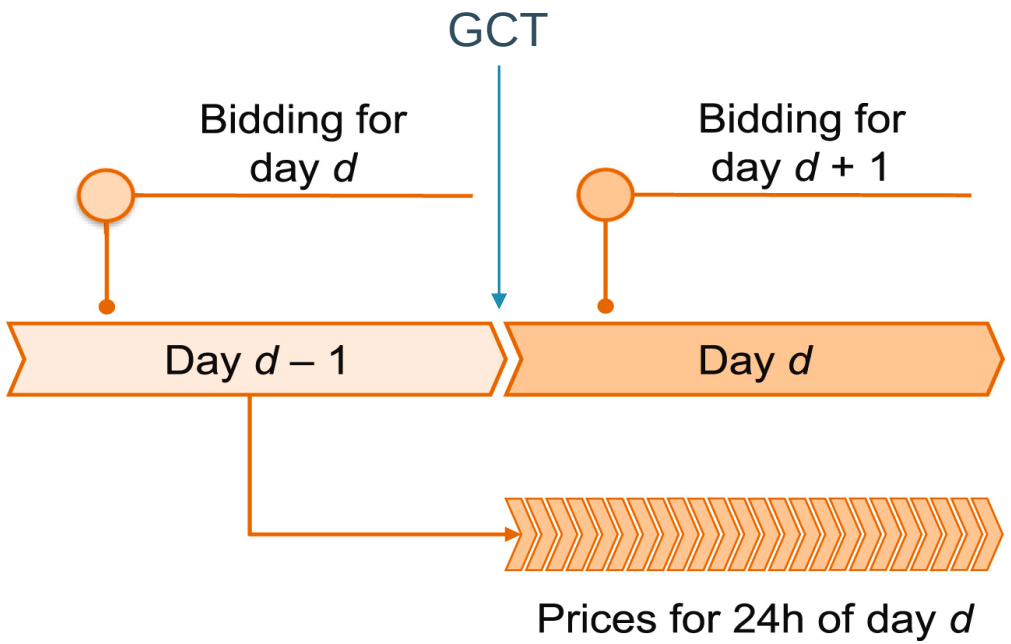
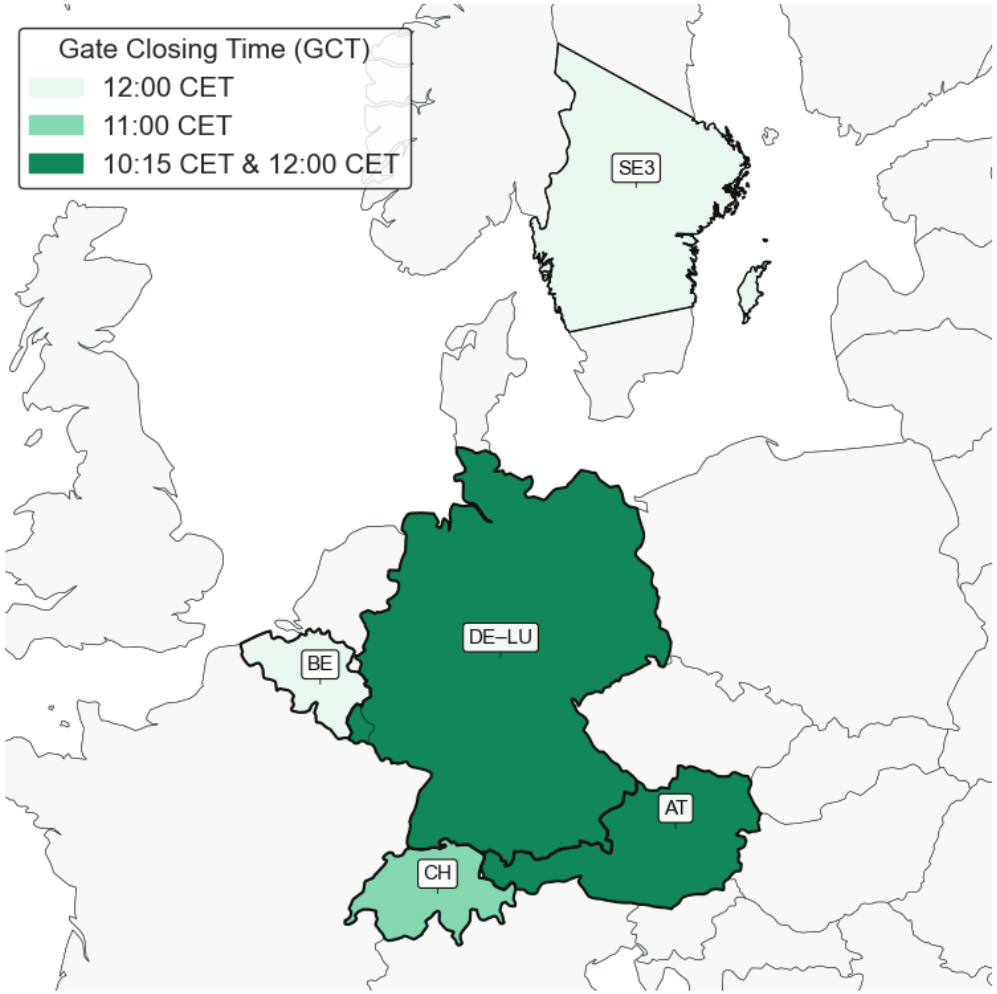
Day-Ahead Forecasts

Asynchronous Day-Ahead Markets

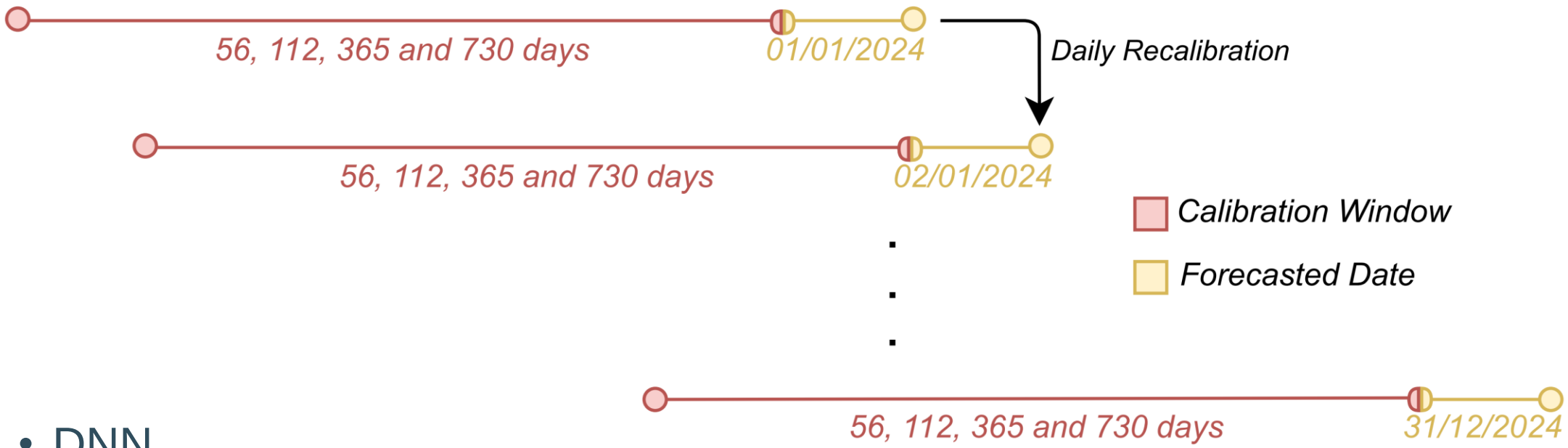


L. Lago, G. Marcjasz, B. De Schutter, and R. Weron, "Forecasting day-ahead electricity prices: A review of state-of-the-art algorithms, best practices and an open-access benchmark," Appl. Energy, vol. 293, p. 116983, 2021. doi:10.1016/j.apenergy.2021.116983.



M. M. Mascarenhas, J. De Blauwe, M. Amelin, and H. Kazmi, "Leveraging asynchronous cross-border market data for improved day-ahead electricity price forecasting in European markets," Applied Energy, vol. 404, p. 127077, 2026, doi: 10.1016/j.apenergy.2025.127077.

Models



- DNN
- LEAR

L. Lago, G. Marcjasz, B. De Schutter, and R. Weron, “Forecasting day-ahead electricity prices: A review of state-of-the-art algorithms, best practices and an open-access benchmark,” Appl. Energy, vol. 293, p. 116983, 2021. doi:10.1016/j.apenergy.2021.116983.

B. Uniejewski, J. Nowotarski, and R. Weron, “Automated variable selection and shrinkage for day-ahead electricity price forecasting,” Energies, vol. 9, no. 8, p. 621, 2016. doi:10.3390/en9080621

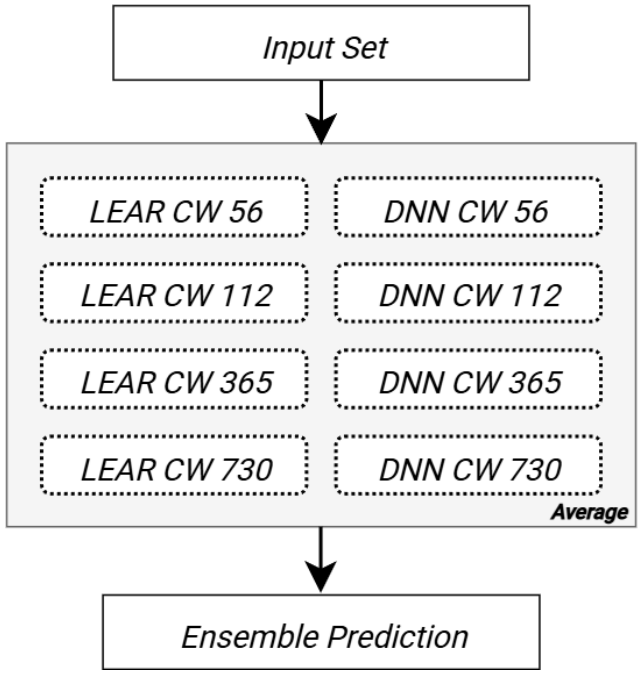
Base Features: BE Data

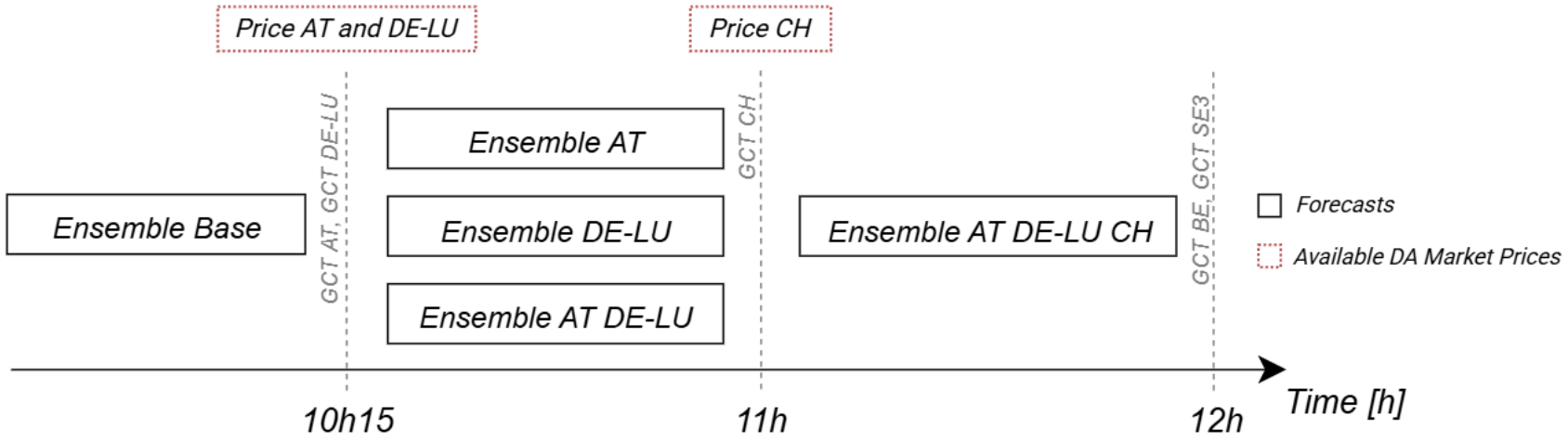
Variable	Unit	Frequency	Source
Load Forecast	MW	Hourly	Entso-E
Wind Forecast (Onshore & Offshore)	MW	Hourly	Entso-E
Solar Forecast	MW	Hourly	Entso-E
Temperature Forecast	°C	Hourly	Open-meteo
Humidity Forecast	%	Hourly	Open-meteo
Day-of-Week Indicator	–	Daily	National Calendar
Public Holiday Indicator	Binary	Daily	National Calendar

Market Features

Variable	Unit	Frequency	Source
DE-LU Spot Price	€/MWh	15-min	Entso-E
AT Spot Price	€/MWh	15-min	Entso-E
CH Spot Price	€/MWh	Hourly	Entso-E

Forecasting Timeline





Forecast Accuracy: BE

Forecast Model	MAE [€/MWh]	rMAE	RMSE [€/MWh]	sMAPE [%]
naive prediction	28.22	1.00	40.99	57.58
ensemble base	13.01	0.46	19.68	31.65

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Forecast Model	MAE [€/MWh]	rMAE	RMSE [€/MWh]
naive prediction	28.22	1.00	40.99
ensemble base	13.01	0.46	19.68
ensemble AT	10.82	0.38	15.67
ensemble DE-LU	**10.18**	**0.36**	**14.57**
ensemble AT/DE-LU	10.45	0.37	15.13

10h15

Forecast Accuracy: BE

Forecast Model	MAE [€/MWh]	rMAE	RMSE [€/MWh]
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ensemble AT/DE-LU/CH	**10.18**	**0.36**	14.85

11h

Forecast Accuracy: BE

Forecast Model	MAE [€/MWh]	rMAE	RMSE [€/MWh]
naive prediction	28.22	1.00	40.99
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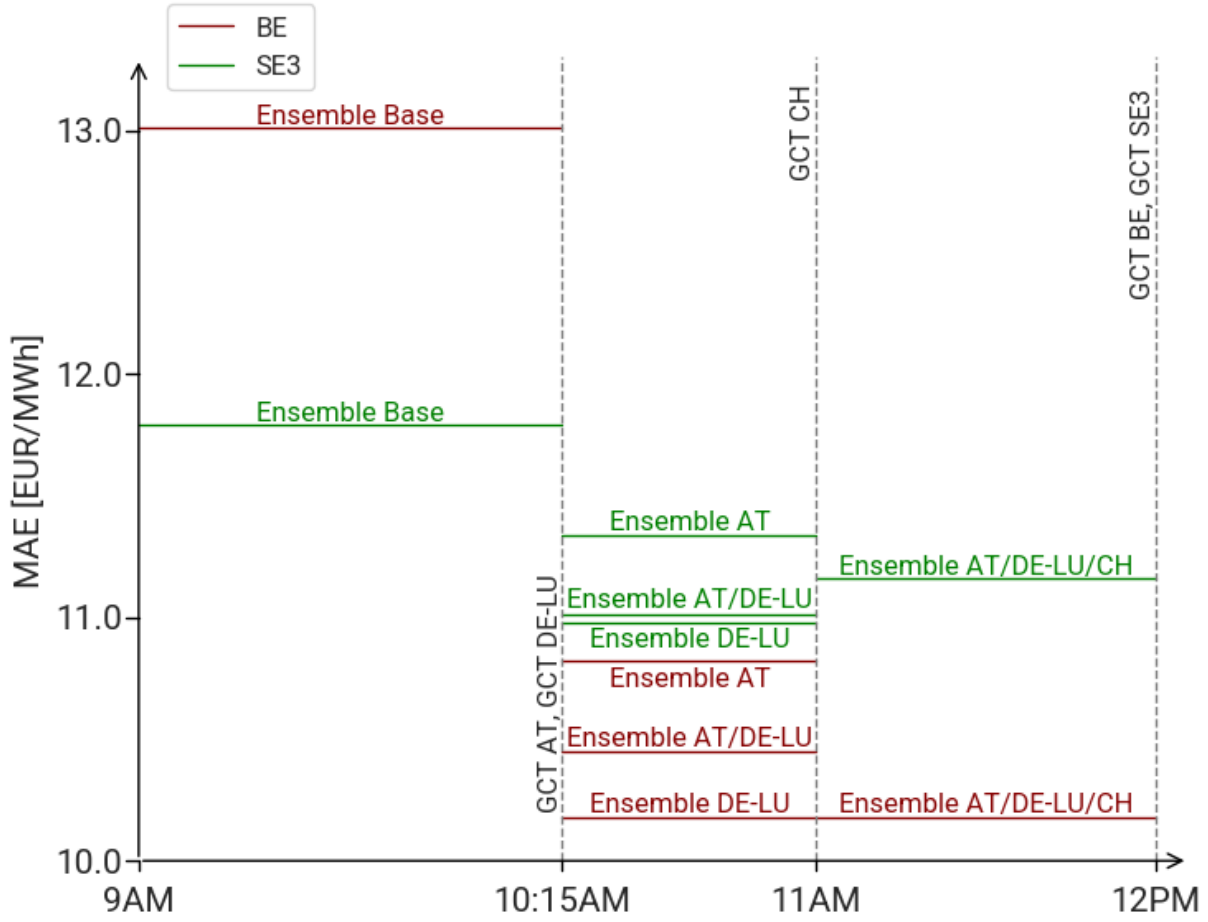
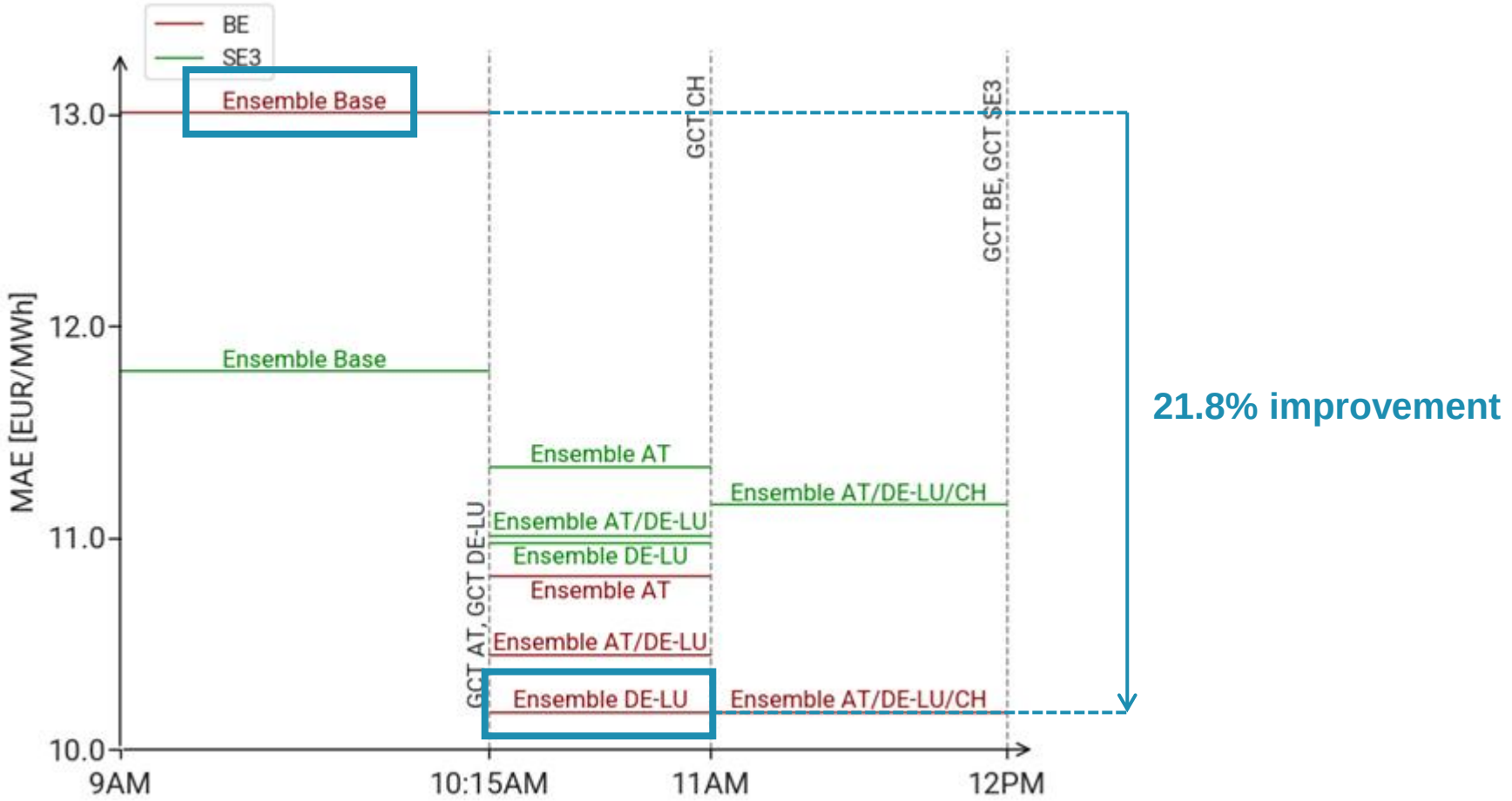
ensemble AT	10.82	0.38	15.67
ensemble DE-LU	**10.18**	**0.36**	**14.57**
ensemble AT/DE-LU	10.45	0.37	15.13
ensemble AT/DE-LU/CH	**10.18**	**0.36**	14.85
Price AT	16.18	0.57	23.22
Price DE-LU	14.55	0.52	21.72
Price CH	18.12	0.64	27.26

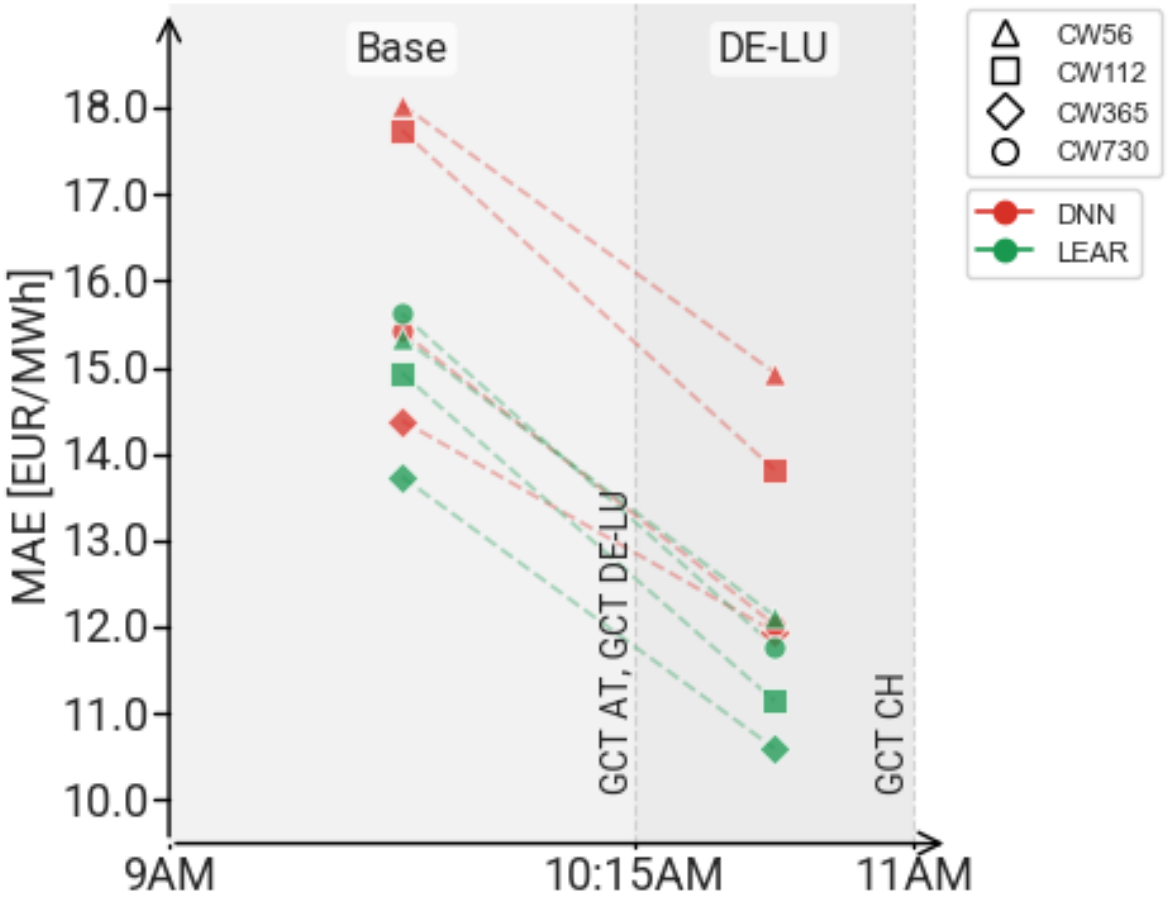
Accuracy Overview



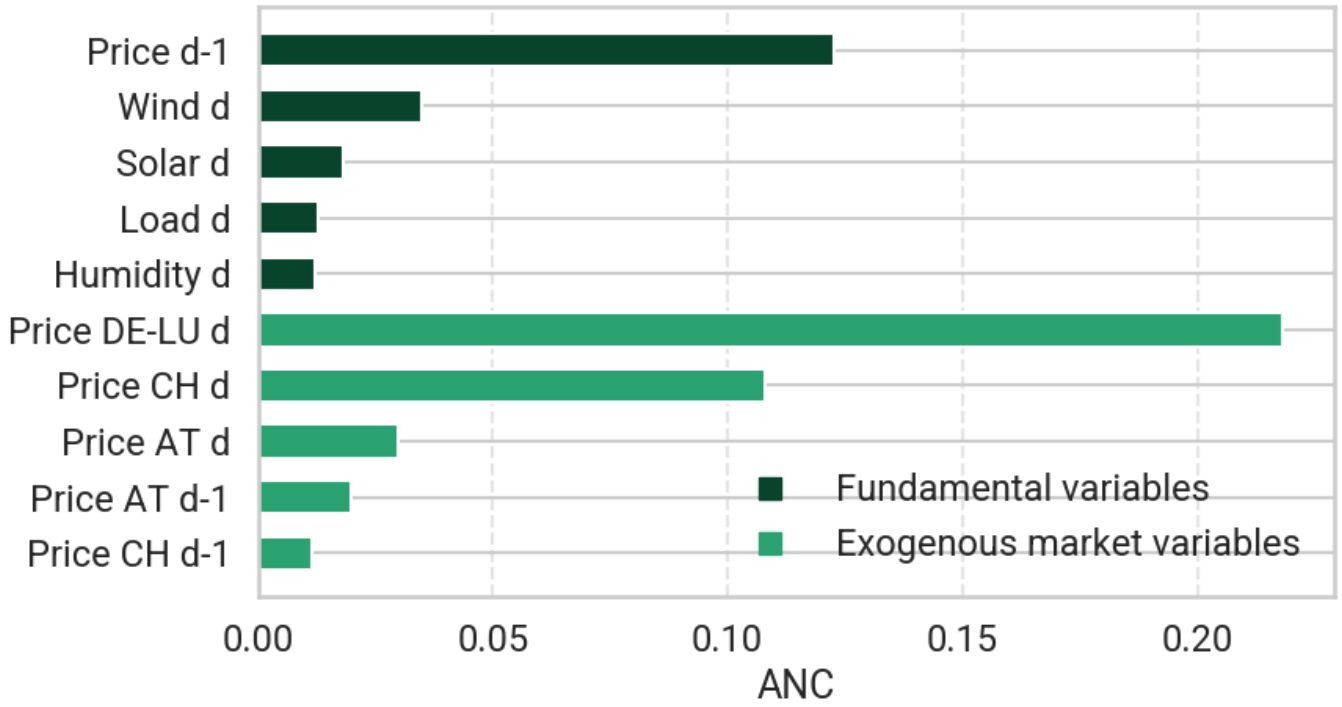
Accuracy Overview



Accuracy: Ensemble Components



Average Absolute Contribution | LEAR CW365 AT/DE-LU/CH



Imbalance Prices

Input Features: Small Set

Variable	Unit	Frequency
Imbalance Prices	€/MWh	15 min
Day-ahead Prices	€/MWh	15 min
System Imbalance	MW	15 min
Calendar Information	-	-

Input Features: Medium Set

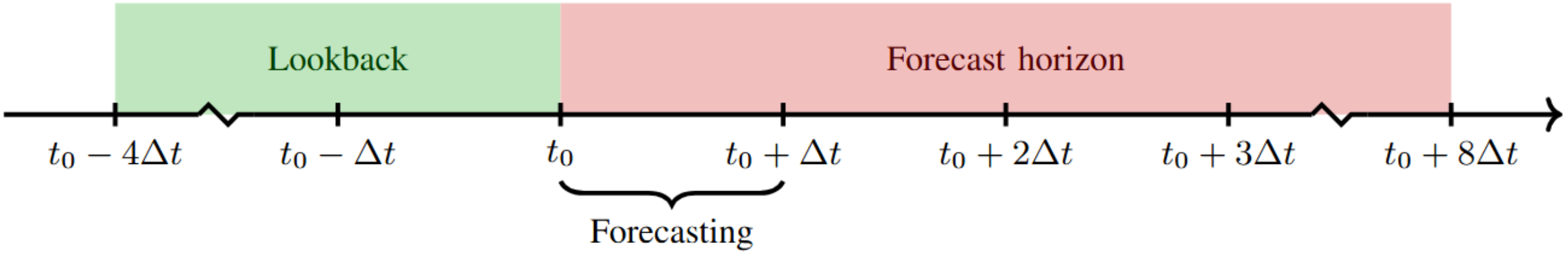
Variable	Unit	Frequency
Imbalance Prices	€/MWh	15 min
Day-ahead Prices	€/MWh	15 min
System Imbalance	MW	15 min
Calendar Information	-	-
IGCC Volume	MW	15 min
IGCC Price	€/MWh	15 min
aFRR Volume	MW	15 min
aFRR Price	€/MWh	15 min
mFRR Volume	MW	15 min
mFRR Price	€/MWh	15 min
Bids Volume	MW	15 min
Bids Price	€/MWh	15 min

Input Features: Large Set

Variable	Unit	Frequency
Imbalance Prices	€/MWh	15 min
Day-ahead Prices	€/MWh	15 min
System Imbalance	MW	15 min
Calendar Information	-	-
IGCC Volume	MW	15 min
IGCC Price	€/MWh	15 min
aFRR Volume	MW	15 min
aFRR Price	€/MWh	15 min
mFRR Volume	MW	15 min
mFRR Price	€/MWh	15 min
Bids Volume	MW	15 min
Bids Price	€/MWh	15 min

Variable	Unit	Frequency
Generation	MW	15 min
Day-Ahead Generation	MW	15 min
Wind Forecast Error	MW	15 min
Solar Forecast Error	MW	15 min
Wind Forecast	MW	15 min
Solar Forecast	MW	15 min
Day-ahead net position with France	MW	15 min
Day-ahead net position with UK	MW	15 min

Forecast Timing



Forecasting Models

- **Considered methods**
  - DNN
  - LEAR
  - XGBoost
- **Ensemble**
  - Weighted with inverse MAE

- **Baselines**
  - Naive persistence model
  - Naive DA price prediction
  - Elia trial forecast

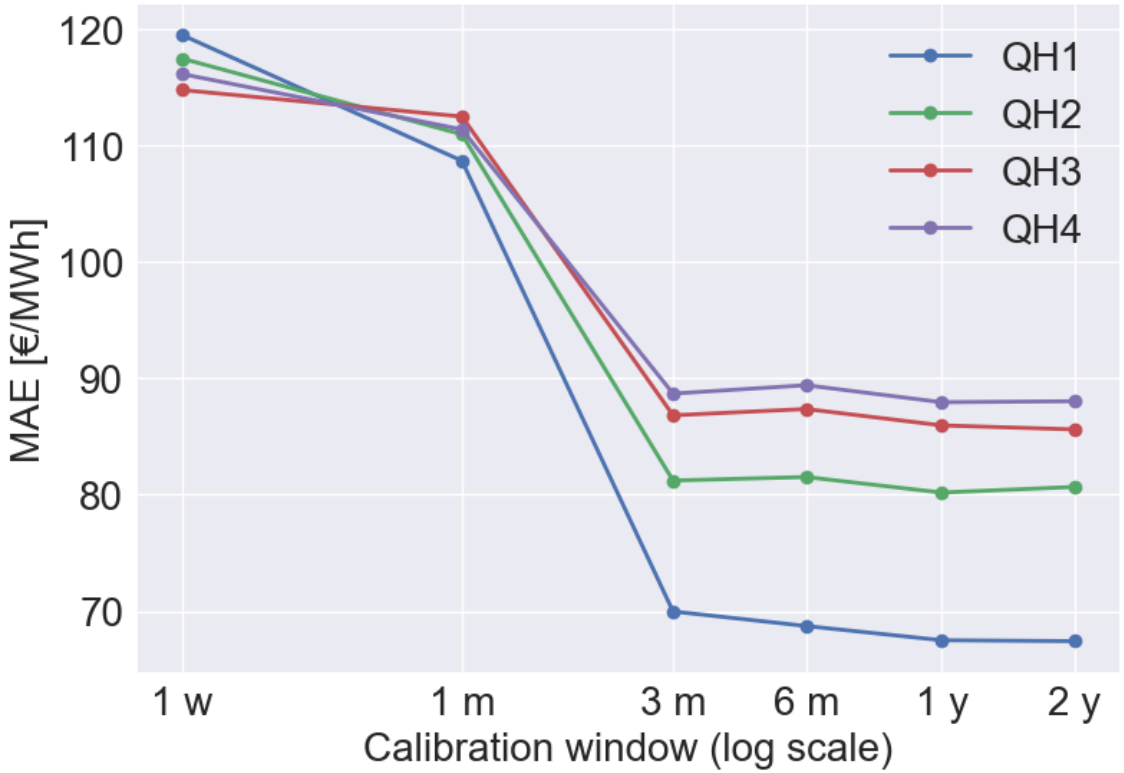
Elia Trial Forecast

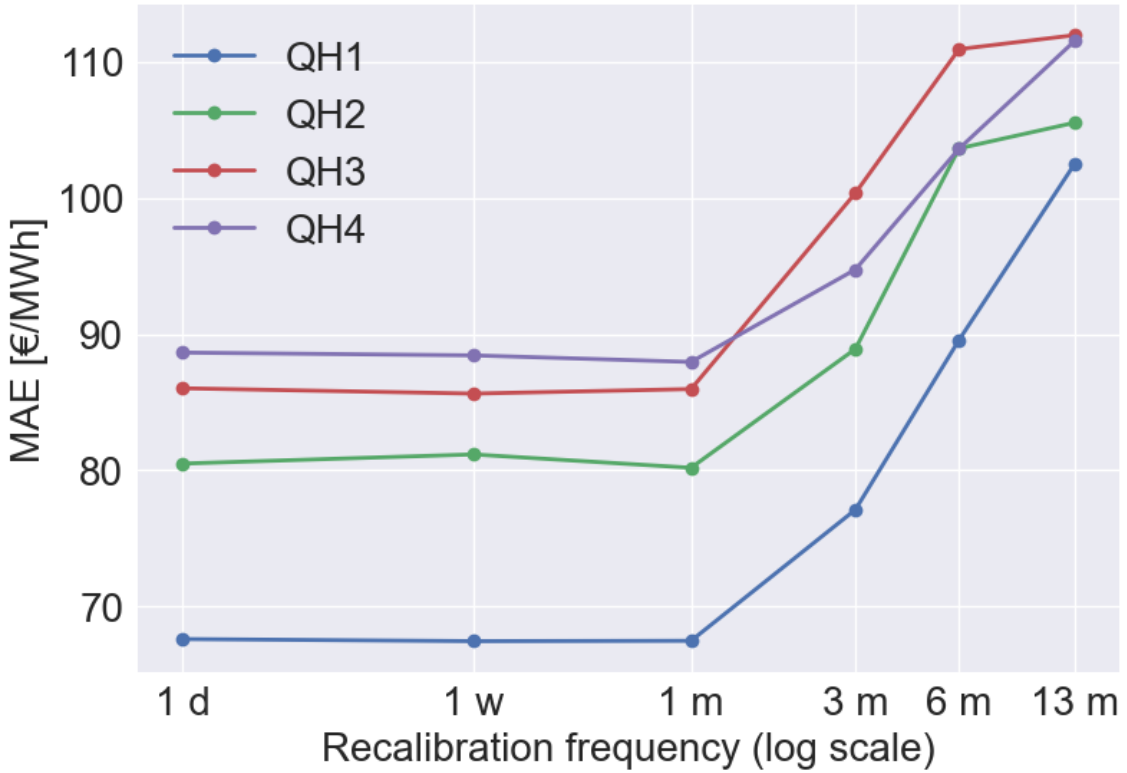
- Elia trial forecast
  - Sept. 17 – Nov. 11, 2024
  - Prediction of **QH2**
  - Confidence indicator

- Elia’s imbalance price per minute publication
  - Can be interpreted as forecast for **QH1**

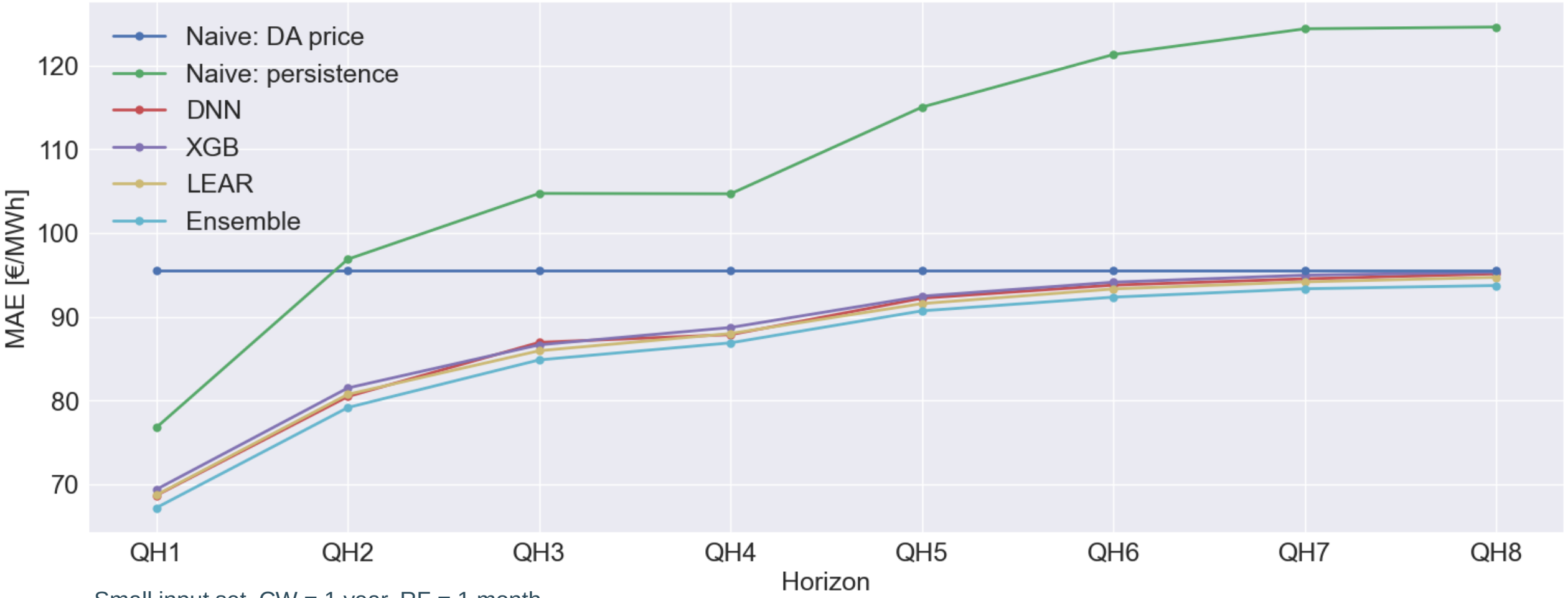
Influence of CW and RF

For the deep neural network, with the small input set, in 2023:



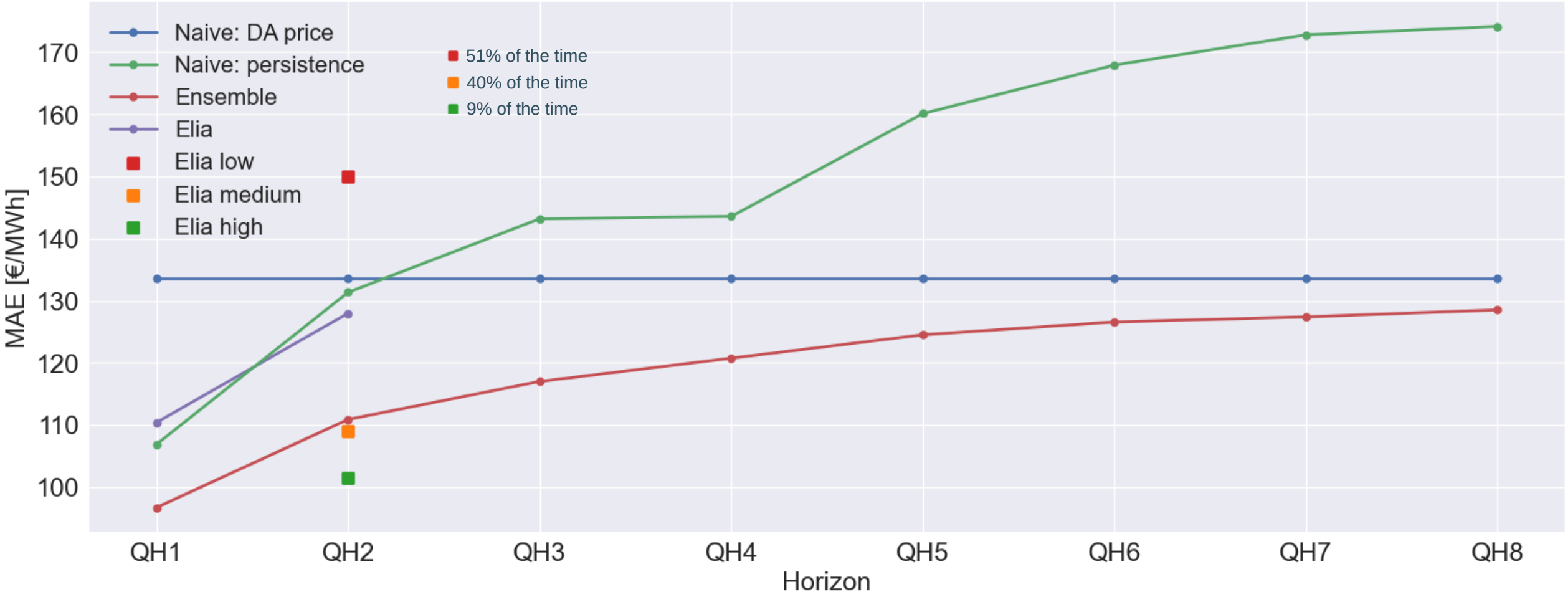


Benchmarking in 2023



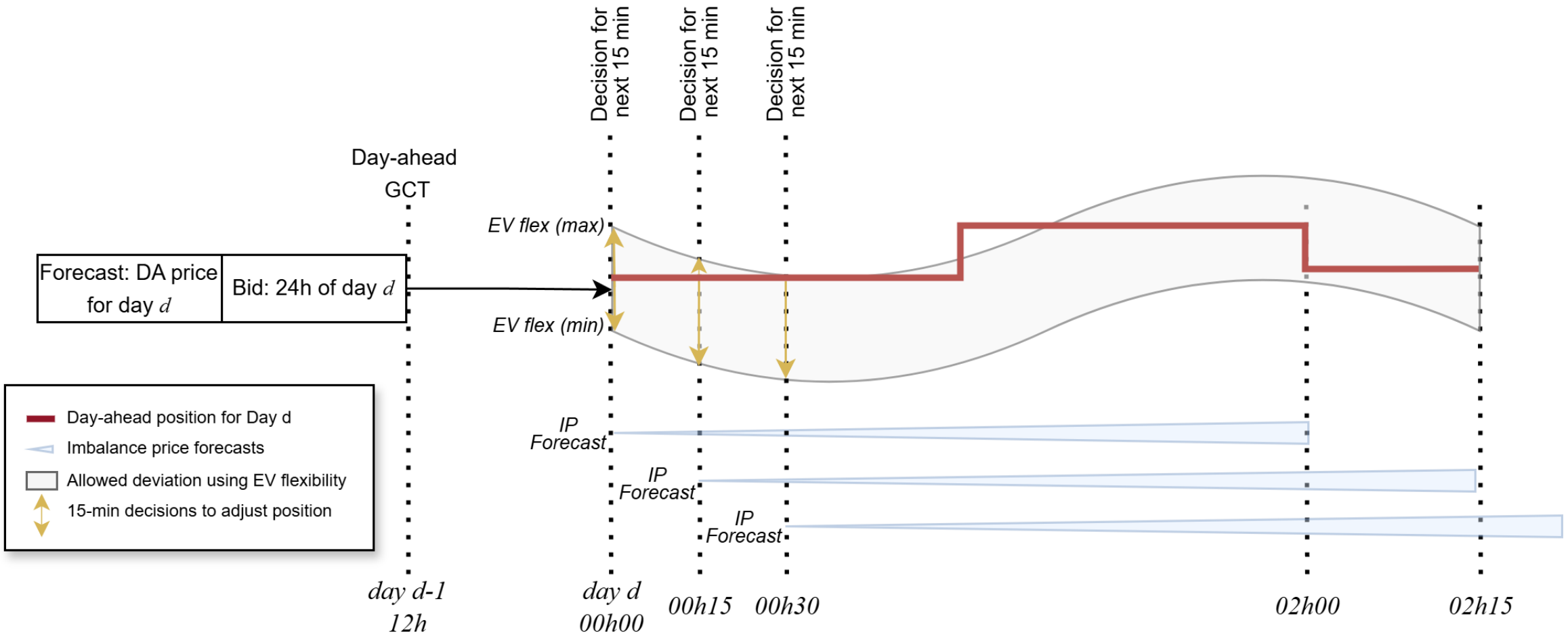
Small input set, CW = 1 year, RF = 1 month
Ensemble: 9 forecasts -> DNN, XGBoost, and the LEAR model, and the three proposed input sets.

Benchmarking: Elia Trial Forecast



CW = 4 months, RF = 1 month

Next Steps


Decision for next 15 min
Decision for next 15 min
Decision for next 15 min
Day-ahead GCT
EV flex (max)
EV flex (min)
Forecast: DA price for day d
Bid: 24h of day d
Day-ahead position for Day d
Imbalance price forecasts
Allowed deviation using EV flexibility
15-min decisions to adjust position
IP Forecast
IP Forecast
IP Forecast
day d-1 12h
day d 00h00
00h15
00h30
02h00
02h15

Conclusions

Day-Ahead Forecasting

- Asynchronous cross-border data significantly improves Belgian day-ahead price accuracy.
- The models assign substantial (potentially excessive) importance to asynchronous cross-border features.

Imbalance Price Forecasting

- Achieves considerably higher MAE than day-ahead price forecasting (to be expected), raising the question of how useful the forecasts are in practice.
- Outperforms Elia’s trial forecast by approximately 13% in MAE.