Quis custodiet ipsos custodes: Bringing more transparency to the ENTSO-E TP data and forecasts on transmission system operations

Maria Margarida Mascarenhas
ELECTA-ESAT (KU Leuven) & Energyville
Leuven, Belgium
margarida.mascarenhas@kuleuven.be

Hussain Kazmi
ELECTA-ESAT (KU Leuven) & Energyville
Leuven, Belgium
hussain.kazmi@kuleuven.be

***Abstract*—The ENTSO-E Transparency Platform (TP) is an ambitious data sharing platform to bring more visibility to transmission system operational data and forecasts. This information is important not just for transmission system operators, but also market players planning their operations in a grid-informed manner. This paper examines the quality of data and forecasts made available on this platform across four European bidding zones (BDZ): Belgium, the Netherlands, France, and Germany-Luxembourg. It reveals data gaps and instances of implausible values (e.g., exceeding installed capacity). Error metrics applied to available day-ahead forecasts also highlight significant performance differences among the BDZ for wind onshore, wind offshore, solar, and load, including outliers such as Dutch solar forecasts, which perform 36 times worse than a simple persistence model. These findings underscore the need for data verification and improved forecasting methods. To increase transparency and future improvements, we also introduce Transparency++, a freely accessible dashboard that continuously tracks data quality and forecast accuracy in near real-time for several European BDZs.**

***Index Terms*—Transparency, ENTSOE, data, forecast, energy transition**

I. Introduction

Transmission system observability provides important information and signals to market participants, balance responsible parties, aggregators, grid operators and regulators. This observability typically comes in the form of openly available data and takes on at least two forms: (1) quasi-static or slow-varying parameters such as network and generation characteristics e.g. the network topology or installed capacity of renewable energy sources in a country, and (2) dynamic or real-time varying parameters such as instantaneous network utilization or energy generation from renewable sources.

The European Network of Transmission System Operators for Electricity (ENTSO-E) is an umbrella organization of 40 transmission system operators (TSOs) in 36 European countries. In addition to helping coordinate and harmonize operations across the European grid, it also provides additional observability via its transparency platform (TP) for all its members [1], [2]. The data in the TP is updated regularly and contains real time observations, historic observations and day-ahead predictions for energy demand and generation for several future time horizons. It also contains information about planned outages, market prices and many quasi-static parameters. As such, by unifying access to this information, the TP marks a considerable step up compared to accessing data from individual TSOs.

However, the TP is not a panacea. It suffers from several shortcomings of its own, some of which have been documented in past research. Most notable among these are (1) poor agreement with data from other sources [2], (2) poor quality data (i.e. missing or unrealistic values) for certain fields, (3) poor quality forecasts [3] and (4) lack of transparency and explainability of the forecasts [4]. There is credible evidence that many of these issues stem from the underlying data sources rather than with the TP itself, i.e. the data being uploaded to the TP is of dubious quality.

In this paper, we present Transparency++, an openly accessible platform which utilizes data from TP, but provides an additional layer of analysis on top. To do so, it provides information about both the publicly available data and forecast quality on TP in a dashboard that is updated in real-time. Furthermore, it compares forecasts made available by different TSOs against each other as well as benchmarks them using existing baselines. Our results show considerable difference in the data quality being provided by different TSOs, as well as scope for improving the quality of forecasts using well-known machine learning algorithms and workflows. Finally, our analysis show that the data on TP is not immutable, but is rather subject to XYZ changes for ABC days after it has been published.

This information should provide impetus not just to regulators to work on improving existing data and forecast quality, but it should also spur more market development for better data-related products and innovation in the future. The remainder of this paper is organized as follows: we first describe the data and forecasts that are made available on TP; next, we discuss the criterion we evaluate these on; this is followed by the results of applying the evaluation metrics to TP data and forecasts.

979-8-3315-1278-1/25/$31.00 ©2025 IEEE

TABLE I: Forecasts available in ENTSO-E TP and corresponding publication deadlines.

Variable	Forecast	Time of Publication		
		Lead	Day	Hour
Load	Day-ahead	D-1	Everyday	2h-GCT
	Week-ahead	W-1	Friday	2h-GCT
	Month-ahead	W-1	1st of Month	-
	Year-ahead	M-1	15th of Month	-
Wind Onshore	Day-ahead	D-1	Everyday	6 PM
Wind Offshore	Intraday	D	Everyday	8 AM
Solar	Current	D	Everyday	Recurrent

II. Data and forecasts

A. Overview of TP services

The TP contains four types of geographic designations: 1) Countries, 2) Bidding Zones (BDZ), which are areas with a uniform spot price, 3) Control Areas, which are areas operated by a single system operator, and 4) Market Balance Areas (MBA), which are areas with a uniform balancing energy price [5]. There are considerable overlaps between these. For instance, Belgium has only one TSO. Consequently, in the TP, the country, BDZ, and control area all cover the same geographic region, resulting in identical values. In contrast, Germany has four TSOs and thus four distinct control areas, yet it shares a single BDZ with Luxembourg. This paper does not consider balancing data, therefore, we do not further consider the MBA formulation.

For each of the discussed geographic regions, the ENTSO-E Transparency Platform publishes extensive datasets provided by the TSOs or other designated entities, depending on local organizational structures [6]. The data are organized into categories covering load, generation, transmission, balancing, outages, and congestion management. In this paper, we focus specifically on load as well as solar, onshore wind, and offshore wind generation, since these variables are typically forecast for generation planning. For a comprehensive overview of all available data on the platform, the reader is referred to [7], and for energy forecasting to [8].

Table I presents a list of some of the more salient forecasts available on the Transparency Platform (TP). In addition to these forecasts, the TP also provides actual load data and a year-ahead load forecast margin. For wind (onshore and offshore) and solar, both the installed generation capacity and actual generation are published as well.

In this paper, the focus of the analysis is exclusively on BDZ level, considering actual load, actual generation for wind (onshore and offshore) and solar, as well as the installed generation capacity for these renewable energy sources. From the available forecasts, we restrict our scope to the day-ahead forecasts. This decision is motivated by several factors. First, the BDZ level aligns with market operations, as it represents areas with uniform spot prices, making it the most relevant scale for energy trading and forecasting accuracy assessment. Second, actual load and renewable generation data provide a ground truth for evaluating forecast performance, while installed capacity serves as a key reference for understanding potential generation limits. Finally, we prioritize the day-ahead forecast because it plays a critical role in market clearing and system planning, directly influencing scheduling decisions and balancing strategies across European power markets.

In summary, this paper analyses publicly available data on load; solar generation; both offshore and onshore wind generation along with their forecasts; and installed capacities for 2024.

B. Comparison with individual TSO forecasts

To compare the data provided by individual TSOs and the information published in TP, Belgium's TSO, Elia, is going to be used as an example. Table II summarizes the forecast offered by Elia.

TABLE II: Overview of forecast offered by Elia.

Variable	**Forecast**	**Time Horizon**	**Quantiles**
Wind (Onshore & Offshore)	Most Recent	–	P10, P90
	Day-Ahead	11 AM & 6 PM	P10, P90
	Week-Ahead	–	P10, P90
Solar	Most Recent	–	P10, P90
	Day-Ahead	11 AM & 6 PM	P10, P90
	Week-Ahead	–	P10, P90
Load	Most Recent	–	P10, P90
	Day-Ahead	6 PM	P10, P90
	Week-Ahead	–	P10, P90

Note: Solar forecasts are provided for the following regions: Antwerp, Brussels, East-Flanders, Flanders, Flemish-Brabant, Hainaut, Liège, Limburg, Luxembourg, Namur, Wallonia, Walloon-Brabant, West-Flanders. Wind onshore forecasts are provided for: Flanders and Wallonia.

In summary, while the TP aggregates data from multiple TSOs to ensure a uniform reporting framework, this comes at the cost of omitting some of the more detailed forecasts such as the multiple day-ahead forecasts and quantile estimates, that individual TSOs like Elia provide. The additional granularity available directly from TSOs offers opportunities for detailed error analysis and risk assessment, which could be valuable for system planning and market operations. It is therefore imperative that future versions of TP target more fine-grained information dissemination.

III. Evaluation criterion

A. Data Quality

The data quality is evaluated based on several criteria, focusing on completeness, plausibility, and consistency. Completeness is measured by the percentage of missing values of each field. Plausibility is assessed by identifying extreme (or nonsensical) values. For the wind offshore, wind onshore and solar generation, and their forecasts, values that are negative or exceed their respective installed capacity are flagged as implausible. For the load and load forecast fields, only negative values are flagged. Additionally, the dataset is also examined for repeated values, specifically, any measurement that appears more than 24 consecutive times is highlighted as a potential issue and further analysed.

On August 17, 2024, the considered variables were collected covering the period from January 1, 2024, through August 17, 2024. Following this initial collection, the dataset has been updated hourly via the TP API, with each fetch refreshing data starting from two days before the date in question up to the current day for actual values, or until the day after for forecasts. This update strategy is implemented deliberately: for operational short-term forecasts, such as day-ahead and intraday forecasts, having access to the most recent data is crucial. If the TP were to update the data later, such changes could not be used for forecasts, and consequently, any alterations made in ENTSO-E after the scheduled update are not captured in the dataset.

B. Forecasts Accuracy

Forecasts are evaluated using a combination of standard error metrics, specifically the Mean Absolute Error (MAE), Root Mean Square Error (RMSE), the relative Mean Absolute Error (rMAE), and the Normalized Mean Absolute Error (NMAE). The MAE is given by:

$$\text{MAE} = \frac{1}{N}\sum_{t=1}^{N} |y_t - \hat{y}_t| \tag{1}$$

Where y_t is the actual value, the $\hat{y}_t$ is the forecast value and N is the total number of observations. Moreover, in order to emphasise larger errors, the RMSE can be used:

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{t=1}^{N} (y_t - \hat{y}_t)^2} \tag{2}$$

The rMAE is defined as the ratio of the MAE of the forecast model to the MAE of a persistence model, where the persistence model uses the previous day's value for solar and wind forecasts and the previous week's value for load forecasts (to account for weekly seasonality). This can be expressed as:

$$\text{rMAE} = \frac{\text{MAE}}{\text{MAE}_{\text{pers}}} = \frac{\frac{1}{N}\sum_{t=1}^{N} |y_t - \hat{y}_t|}{\frac{1}{N}\sum_{t=1}^{N} |y_t - y_{t-\delta}|} \tag{3}$$

where δ is set to 1*24 (1 day x 24 hours) for solar and wind forecasts, or 7*24 (7 days x 24 hours) for load forecasts. Finally, the NMAE normalizes the MAE by the installed capacity and is expressed as a percentage. This metric is defined as:

$$\text{NMAE} = \frac{\text{MAE}}{C_{\text{installed}}} \times 100 = \frac{\frac{1}{N}\sum_{t=1}^{N} |y_t - \hat{y}_t|}{C_{\text{installed}}} \times 100 \tag{4}$$

where $C_{\text{installed}}$ represents the installed capacity. For the load, since this is not possible, the normalization is made by dividing the MAE by the average load of 2024. The rMAE and NMAE error metrics are scale independent, making them ideal for comparison between different BDZ and variables.

Aggregated results for the year 2024 are computed using these metrics for each BDZ. Furthermore, to assess potential seasonality in forecast performance, the rMAE is also calculated on a monthly basis. Finally, by comparing the rMAE across different TSOs, it is possible to determine which BDZ have higher forecast accuracy.

C. Zonal vs. overall statistics

To evaluate zonal forecast performance, a geospatial view with the net load MAE for 2024 for each BDZ is used. The net load represents the effective load after accounting for renewable generation and is given by:

$$NL_t = L_t - \left(W_t^{\text{on}} + W_t^{\text{off}} + S_t\right) \tag{5}$$

Where L_t is the actual load at time t, and $W_t^{\text{on}}, W_t^{\text{off}}$ and S_t are the actual wind onshore, wind offshore, and solar generation, respectively. Therefore, the net load MAE is given by:

$$MAE_{NL} = \frac{1}{N}\sum_{t=1}^{N} \left|NL_t - NL_t^f\right| \tag{6}$$

where the NL_t^f is the net load of the forecast values.

IV. Analysis results and discussion

As mentioned before, the analysis is made for load, solar generation, wind offshore and wind onshore generation; and their forecasts for the year 2024 at an hourly resolution. While only results for four BDZ (Belgium (BE), the Netherlands (NL), France (FR) and Germany-Luxembourg (DE_LU)) are presented here, the TP++ contains analysis for other BDZ as well.

A. Data Quality

Table III shows the percentage of missing data for each BDZ and variable. The ones that are not present in the table had no missing values.

TABLE III: Completeness: Percentage of Missing Data by BDZ and variable.

BDZ	Variable	Missing Values (%)
BE	Wind offshore	10.79
NL	Load	0.24
FR	Load	0.11
FR	Solar forecast	0.01
FR	Wind offshore	0.23
FR	Wind onshore forecast	0.01
DE_LU	Load	0.25
DE_LU	Solar forecast	0.55
DE_LU	Wind onshore forecast	0.27

Regarding data completeness for BE, the wind offshore has significant data gaps, 10.79 % of this data is missing. The remaining variables have complete datasets for 2024. For the NL region, the load data has a 0.24% rate of missing values, specifically from 13:00 UTC on 12 December 2024 until 09:00 UTC on 13 December 2024. Although the current TP website no longer shows these missing entries, this discrepancy indicates that the data was updated after the initial extraction; further investigation revealed that the missing data points were later updated on 09 January 2025 and 10 January 2025. In the FR region, the data remains incomplete for several fields to date i.e. TP has not (yet) been updated. In the DE_LU region, the same situation as in the NL was observed. The missing values were filled in later updates. It is of course positive that data gaps are eventually filled, ensuring that the historical record is complete over the long term. However, for real-time workflows which rely on this data (e.g. short-term forecasts), immediate data availability and accuracy is crucial. Delays in updating missing values mean that operational models might initially be calibrated on incomplete data (or might run inference on incorrect data).

Appendix Table V presents the installed capacities for wind and solar for the considered BDZ. This information is used to determine implausible values. Based on this data, it was determined that only the wind offshore in NL has values above the installed capacity (1.20 % of the time). No negative values are present for any variable or BDZ.

Finally, the consistency was analyzed, and it was found that in the NL region, from 00:00 UTC on December 1, 2024, until 06:00 UTC on December 2, 2024, both wind onshore and offshore values were recorded as zero, while the corresponding forecasts displayed the expected distributions. This issue was later resolved, with updates to the TP data on December 29 and 30, 2024. Additionally, the wind offshore forecast for France showed a constant value of 240 from December 30, 2023, until 03:00 UTC on January 4, 2024. Although data from 2023 is not considered, the anomaly was flagged starting January 1, 2024, leading to an analysis to determine whether this truly marked the start of the anomaly.

B. Forecast Accuracy

In Table IV, it is possible to see the evaluation metrics for the forecast variables for the four BDZ considered.

TABLE IV: Evaluation metrics for the forecasted variables across BE, NL, DE_LU, and FR.

Region	Variable	MAE [MW]	RMSE [MW]	rMAE [-]	NMAE [%]
BE	Load	212.56	286.20	0.56	2.31
	Solar	152.08	320.48	0.37	1.73
	Wind Onshore	99.57	144.06	0.22	3.26
	Wind Offshore	162.50	240.35	0.25	7.18
NL	Load	1937.94	2649.50	1.58	15.97
	Solar	763.43	1339.95	36.89	3.15
	Wind Onshore	791.56	1099.42	1.82	11.62
	Wind Offshore	1097.31	1399.85	0.99	27.58
DE_LU	Load	2024.85	2650.91	0.77	3.83
	Solar	632.79	1252.63	0.35	0.82
	Wind Onshore	1102.43	1574.81	0.15	1.84
	Wind Offshore	574.01	817.98	0.34	6.79
FR	Load	1084.95	1453.77	0.34	2.22
	Solar	552.11	945.02	0.91	3.17
	Wind Onshore	786.75	1262.16	0.31	3.55
	Wind Offshore	95.45	136.75	0.32	6.44

Appendix Table V shows that while the wind onshore forecasts for BE achieve the lowest rMAE, indicating a significant improvement over the persistence baseline, this advantage is not reflected in the NMAE, which indicates an error of 3.26% of the installed capacity. Additionally, although the solar forecasts have a relatively high RMSE of 320.48 MW, they perform well in relative terms. The load forecast, despite having higher absolute errors as expected, exhibits an rMAE of 0.56, roughly twice as good as the persistence model.

The NL region, however, faces significant challenges in forecast accuracy. The forecasts for load, solar, and wind onshore all underperform compared to a simple persistence benchmark, and even though the wind offshore forecast performs comparably in terms of rMAE, its NMAE is extremely high.

In the DE_LU region, the wind onshore forecast stands out with an exceptionally low rMAE of 0.15. Despite high MAE and RMSE values, attributable to an installed capacity of 60049.0 MW, the NMAE remains quite low.

Finally, for FR, Table IV shows that the rMAE for load and wind are very similar (around 0.3), indicating a significant improvement over the persistence benchmark. However, the wind offshore forecast exhibits a significantly higher NMAE, while the solar forecast, despite a higher rMAE of 0.91, maintains an acceptable NMAE.

It is important to interpret the non-relative metrics, MAE and RMSE, with caution. These values can vary significantly between countries and variables due to differences in installed capacities and load ranges. For this purpose, we present the forecast error as a heatmap for each BDZ in Figure 1. Each heatmap shows the rMAE for each month of the year for the solar, wind offshore, wind onshore and load forecasts. The figure excludes the solar forecast in the NL area due to its extremely high values. Dutch load forecasts also exhibit higher errors in the first half of the year, peaking in June. Likewise, wind onshore forecasts also deteriorate significantly in the second half of the year, with rMAE values spiking above 4 in later months, while wind offshore forecasts remain relatively more stable, though still less accurate than in other regions.

The situation is markedly different in other regions. For Belgium, load forecasts generally perform well with rMAE values below 0.8 for most months. However, there is a noticeable increase in error during February and June. Solar and wind offshore forecasts in Belgium show moderate variability; Notably, the solar forecast error rises in November. Wind onshore forecasts are relatively stable throughout the year, indicating consistent model performance. In France, we see a low load forecast error during winter and early spring, with an increase during early summer before returning to low rMAE values towards the end of the year. Solar forecasts in France are fairly consistent, fluctuating around rMAE values of 0.7 to 1.2, while both wind offshore and wind onshore forecasts maintain stable and low errors throughout the year.

Finally, the DE_LU region shows relatively stable load forecast performance, with rMAE values between 0.58 and 1.07, and only a minor seasonal peak in August. Solar forecast accuracy in DE_LU is good for most months, except for a noticeable rise in error during October and November. Wind offshore forecasts show moderate variability, whereas wind onshore forecasts are exceptionally consistent and low, indicating a particularly robust forecasting approach for wind onshore generation in DE_LU.

This information can be further summarized, as seen in Figure 2, which shows a radar plot with the rMAE of all the forecast variables for BE, DE_LU and FR. The data for NL

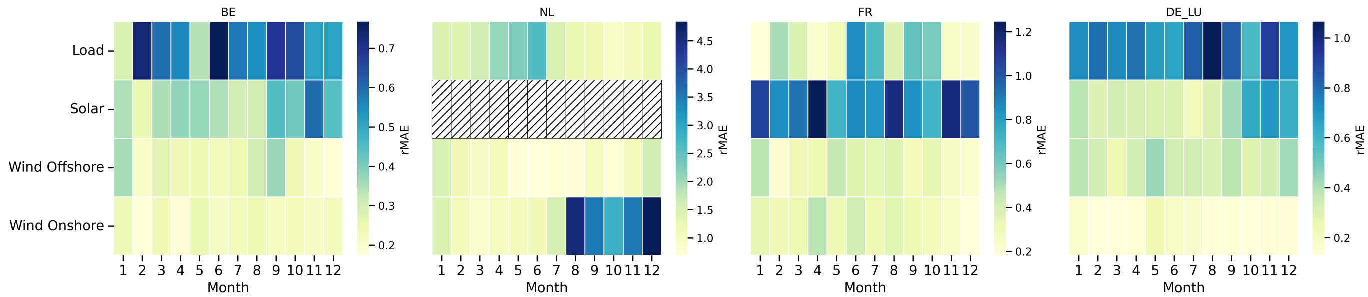

Fig. 1: Heatmap for each BDZ representing the rMAE of solar, wind offshore, wind onshore and load forecasts.

was not included due to significantly higher values. However, the results for NL can be consulted in Table IV, or directly on the TP++ platform[1].

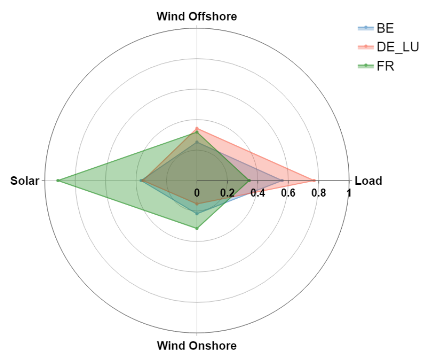

Fig. 2: rMAE of solar, load, wind offshore and onshore generation for BE, DE_LU and FR.

According to Figure 2, for load forecasts, France leads with the lowest rMAE, followed by Belgium and then DE_LU, while the Netherlands significantly underperforms. In the case of solar forecasts, Belgium and DE_LU show comparable performance in terms of rMAE, outperforming the FR solar forecast. The Netherlands, however, exhibits an extreme outlier with an rMAE of 36.89. Looking at wind offshore, Belgium again performs best, with France and DE_LU close behind, while the Netherlands records a higher rMAE of 0.99. For wind onshore forecasts, DE_LU stands out with the best performance, followed by Belgium and France, and finally the Netherlands. It must be noticed that BE and DE_LU have similar behaviour, where the load is the most difficult variable to predict, unlike FR, which struggles the most with solar.

Figure 3 builds on top of this information and shows a map of the considered BDZ with a color scale indicating the net load MAE. It reveals significant differences in forecast errors across the regions. These variations may reflect differences in system size, load variability, and the complexity of the underlying generation mix in each zone. Some variables in some locations may be inherently difficult to forecast (e.g. solar production in sunny locations), resulting in higher net load MAE. However, this also provides insights into correlated system failures, and whether TSO's err in similar ways, which could lead to cascading outages in the worst case scenario. This information on net load errors is updated in real-time on the Transparency++ platform.

[1]https://huggingface.co/spaces/EDS-lab/Transparency_Plus

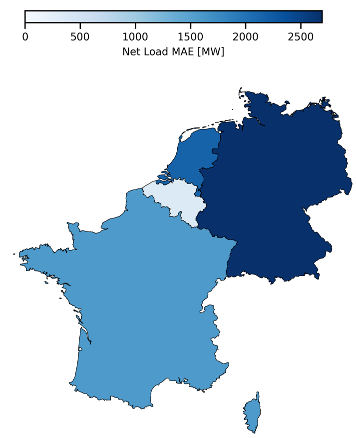

Fig. 3: Map of the considered BDZ, representing the net load MAE.

V. Conclusions

Our findings in this paper reveal significant differences in both data quality and day-ahead forecast accuracy across different ENTSO-E bidding zones. In particular, the solar forecasts for the Netherlands perform around 36 times worse than a simple persistence model, and stand in stark contrast against other countries where generally good forecasting accuracy is seen. Our analysis shows that these inconsistencies stem not only from bad forecasting models but also from data quality issues. Increased data quality and real-time reporting are clearly needed to improve downstream decision-making in power systems and markets, but the current incarnation of TP leaves a lot to be desired. To support this, we have introduced Transparency++, a public dashboard updated hourly that analyzes data quality and forecast accuracy at the bidding zone level of the data published by the TP. By making these assessments openly accessible and updated hourly, Transparency++ aims to encourage more transparent data sharing, ultimately leading to better forecasts and better-informed downstream decision-making.

REFERENCES

[1] J. Verseille and K. Staschus, "The mesh-up: Entso-e and european tso cooperation in operations, planning, and r&d," *IEEE Power and Energy Magazine*, vol. 13, no. 1, pp. 20–29, 2014.

[2] L. Hirth, J. Mühlenpfordt, and M. Bulkeley, "The entso-e transparency platform–a review of europe's most ambitious electricity data platform," *Applied energy*, vol. 225, pp. 1054–1067, 2018.

[3] H. Kazmi and Z. Tao, "How good are tso load and renewable generation forecasts: Learning curves, challenges, and the road ahead," *Applied Energy*, vol. 323, p. 119565, 2022.

[4] M. M. Mascarenhas, M. Amelin, and H. Kazmi, "Bridging accuracy and explainability in electricity price forecasting," in *2024 20th International Conference on the European Energy Market (EEM)*, 2024, pp. 1–6.

[5] VVA, Copenhagen Economics, Neon, Deloitte, "A review of the entso-e transparency platform," European Commission, Technical Report, 2017. [Online]. Available: https://energy.ec.europa.eu/system/files/2018-05/review_of_the_entso_e_plattform_0.pdf

[6] ENTSO-E, "Generation Forecasts for Wind and Solar [14.1.D]," 2023. [Online]. Available: https://transparencyplatform.zendesk.com/hc/en-us/articles/16648445340180-Generation-Forecasts-for-Wind-and-Solar-14-1-D

[7] ——, "Detailed data descriptions," ENTSO-E, Technical Report Version 3, Release 4, 2023. [Online]. Available: https://eepublicdownloads.entsoe.eu/clean-documents/Transparency/MoP_Ref2_DDD_v3r4.pdf

[8] H. Kazmi, C. Fu, and C. Miller, "Ten questions concerning data-driven modelling and forecasting of operational energy demand at building and urban scale," *Building and Environment*, vol. 239, p. 110407, 2023.

APPENDIX

TABLE V: Installed Capacities in 2024 (MW) for Solar, Wind Onshore, and Wind Offshore from ENTSO-E TP.

Country	**Solar [MW]**	**Wind Onshore [MW]**	**Wind Offshore [MW]**
BE	8789.0	3053.0	2262.0
NL	24261.0	6812.0	3978.0
FR	17419.0	22134.0	1483.0
DE_LU	77016.0	60049.0	8456.0