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The ENTSO-E Transparency Platform – A review of Europe's most ambitious electricity data platform

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HIGHLIGHTS

- The ENTSO-E Transparency Platform is meant to become the most important data source of European power systems.
- This paper provides an introduction to and an assessment of the platform.
- We find mixed results and identify a range of shortcomings.
- Our suggestions include improving the governance structure and giving users more say.

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ABSTRACT

Applied power system research is data intensive, often requiring hour-by-hour data on electricity consumption and generation as well as detailed information about technical and cost parameters of power stations. The European Union obliges firms to publish much of this information on a common website, the "ENTSO-E Transparency Platform" operated by the association of transmission system operators. It is possibly the most ambitious platform for power system data globally. However, anecdotal evidence from users indicates significant shortcomings regarding data quality and usability. This paper provides an introduction to and an assessment of the Transparency Platform, helping researchers to use it more efficiently and to judge data quality more rigorously.

1. Introduction

Studying real-world electricity systems and markets is very data intensive. Model-based studies regularly require large amounts of time-series data, including hour-by-hour information on electricity consumption, wind and solar generation, import and export constraints and prices. They also require detailed information about individual power stations including heat rate, cost parameters and operational constraints.

In many parts of the world, much of this information is not available to the public. European researchers are in the lucky position to have access to a wide range of power system data. The single most important data source is likely to be the Transparency Platform (TP) [1] operated by the European Network of Transmission System Operators for Electricity (ENTSO-E).

Anecdotal evidence from fellow researchers as well as our own experience with using the TP has hinted at various shortcomings and problems both in terms of usability and data quality. This paper provides an in-depth and systematic assessment of the platform and the data it provides. To the best of our knowledge, this is the first academic paper that reviews the platform.

We ran a Google Scholar search to identify the papers that have made use of this data, restricting ourselves to peer-reviewed publications. We found 18 publications, indicating the relevance that the platform has gained during its short life-time for energy research [2–19].

This article is structured as follows: We start by providing background on the data platform (Section 2) and briefly outlining our methodology (Section 3). We then discuss data quality (Section 4) and usability, where we suggest a number of improvements (Section 5). Section 6 concludes.

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2. About the ENTSO-E Transparency Platform

The ENTSO-E Transparency Platform is an online data platform for European electricity system data. It was established through the Regulation (EU) No. 543/2013 [20], sometimes called the "Transparency Regulation". The purpose of the TP is to serve market participants, such as generators, retailers and traders: transparency is meant to reduce insider trading and level the playing field between small and large actors. The TP currently has 9000 registered users and is developed, maintained and operated by ENTSO-E, the association of transmission system operators (TSOs).

2.1. Platforms for electricity data

Previous transparency data platforms operated by ENTSO-E include "ETSO-vista" and "ENTSOE.net". While the former is no longer operational and data originally published there can no longer be accessed, the latter is retained in a separate section on the TP Website. In addition to the TP, ENTSO-E also provides the "Monthly statistics data collection". These contain mostly monthly aggregated datasets, but notably also hourly load values. This data is split up over two other data platforms called "Power Statistics" (data since 2016) and "Data Portal" (until 2015). Fig. 1 provides an overview.

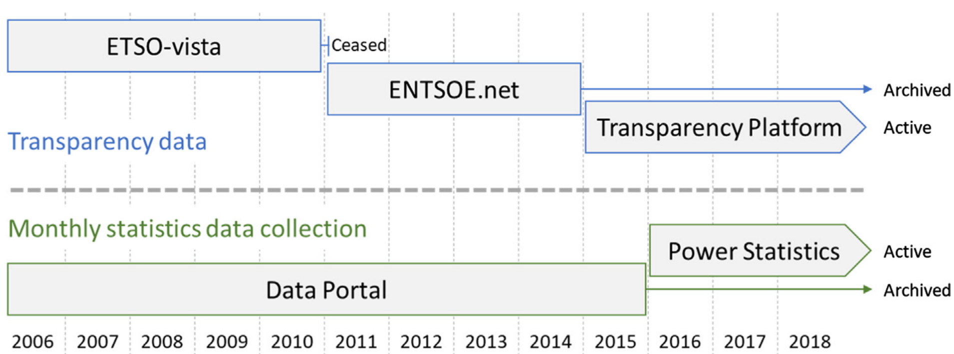

Fig. 1. Data Platforms operated by ENTSO-E. *Transition from ENTSOE.net to ENTSO-E Transparency Platform was carried out on 05.01.2015.

To add to the complexity, the TP is not the only "transparency platform": as a response to another law, Regulation (EU) No. 1227/2011 (REMIT) [21], which stipulates the publication of inside information on energy markets, a number of inside information platforms have emerged, some of which are called "transparency platforms", e.g. EEX Transparency [22]. While there is some overlap in data, these platforms are based on independent legal requirements.

2.2. Content and size

Regulation 543/2013 stipulates in detail which data items must be published for which geographic frameworks on the TP; it also defines deadlines. It specifies a total of 49 data items to be published on the TP, each of which carries an alphanumerical identifier (see Table 6 in the Appendix A). We will use the data item names and identifiers throughout this article. Technical procedures and definitions are specified in a handbook called the "Manual of Procedures" [23]. An annex to the MoP is the "Detailed Data Descriptions", which specifies data items in more detail than the Regulation [24].

On the TP website, data items are grouped into six categories ("data domains"): "Load", "Generation", "Transmission", "Balancing", "Outages" and "Congestion Management". The TP includes no other data than those mentioned in the Regulation. Data are reported at different spatial and temporal granularities, depending on the item and the reporting TSO.

While some data items are reported by individual generation units, the majority of items are aggregates for geographical areas or borders. Four different geographical frameworks are used, representing different ways of subdividing the power system into geographical areas. Each area carries an Energy Identification Code (EIC) [25], a coding scheme developed by ENTSO-E:

- countries (e.g., Germany),
- bidding zones (BZ), areas in which there is a uniform spot price (e.g., Germany-Austria-Luxemburg),
- control areas (CA), areas in which the grid is operated by a single system operator (e.g., 50Hertz control area in eastern Germany), and
- market balance areas (MBA), areas in which there is a uniform balancing energy price (e.g., Germany).

For each data item, the Transparency Regulation specifies the framework to be used for reporting, in most cases control areas. Some data items are available for additional frameworks, resulting in redundant data. For example, "Actual Total Load" (6.1.A) is available for three frameworks: countries, bidding zones and control areas.

The temporal resolution differs by TSO, depending on the "market time unit" of the respective power market. Austrian, Belgian, Czech, Dutch, German and Hungarian data are reported every 15 min and British, Cypriot and Irish data every 30 min, while most other countries report hour-by-hour.

As of April 2017, the CSV files available on the FTP server contained about 35 GB of data covering 2.5 years. "Generation" is the largest data domain, because it includes data reported by generation unit. Most TP data are organized in time series. We do not know the total number of time series, but gauge that it could be more than 10,000.

2.3. Data access

There are three options to access TP data: the website's graphical user interface (GUI), a Restful application programming interface (API) and a File Transfer Protocol (FTP) server. Table 1 provides details. Three additional access options exist but will be phased out.

2.4. Data providers and ownership

ENTSO-E operates the technical platform but does not provide the data. Institutions such as TSOs or generators continuously provide data to the platform; this is a legal requirement of Regulation 543/2013. These institutions are called "Primary Data Owners". Exact numbers are not

Table 1
Data access and download options.

Name	Description	File size/scope	File types	Updates
Website GUI	Manual download via graphical user interface	Daily or yearly files for single areas/units	XML, CSV, XLSX	Close to real time
Restful API	Send specific download request via scripting languages	Up to yearly files for single areas/units. For outage data: up to 200 reports	XML	Close to real time
FTP server	Bulk access to all country data for any data item using the File Transfer Protocol	Monthly files for all areas/units	CSV	Once daily

available, but we gauge that there might be several thousand Primary Data Owners, possibly including all European TSOs, DSOs, power exchanges, larger generation companies and merchant link operators. Most Primary Data Owners do not provide data directly to the TP, but through intermediaries called "Data Providers". There are around 50 Data Providers, including all TSOs and most power exchanges.

Hence data flows as follows: Primary Data Owners → Data Providers → ENTSO-E TP → data users.

3. Methodology

We assess the data quality (completeness and consistency) and usability of the Transparency Platform. Our assessment is based on a literature review, statistical analysis, user survey and interviews.

3.1. Evaluation criteria

Assessing completeness means verifying whether all data items specified in Regulation 543/2013 are available on the TP for all geographic entities that apply and for all time steps since 2015.

The consistency analysis aims to identify whether data are "correct". However, inconsistency does not necessarily imply TP data are "wrong"—it might be the other data source that is inaccurate, or the two sources might differ in definitions. It is, however, reason for concern.

Usability addresses topics such as navigating the website, data documentation and the availability of download options.

3.2. Assessment techniques

To deliver a thorough, comprehensive and fair assessment, we applied four complementary approaches: (i) a review of other (previous) TP evaluations, (ii) new statistical data analysis, (iii) an online user survey and (iv) expert interviews. Previous TP assessments include the minutes of meetings of the ENTSO-E Transparency User Group (ETUG) [26] and two "opinions" issued by the Agency for the Cooperation of Energy Regulators (ACER) [27,28].

Our own statistical analysis is based on a snapshot of data from 2015 and 2016 retrieved in April 2017 through the FTP server. Completeness is primarily assessed by searching for gaps in time-series data. Consistency is assessed by comparing TP data to other data sources such as ENTSO-E's Data Portal/Power Statistics, Eurostat, national statistical offices, and data collected from individual TSOs' websites. For some of these data items, it is possible that the definitions differ depending on the source; however, we believe the results give a valid analysis of data inconsistencies.

For processing and analysing the files, we used Microsoft Excel and Python. The Excel files as well as the Python code contained in Jupyter Notebooks used for our data analysis are open source and available at http://neon-energie.de/transparency-platform.

To assess usability, we sent an online survey to 600 energy data users, of which 80 responded. Table 7 in the Appendix A lists the questions of the online survey. We also conducted 23 semi-structured expert interviews (see list in Table 8 in the Appendix A).

3.3. Limitations

The sheer size of the TP presents a limitation to this study: not all data items can be scrutinized to the same degree, nor can all findings be presented in tables or figures. An additional limitation is the fact that we used a snapshot of data retrieved in mid-2017. Any improvements thereafter remain neglected in this study. Finally, we used the FTP server to retrieve data, a method that was in test mode by then.

4. Data quality

Our analyses reveal shortcomings, including gaps in most items we assessed. Several of the market actors whom we interviewed stated that they rely on other – often commercial – sources because of data quality issues. We also find that the quality of several (but not all) data items has improved over time. Due to space constraints, we focus on the most relevant and prominent data items in the following.

A shortcoming by design of the TP is the fact that data are only available from 2015 onwards. Power system research often requires long time series covering multiple years, for which the TP cannot be used. Alternatives for some of the data items (e.g. load and wind/solar

Table 2
Gaps in "Actual Total Load" (6.1.A) by country.

Country	# of gaps	Share of obs. missing
Austria	0	0.0%
Belgium	26	0.3%
Bulgaria	0	0.0%
Croatia	2	0.1%
Cyprus	1	86.2%
Czech Republic	19	0.7%
Denmark	2	2.7%
Estonia	27	0.4%
Finland	47	0.3%
France	15	0.1%
Germany	0	0.0%
Greece	28	0.4%
Hungary	3	0.0%
Ireland	78	1.2%
Italy	14	2.5%
Latvia	21	0.2%
Lithuania	55	2.5%
Luxembourg	0	0.0%
Malta	1	100.0%
Netherlands	0	0.0%
Poland	0	0.0%
Portugal	0	0.0%
Romania	20	0.8%
Slovakia	35	0.3%
Slovenia	1	0.0%
Spain	18	0.2%
Sweden	1	7.5%
United Kingdom	0	0.0%

generation) include ENTSO-E's Data Portal/Power Statistics, TSO websites or aggregators like Open Power System Data.

4.1. Load

Within the data domain "Load", we focused on the data item "Actual Total Load" (6.1.A). "Actual Total Load" is defined by the Detailed Data Descriptions [24] as the sum of power generated by plants on both TSO/DSO networks, subtracting the balance of exchanges on interconnections between neighbouring bidding zones and the power absorbed by energy storage resources, averaged over each market time unit.

4.1.1. Completeness

Table 2 shows the number of gaps (where each gap can span one or more time steps) as well as the share of observations that is missing for each EU Member State during 2015–16. The time series are complete for one-third of all countries. For several countries, hundreds of observations are missing.

The pattern of data unavailability suggests different reasons for missing data: for some countries, data came in late at first, but are nearly complete since then (Cyprus, Denmark, Sweden). Other countries have many short gaps (Romania, Slovakia, Spain). Yet other countries feature a larger number of longer gaps that seem to be randomly distributed over the time period (Ireland, Italy, Lithuania).

A positive observation is that the "extra hour" in October due to daylight saving time—a notorious weak spot of power system data—does not seem to pose a systematic problem.

4.1.2. Consistency

We compare "Actual Total Load" (6.1.A) to two other sources of load data:

- ENTSO-E's Data Portal [29]/Power Statistics [30][1]. It is our understanding that those data are sourced and processed independently from the Transparency Platform.
- Eurostat [31].

These sources differ in two important aspects:

- TP data are delivered one hour after real time, while the other sources undergo revisions.
- The TP publishes total load, while the Data Portal/Power Statistics may report a share of the total, as indicated by the possibility to report a country-specific "Representativity Factor".

The first difference implies that we can expect random deviations between TP and the other sources resulting from close-to-real-time estimation errors. These errors should not be systematic, i.e. they should average out over longer time periods. The second difference would imply systematic differences; however, as all Representativity Factors [30] are reported to be 100%, this should not be the case.

In almost all countries we find significant and persistent deviations among all three sources; in most but not all cases, TP numbers are smaller than the other statistics (see Fig. 2). Deviations in the double-digit percentage range are not uncommon. Moreover, deviations vary among countries: in Slovakia, TP load is somewhat larger than the other two sources while in Austria, it is about 20% smaller.[2] Our findings resemble inconsistencies reported by Schuhmacher and Hirth [32].

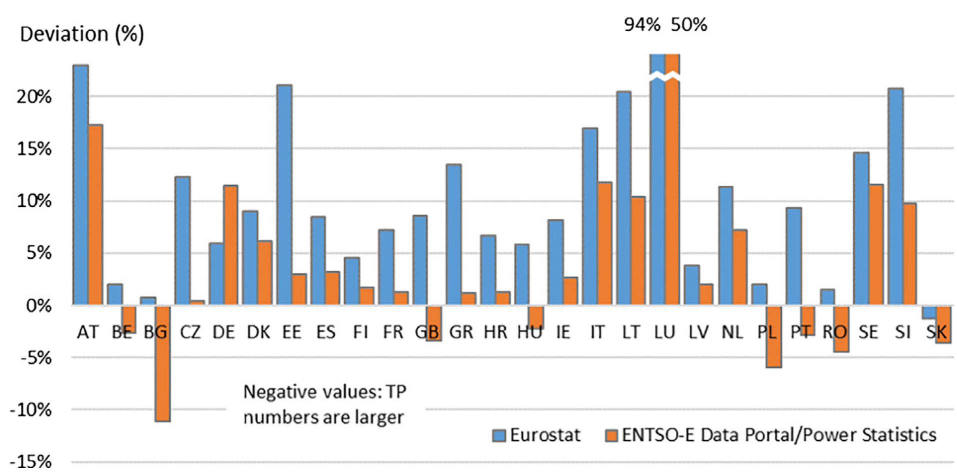

Fig. 2. Deviation of load between TP and other sources, 2015–16. "Actual Total Load" (6.1.A) values are inconsistent with other sources' load data, including ENTSO-E Power Statistics. The deviations are often significant in size (> 10%).

Fig. 3 gives more detail for four countries on a month-by-month basis (Eurostat data are not available at a finer granularity). These countries were selected because they represent different patterns of inconsistency. The different patterns suggest that the underlying problems are different depending on the country. In Germany, the difference between TP data and other sources is sometimes small (August 2015) and sometimes large (January and December 2016). Consistency does not seem to improve over time. TP data for France are similar (albeit not identical) to Data Portal/Power Statistics, while Eurostat is larger at a relatively constant margin. This pattern suggests that Eurostat might apply a different data definition, but both definitions seem to be applied consistently. Denmark is a case with dramatic and fluctuating deviations over time. The inconsistencies in the Netherlands seem to have improved since 2015.

[1] Monthly aggregated load data are available under the titles "Monthly consumption" on the Data Portal (until the end of 2015) and "Monthly Domestic Values" on Power Statistics (since 2016).

[2] For the Austrian case, we were informed through personal communication by ENTSO-E that "the reason for the deviation in Austria results from different definitions of the respective sources. On the Transparency Platform, Total Load includes only data of the control area APG. Instead, the values on Power Statistics include data for the whole country (also including data of large industry with own production units and railroad consumption, which are not directly connected to the grid of APG)."

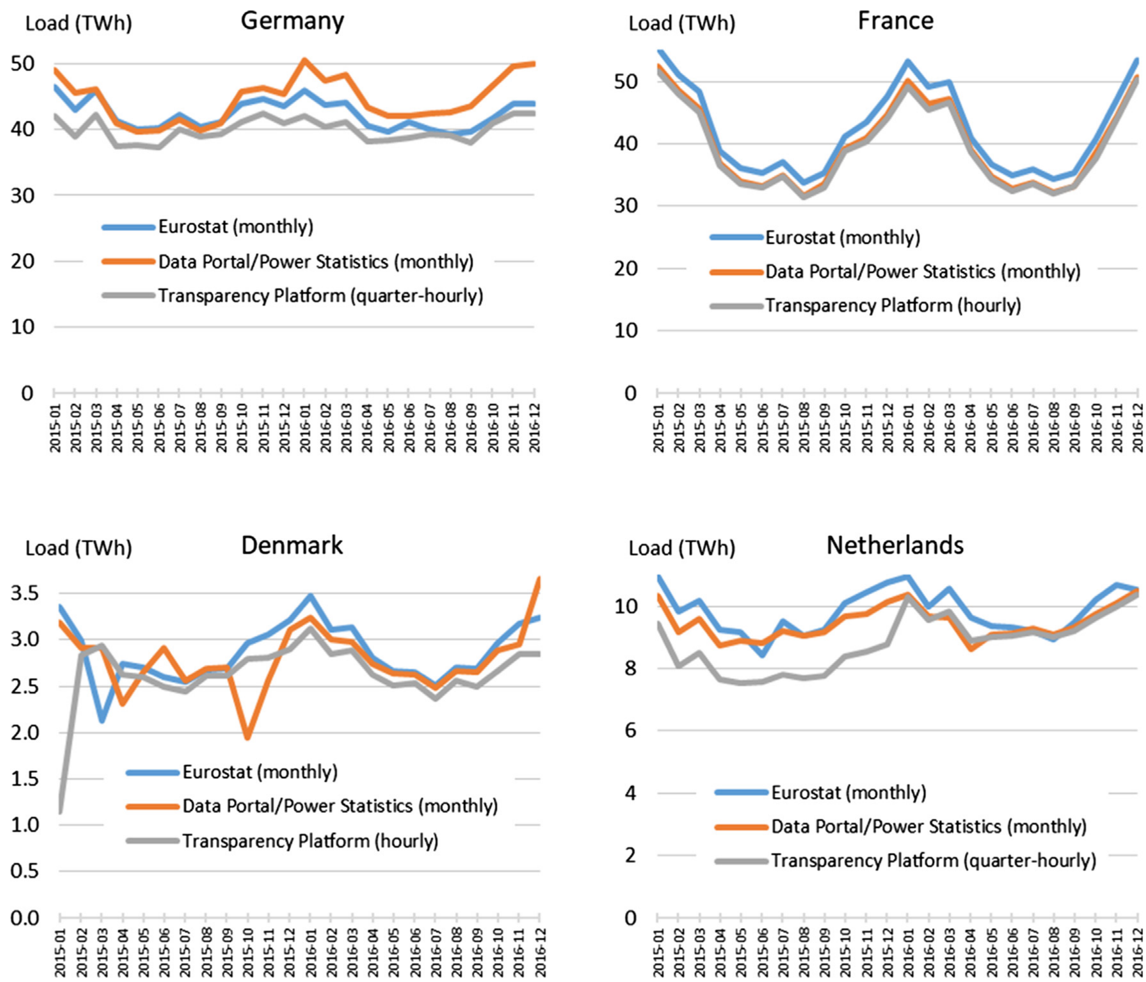

Fig. 3. Comparing "Actual Total Load" (6.1.A) with load data from Eurostat and Data Portal/Power Statistics. Deviations differ among countries both by pattern and degree. Further country analyses are available at https://neon-energie.de/transparency-platform.

4.2. Generation

For this study, we assessed the item "Aggregated Generation per Type" (16.1.B&C), which is defined in the Detailed Data Descriptions [24] as the sum of all net generation output per technology, averaged over each market time unit. Due to space constraints, we focus on the most common technologies.

4.2.1. Completeness

Coloured cells in Fig. 4 show the share of observations missing (reported as "N/A" on the TP website). White fields containing "n/e" indicate that generation data from that country and technology are not expected on the TP, e.g. because that technology does not exist in the respective country. Croatia (all values "N/A") as well as Luxembourg and Malta (all values "n/e") do not report any data for this data item.

Few time series are truly complete. Coverage is nearly complete in Austria, Belgium, Germany, Denmark and Portugal. In Italy and Slovenia, a year is missing for some or all technologies, resulting in shares of around 50% missing values for the two years covered.

Fig. 5 depicts the evolution of completeness over time. It shows the number of observations per week aggregated over all countries and production types and compares this to the expected total if all data were reported. Under the assumption that no technology disappeared, the number of expected observations does not change over time. The number of actual observations per week seems to increase from 2015 to 2016, indicating improved completeness. However, this pattern is due to the appearance of Italian data in 2016, which were missing in 2015 altogether. Disregarding the Italian data, the overall completeness of the data shows some ups and downs but seems to stabilize around 1000 missing observations per week.

	Biomass	Fossil Gas	Fossil Hard coal	Hydro Pumped Storage	Hydro Run-of-river and poundage	Hydro Water Reservoir	Nuclear	Solar	Wind Onshore	Other
AT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	n/e	0.3%	0.3%	0.0%
BE	0.0%	0.0%	0.0%	0.0%	0.0%	n/e	0.0%	1.0%	1.4%	0.0%
BG	0.3%	100%	100%	0.1%	100%	0.0%	0.3%	0.1%	0.4%	n/e
CY	n/e	n/e	n/e	n/e	n/e	n/e	n/e	100%	28.2%	n/e
CZ	0.1%	0.1%	0.1%	0.0%	0.1%	0.1%	0.1%	0.2%	0.1%	0.2%
DE	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
DK	0.0%	0.0%	0.0%	n/e	32.4%	n/e	n/e	0.0%	0.0%	n/e
EE	0.3%	0.3%	n/e	n/e	0.3%	n/e	n/e	0.3%	0.3%	0.3%
ES	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%	0.1%
FI	0.3%	0.3%	0.3%	n/e	0.3%	n/e	0.3%	n/e	0.3%	0.3%
FR	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	0.2%	n/e
GB	100%	0.0%	0.0%	0.8%	0.8%	n/e	0.8%	0.0%	0.0%	0.2%
GR	n/e	0.5%	n/e	n/e	n/e	n/e	n/e	0.2%	0.2%	n/e
HR	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
HU	0.3%	0.1%	n/e	n/e	0.4%	0.1%	0.3%	n/e	0.3%	0.1%
IE	n/e	15.2%	15.2%	15.2%	15.2%	n/e	n/e	n/e	35.6%	15.2%
IT	50.1%	49.8%	49.9%	49.8%	49.9%	49.8%	n/e	49.8%	49.8%	49.9%
LT	4.7%	4.7%	n/e	4.7%	4.7%	n/e	n/e	4.7%	4.7%	4.7%
LU	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e
LV	0.3%	0.3%	n/e	n/e	11.7%	88.6%	n/e	n/e	0.3%	0.3%
MT	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e	n/e
NL	1.4%	0.0%	35.4%	n/e	n/e	n/e	9.0%	3.8%	1.0%	9.7%
PL	0.1%	0.1%	0.1%	0.3%	0.1%	0.1%	n/e	n/e	0.0%	n/e
PT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	n/e	0.0%	0.0%	0.0%
RO	0.8%	0.8%	0.6%	100%	0.9%	1.1%	0.8%	0.7%	0.8%	100%
SE	n/e	n/e	n/e	n/e	n/e	1.0%	1.0%	n/e	0.5%	1.0%
SI	50.1%	0.0%	n/e	0.0%	0.0%	n/e	0.0%	0.0%	50.1%	n/e
SK	1.9%	1.9%	2.0%	1.9%	1.9%	1.9%	1.9%	1.9%	1.9%	2.0%

Fig. 4. Completeness of "Aggregated Generation per Type" (16.1.B&C) by country, calculated as share of missing values (reported on TP as "N/A") for selected technologies. For the majority of countries, a significant amount of data is missing. Due to space constraints, we have restricted the figure to a subset of all technologies. Latvia operates one hydropower plant that was classified as "Hydro Water Reservoir" until 25.03.2015 and as "Hydro Run-of-river and poundage" afterwards, leading to two columns where one of two values is always "N/A" or "n/e".

4.2.2. Consistency

We compare "Aggregated Generation per Type" (16.1.B&C) as reported on the TP for each market time unit to three alternative data sources:

- For Germany, we compare generation by all technologies to yearly data from the German Federal Statistical Office [33]/AG Energiebilanzen [34].
- For seven Member States, we compare wind and solar generation data to TSO websites.
- For 22 Member States, we compare wind and solar generation to data from Eurostat and the ENTSO-E Data Portal/Power Statistics.

Fig. 6 shows the result of the first comparison. We find differences between the two datasets for most production types. Differences for individual technologies could be due to diverging rules on assigning individual power plants to production types but should cancel each other out when aggregating all technologies. This is the case for natural gas: TP reports 15 TWh while Destatis reports 47 TWh. This is compensated by "Other", where numbers are 39 TWh and 1 TWh, respectively. The surprising reason for this discrepancy lies in the fact that combined cycle gas turbines are reported as "Other" generation on the TP. This fact, strange in itself, to the best of our knowledge is not documented anywhere; we only learned about it via a service desk inquiry.[3] For hard coal, the TP reports 78 TWh compared to 100 TWh on Destatis, for reasons unclear to us. Differences for renewable and nuclear generation are minor. Total generation across all technologies as reported by Destatis is 29 TWh higher than the TP data, the reason for which is unclear to us.

Furthermore, for seven countries, we collected hourly resolution wind and solar generation data from the websites of their respective TSOs (available on Open Power System Data [35]). As the original data source is identical, we expect identical data. Fig. 7 shows that this is indeed the case for several countries, notably Austria and France. Additionally, solar data from Germany as aggregated from four individual TSO websites are almost always identical to the corresponding TP data. However, for other countries the two respective sources show different values.

[3] From an email from the ENTSO-E service desk, Jul 4: "Other means other conventional and in our case it includes combined cycle gas turbines".

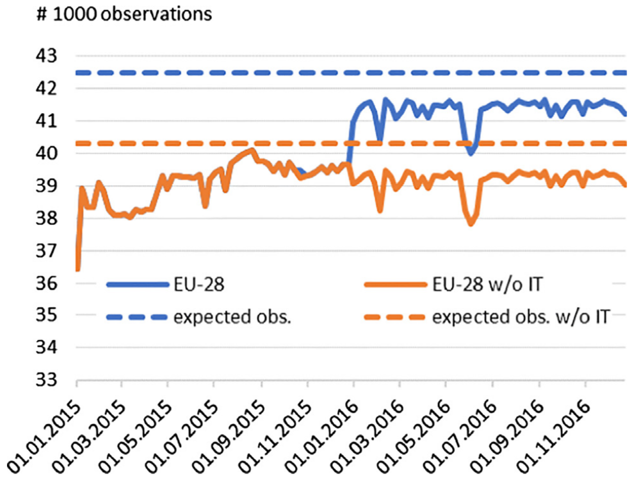

Fig. 5. Weekly number of "Aggregated Generation per Type" (16.1.B&C) observations. We cannot identify a trend toward improvement of completeness over time. In a week, the expected number of observations 42,504 = 168 h × 253 country–type combinations. Excepting Italy, it is 40,320 = 168 h × 240 country–type combinations. The total number of country–type combinations on the FTP server is 260; however, this includes combinations that are always marked as "n/e" on the TP website and are thus disregarded.

- Danish, Czech and Polish wind generation data reported on the websites of the respective national TSOs are often different values than those on the TP.
- Danish onshore wind generation is rarely identical. This inconsistency is not due to different coverage, as evidenced by the fact that for all countries in which deviations occur, they are sometimes positive and sometimes negative.
- According to ENTSO-E, in the case of Poland differences can be explained by different calculation methods: hourly wind generation on PSE's website is calculated as the average of quarter-hourly observations, while on the TP, hourly averages are based on more frequent observations. The TP values can thus be regarded as more accurate.

Finally, we compare aggregated hourly TP wind generation data with Eurostat's monthly "nrg_105m" [31] statistics as well as ENTSO-E's "Detailed monthly production" [36] from the Data Portal and "Monthly Domestic Values" [30] from the Power Statistics. For those countries in which the data are complete enough on the TP to allow for a comparison, aggregate results are shown in Fig. 8. In all countries, we find inconsistencies; however, some cases are less worrisome than others. France sticks out as a positive example and the United Kingdom (GB) as a negative. During interviews, we were told by stakeholders that GB data are problematic because offshore and/or plants connected at the distribution level are excluded from certain statistics, but we could not find any written documentation of this discrepancy.

Fig. 9 shows a comparison of wind generation data over time for selected countries. A promising observation is that in several countries, inconsistencies seem to improve over time:

- Germany's large differences among sources seem to have disappeared since mid-2016.
- The deviations visible in France during the winter season seem to be less pronounced in late 2016 compared to the years before.
- A reporting bug seems to have shifted Dutch Power Statistics data by one month in 2015, an error that did not reoccur in 2016.

It should be noted, however, that power system researchers regularly require long time series of data, such that the stark inconsistencies found during 2015 remain an issue for them.

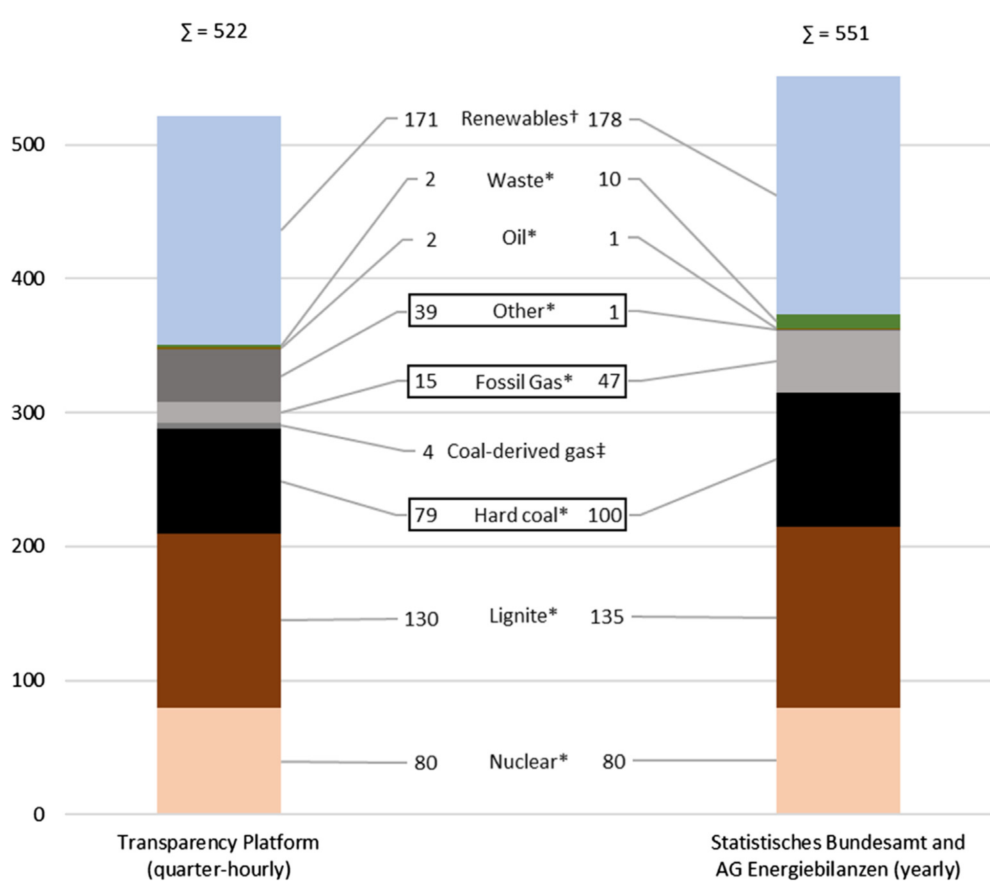

Fig. 6. Comparing "Aggregated Generation per Type" (16.1.B&C) with 2016 German generation data from Destatis and AG Energiebilanzen. TP reports noticeably smaller values for fossil gas and hard coal compared to other sources. *yearly data from Destatis, †yearly data from AG Energiebilanzen, ‡no equivalent in Destatis/AG Energiebilanzen.

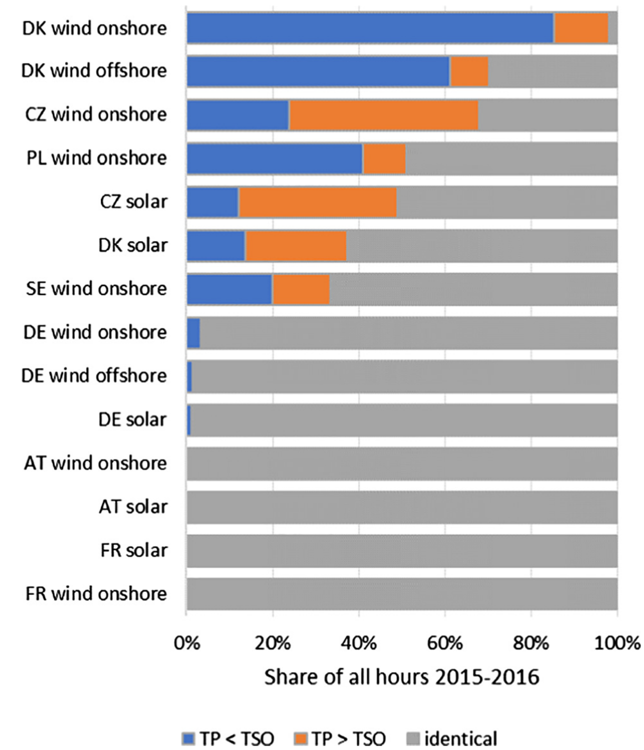

Fig. 7. Frequency of deviations of selected generation data between TP and TSOs. Some TSOs publish identical data on their websites and on the TP; others do not. All countries for which we have collected data are listed. The selection was made based on availability and user-friendliness of TSO data. Sometimes wind generation for one country is reported with up to two decimals precision in one source but as integers in the other. In order not to count this as a deviation, differences of up to 1 MW are regarded as identical.

4.3. Other data items

Within the data domain "Transmission", we evaluated the data items "Day-ahead Prices" (12.1.D) and "Scheduled Commercial Exchanges" (12.1.F). For both items, we only assessed completeness. "Scheduled Commercial Exchanges" is one of the patchier data items. For some time series, a year of data is missing, which is the case for some of the Italian, Lithuanian and Norwegian borders. Others exhibit frequent shorter gaps, e.g. borders between Bulgaria and Greece and their respective neighbours. Table 3 lists the 10 borders between bidding zones for which we found the least complete data. 51 borders (45%) had no data gaps.

"Day-ahead Prices" show fewer gaps than the other data items (see Table 4); however, there is only one complete time series of day-ahead prices (Spain). No price data are expected for bidding zones that have not introduced a power exchange. This was the case in Bulgaria (ESO BZ) and Croatia (HOPS BZ) prior to January/February 2016 and still is the case in Malta. However, Bulgaria reports prices only from November 2016 and Croatia not at all. Until March 2017, price data for Poland (PSE SA BZ) were not expected for hours with zero energy exchange with neighbouring countries, which was the case 25% of the time in 2015–2016. Overall, there is no trend of improvement over time.

From the "Balancing" data domain, the data item "Total Imbalance Volumes" (17.1.H), which is reported per market balance area, was chosen for analysis (see Table 5). The Finnish TSO Fingrid provides data from March 2015 onwards and has frequent gaps. Overall, however, completeness is better than in any other data item we assessed: for two-thirds of all balancing areas, fewer than 0.2% of all observations are missing. About one-quarter of all imbalance volume time series are complete.

5. Usability: issues and suggestions

Usability (or "user-friendliness") is different from completeness and consistency in the sense that it concerns the platform itself rather than the data contained in it. It is best assessed via a qualitative analysis. Therefore, we rely mostly on the user survey and the expert interviews. In this section, we discuss issues and suggest solutions.

5.1. Information, navigation, documentation

The issues. A recurring issue is the lack of accessible documentation. Some information on data definitions and data quality is available, but it is scattered throughout the website, cannot be found through search engines or is buried in PDF documents, sometimes as annexes to minutes of meetings. Moreover, the documentation leaves room for interpretation by Data Providers and confusion on the user side. One example is that the 100 MW reporting threshold for "Actual Generation per Generation Unit" (16.1.A) seems to be applied inconsistently—sometimes to entire power stations, in other cases to individual electricity generators.

Navigation on the website can feel unintuitive—e.g. spot prices are reported under transmission—and makes sense only once one knows the legal background of the TP. When navigating the website, one frequently encounters empty tables because many items are only

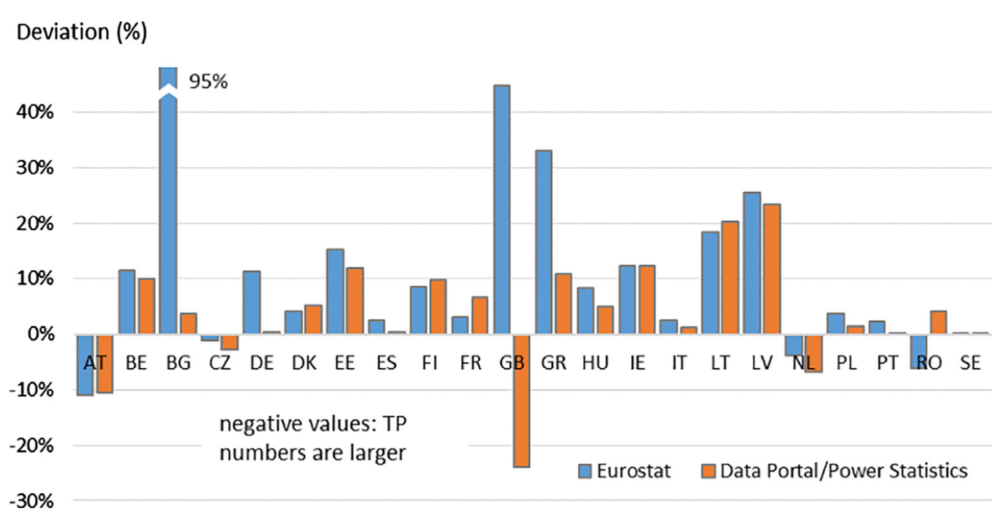

Fig. 8. Deviation of wind generation between TP and other sources. TP wind generation data (16.1.C) often deviate significantly from other sources (> 10%), including ENTSO-E Power Statistics.

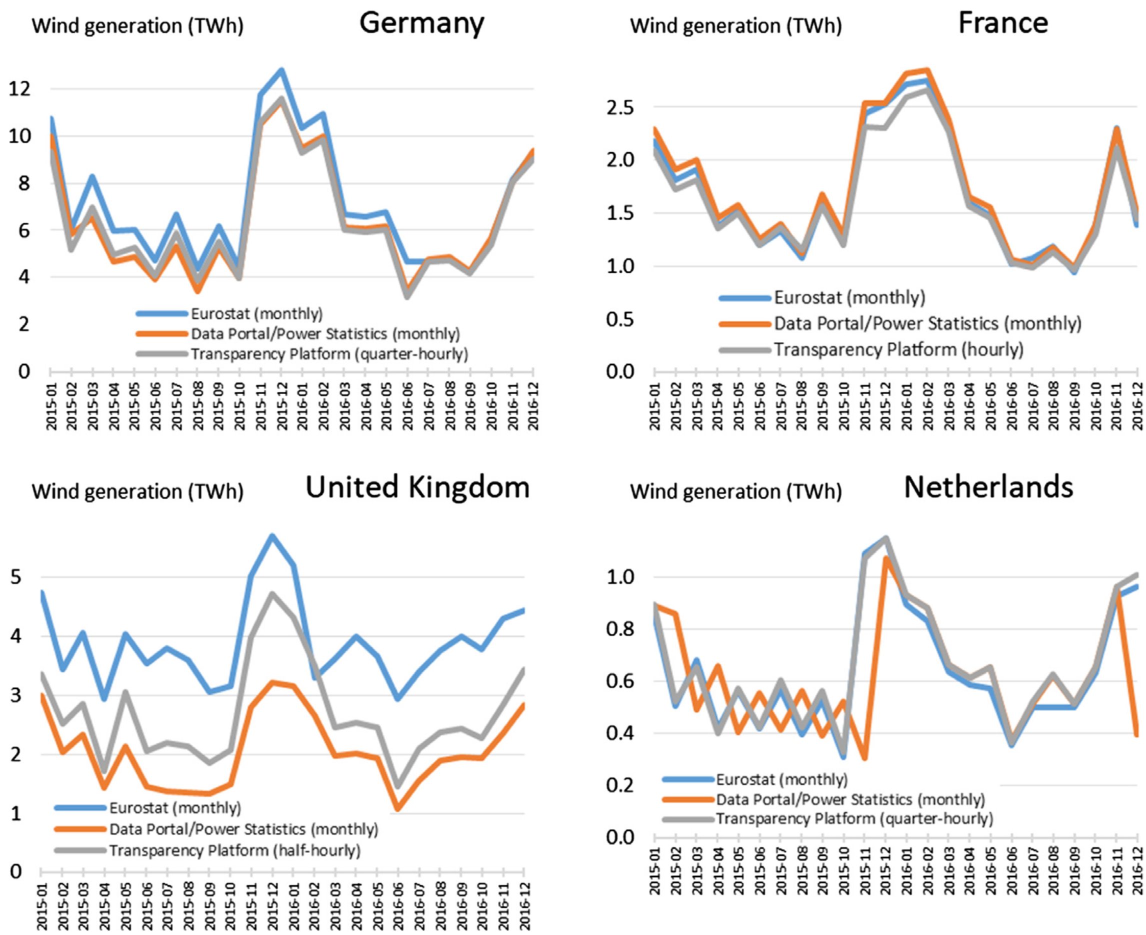

Fig. 9. Comparing TP wind generation data (16.1.C) with wind generation data from Eurostat and Power Statistics. Wind generation data show stark inconsistencies among sources for some countries, but also a general trend of improvement. Further country analyses are available on https://neon-energie.de/transparency-platform.

Table 3
Gaps in "Scheduled Commercial Exchanges" (12.1.F) by bidding zone border (10 borders with least coverage).

Bidding zone border	# of gaps	Share of obs. missing
NO5 → NO3	5	59%
NO3 → NO5	4	59%
TR → BG	16	26%
BG → TR	15	26%
GR → BG	10	24%
GR → AL	28	23%
UA → PL	2	12%
MK → BG	20	11%
BG → MK	19	11%
DE_AT_LU → SE4	5	8%

Table 4
Gaps in day-ahead prices by bidding zone. (12 bidding zones with least coverage).

Bidding zone	# of gaps	Share of obs. missing
HOPS BZ	1	100.0%
ESO BZ	11	93.8%
PSE SA BZ	775	25.4%
Elia BZ	3	1.1%
IT-Foggia BZ	3	1.1%
DE-AT-LU	2	1.0%
RTE BZ	2	1.0%
IT-Centre-South BZ	2	1.0%
IT-GR BZ	2	1.0%
IT-Sicily BZ	2	1.0%
Italy_Saco_AC	2	1.0%
Italy_Sacodc	2	1.0%

available for certain geographic frameworks (but the tables are displayed anyway). The TP does not publish the identity of Data Providers or Primary Data Owners.

Our proposals. Small changes could improve the usability of the platform considerably. Specifically, we propose the following:

- The landing page of the TP should explain the purpose of the TP and the fact that its existence, content and governance are specified in Regulation 543/3013.
- A complete list of all bidding zones, control areas, market balancing areas, borders, generation units, Data Providers and Primary Data Owners should be published (so-called "Master Data").
- Metadata, such as data sources and definitions, should be published in a machine-readable format. We recommend considering the Tabular Data Package [37] standard by Open Knowledge International.
- Users need to be informed which data are available. We propose a table showing the availability of each data item by geographic entity. Fig. 10 provides an example of such a data availability matrix from another data platform, Open Power System Data.

5.2. Download options

The issues. Users find it difficult to download the exact data they want. The website lacks filtering options and does not allow downloading data from more than one country at a time. Users report both the FTP and API to be useful (see Fig. 11), but both options are poorly documented. Several users report sluggish server response and frequent

Table 5
Gaps in “Total Imbalance Volumes” (17.1.H) by market balancing area (10 market balance areas with least coverage).

Bidding zone	# of gaps	Share of obs. missing
Litgrid MBA	74	19.7%
Fingrid MBA	281	15.0%
REN MBA	9	1.6%
IT-MACROZONE NORTH MBA	14	1.5%
MAVIR MBA	5	1.0%
IT-MACROZONE SOUTH MBA	10	0.8%
Sweden MBA	5	0.6%
Elering MBA	3	0.3%
RTE MBA	73	0.2%
TenneT NL MBA	23	0.2%

“time out” errors, an issue also reported by an ETUG user survey.

Our proposals. The GUI should allow downloading multiple countries at a time. Both FTP and API need to be documented in detail. The API should allow retrieving data in file formats other than XML. Acceptable server-response time and stability should be a priority.

5.3. Data quality reporting

The issues. There is no public reporting on data quality. It is impossible for users to judge completeness and consistency of data without extensive tests. This forces users to monitor data quality individually, significantly wasting resources (this very study might serve as an indicator how time-consuming data quality checks can be: it took 12 person-months to complete). When users encounter issues, there is no process to publicly flag missing information as a warning for other users. There is also no direct way of contacting Data Providers or Primary Data Owners. The only way to inform the Data Providers of gaps is through the ENTSO-E service desk, where it can take weeks or months to receive a response.

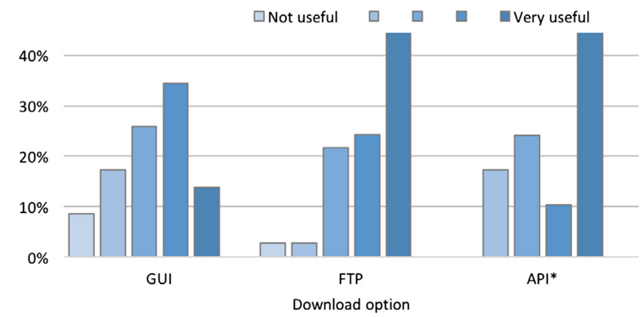

Fig. 11. Percentage of users rating usefulness of download options on a scale of 1–5. FTP and API download options were reported as very useful by nearly half of users. The asterisk indicates that fewer than 30 users responded to the question regarding the API download option.

Our proposal (1). We propose ongoing, regular and public data quality reporting. Completeness and timeliness of data delivery should be reported automatically. Consistency should be checked in regular manual assessments. The reports should be linked prominently on the TP landing page and be accessible from each data item directly. They should not only report problems, but also report the reason for the problem and identify the actor responsible for the issue. It is our understanding that automatic quality reporting is a capability the TP already has; however, at this point it is used only internally.

Our proposal (2). We propose establishing a public data error log. Registered users should be able to post an item on the list if they encounter issues with missing or inaccurate data. ENTSO-E, the Data Provider and other users could respond and comment; all comments are public. Once the issue is solved the service desk would flag the item as “solved”. The posting and comments remain online. Such a crowd-sourced public data log has multiple benefits:

	Time series				List of power plants		National generation capacity	Weather data
	Prices	Load	Wind	Solar	Renewable	Conventional		
AT	2015+	2006+	2015+	2015+				
BE	2015+	2006+	2015+	2015+				
CH	2015+	2007+	2015+	2015+	KEV plants	Hydro, nuclear		
CZ	2015+	2006+	2012+	2012+		> 100 MW		
DE	2005+	2006+	2012+	2012+	EEG plants	> 10 MW		
DK	2006+	2010+	2014+	2014+	Wind, solar			
ES	2015+	2006+	2015+	2015+				
FI	2015+	2010+	2015+	2015+				
FR	2015+	2006+	2015+	2015+				
IT	2015+	2006+	2015+	2015+				
NL	2015+	2006+	2015+	2015+				
NO	2006+	2006+	2015+	2015+		> 100 MW		
PL	2015+	2008+	2013+	2015+		Centrally dispatched units		
SE	2006+	2005+	2005+	2011+		> 100 MW		
UK	2015+	2011+	2015+	2015+				
20+ more								

Fig. 10. Data availability overview table from data platform Open Power System Data [38]. It should be noted that the TP is larger in size and dimensionality. In this example, all blue fields indicate existing data. These fields can be clicked and lead directly to the data.

- Users are warned about issues and can use data with additional care.
- Data providers are warned immediately about issues and have the chance to respond quickly. They also can explain that there is not an issue if that is the case.
- Other users can post solutions or explanations.
- A log creates transparency about structural problems and hence provides an incentive for Data Providers to improve the quality of their data and processes.

The combination of a user-reported data quality log and automatic reports would not fix all problems relating to data quality, but it would save users time and could help create accountability.

5.4. Governance, ownership and incentives

The issues. To us, the governance structure of the TP seems to be the underlying cause of many of the issues discussed above. Dispersed ownership and lack of incentives seem to lead to neglecting user needs. To us, it seems that responsibility and accountability are lacking:

- ENTSO-E points out that it maintains the technical database; all data quality issues are a matter for Data Providers.
- Data Providers are hard to contact and, to our knowledge, face no material incentives to improve quality.
- National Regulatory Authorities (NRAs) apparently lack the capacity or the incentive to monitor data quality properly and impose sanctions on non-complying Data Providers.
- ACER lacks the mandate and the capacity to monitor data quality continuously; ACER recommendations are not binding.

Our proposals. Building a useful power system data platform is a highly complex task. It can never be a one-shot project, but rather requires ongoing improvements. This is burdensome and costly. We recommend improving incentives through transparency and—ultimately—sanctions and adapting the governance structure to focus more on users' needs. We recommend that:

- ENTSO-E gets a clear mandate to specify data definitions further to improve consistency among Data Providers.
- Users be able to publicly report issues (see above).
- Data quality be systematically monitored, with reporting by Data Providers and all monitoring reports made public (see above).
- NRAs receive yearly reports about compliance of all Data Providers of their jurisdiction. These reports should be public as well.
- At some point, Data Providers face monetary sanctions for non-compliance with quality requirements and submission deadlines. If NRAs are responsible for imposing such sanctions, the size of the penalties should be public.
- The ENTSO-E Transparency User Group (ETUG), representing the users of the platform, should be formalized and its role expanded.
- Users beyond market participants—in particular, civil society and academia—be represented formally in ETUG.

6. Conclusions

The objective of this study was to evaluate the ENTSO-E Transparency Platform. The platform is a highly ambitious project with the goal of publishing most relevant European power system data in one single place.

Significant effort has already been made to set up and improve the platform. Despite improvements, we have identified a number of shortcomings. To become truly useful for industry users and researchers, both data quality and usability have to improve further. To us, it seems that the governance and incentive structures lie behind most of the problems. By providing this analysis and suggesting the above improvements, we hope that we can help the TP become even more useful for its users.

Acknowledgements

This paper is based on parts of a study commissioned by the European Commission entitled "Study on the quality of electricity market data of transmission system operators, electricity supply disruptions, and their impact on the European electricity markets" (ENER/44/2016.689/SER/SI2.754918). Our contribution to that study - the assessment of the Transparency Platform - can be accessed through https://ec.europa.eu/energy/sites/ener/files/documents/review_of_the_entso_e_plattform.pdf and through https://neon-energie.de/transparency-platform/.

We would like to thank our interview partners and survey participants for participation and ENTSO-E staff, DG ENER staff as well as three anonymous reviewers for their comments. All remaining errors are ours.

Appendix A

A.1. List of data items

See Table 6.

Table 6
Overview of data items available on the ENTSO-E TP.

Category on TP website	Article in Regulation 543/2013	Data item (49 in total)
Load	6.1.A	Actual Total Load
	6.1.B	Day-ahead Total Load Forecast
	6.1.C	Week-ahead Total Load Forecast
	6.1.D	Month-ahead Total Load Forecast
	6.1.E	Year-ahead Total Load Forecast
	8.1	Year-ahead Forecast Margin
Generation	14.1.A	Installed Generation Capacity Aggregated
	14.1.B	Installed Generation Capacity per Unit
	14.1.C	Day-ahead Aggregated Generation
	14.1.D	Day-ahead Generation Forecasts for Wind and Solar
	16.1.A	Actual Generation per Generation Unit
	16.1.B	Aggregated Generation per Type
	16.1.C	Aggregated Generation per Type
	16.1.D	Aggregate Filling Rate of Water Reservoirs and Hydro Storage Plants

(*continued on next page*)

Table 6 (*continued*)

Category on TP website	Article in Regulation 543/2013	Data item (49 in total)
Transmission	9.1	Expansion And Dismantling Projects
	11.1.A	Forecasted Day-ahead Transfer Capacities
	11.1.B	Day Ahead Flow Based Allocations
	11.3	Cross-border Capacity for DC Links
	11.4	Yearly Report About Critical Network Elements Limiting Offered Capacities
	12.1.A	Explicit Allocations - Use of the Transfer Capacity
	12.1.B	Total Nominated Capacity
	12.1.C	Total Capacity Already Allocated
	12.1.D	Day-ahead Prices
	12.1.E	Implicit Allocations - Net Positions
	12.1.F	Scheduled Commercial Exchanges
	12.1.G	Physical Flows
	12.1.H	Transfer Capacities Allocated with Third Countries
Balancing	17.1.A	Rules on Balancing
	17.1.B	Amount of Balancing Reserves Under Contract
	17.1.C	Price of Reserved Balancing Reserves
	17.1.D	Accepted Aggregated Offers
	17.1.E	Activated Balancing Energy
	17.1.F	Prices of Activated Balancing Energy
	17.1.G	Imbalance Prices
	17.1.H	Total Imbalance Volumes
	17.1.I	Financial Expenses and Income for Balancing
	17.1.J	Volumes of Exchanged Bids and Offers
Outages	7.1.A	Planned Unavailability of Consumption Units
	7.1.B	Changes in Actual Availability of Consumption Units
	10.1.A	Planned Unavailability in the Transmission Grid
	10.1.B	Changes in Actual Availability in the Transmission Grid
	10.1.C	Changes in Actual Availability of Off-shore Grid Infrastructure
	15.1.A	Planned Unavailability of Generation Units
	15.1.B	Changes in Actual Availability of Generation Units
	15.1.C	Planned Unavailability of Production Units
	15.1.D	Changes in Actual Availability of Production Units
Congestion management	13.1.A	Redispatching
	13.1.B	Countertrading
	13.1.C	Costs of Congestion Management

A.2. Questions in online user survey

See Table 7.

Table 7
Questions in online user survey.

Part I: Introduction

- Which data domains from the Transparency Platform have you used?
- Do you rely on Transparency data to make business decisions?
- What do you use Transparency data for? [Fundamental power system modelling/Econometric analysis/Statistical analysis/Other (write-in)]
- Approximately how frequently do you download data from the Transparency Platform? [Rarely—I do so a couple of times each year/Regularly—I do so a couple of times each month/Frequently—I do so several times each day/Other (write-in)]
- How experienced are you with analysing (downloaded) Transparency Platform data? [Not very—I use the data rarely/Somewhat—I use the data on a monthly basis/Very—I use the data everyday/Other (write-in)]

Part II: Completeness

- Are there missing observations or gaps in the data? [There are many gaps/There are some gaps/There are no gaps/I'm not sure]
- Please specify any incompleteness issues regarding gaps in the data by time series and/or geographic area.
- Are there any types of data not currently available that you would like to see provided on the Transparency Platform?

Part III: Accuracy

- Do you find data on the platform to be accurate (correct)? [Most values seem implausible/Some values seem implausible/Data seems correct/I'm not sure]
- Please specify any inaccuracies and to which data they are related.
- Do you find Transparency Platform data to be inconsistent with other sources? If so, which data and which other sources?

Table 7 (*continued*)

Part IV: Timeliness

- Within what timeframe do you need electricity market data? [Intraday/Within one week/Within one month/Other (write-in)]
- Do you find data on the platform to be available when you need it? [Data is rarely available when I need it/Data is usually available when I need it/Data is always available when I need it/I'm not sure]
- Please specify any timeliness issues and to which data they are related.
- Are historical data being updated with more recent data?
- Are data updated in a way such that useful legacy data are overwritten?
- Please specify any issues with updates and to which data they are related.

Part V: User-friendliness

- Is finding data on the Platform unintuitive or intuitive [scale of 1–5]?
- Do you have any suggestions for making the Platform more user-friendly?
- Do you find server response waiting times to be slow or fast [scale of 1–5]?
- Are you aware of the following options for accessing data (Website GUI, FTP server, Restful API, Data repository, Subscriptions, Web services, ECP)? [Not aware of/Aware of but have not used/Have used]
- Why did you choose your current method of accessing the data? [Only option I was aware of/Other (write-in)]
- Please rate the usefulness of the following methods for accessing data: website GUI, FTP server, Restful API [scale of 1–5].
- Linked here is the data documentation. Were you already aware of this documentation?
- Do you find the documentation to be of sufficient quality?
- Is there something missing from the data documentation?
- Are you aware of the data licence for information obtained from the Platform?
- Has data licensing prevented you from using the data for any purpose?

Part VI: Wrapping up

- What suggestions do you have for Neon regarding improving the Platform?
- Any additional comments or concerns?
- How experienced would you consider yourself in using the Transparency Platform? Limited experience or expert [scale of 1–5]?
- Do you have any suggestions of other Platform users who might be interested in joining us for an interview?
- Type of institution [Research/Consulting/Industry/NGO or journalism/Other (write-in)]

A.3. List of interview partners

See Table 8.

Table 8
List of interview partners.

Name	Institution	Sector
Jan Abrell	ETH Zürich	Academia
Lissy Langer	TU Berlin	Academia
Jens Weibezahn	TU Berlin	Academia
Florian Ziel	University Duisburg-Essen	Academia
Paul-Frederik Bach	Freelance consultant	Consulting
Philip Hewitt	EnAppSys	Data service provider
Olivier Corradi	Tomorrow	Data service provider
Talia Parisi	Genscape	Data service provider
Ralf Uttich	RWE	Industry
Christian Bärwolf	LEAG	Industry
Jens Wimschulte	Vattenfall	Industry
Chris Münster	Vattenfall	Industry
Tobias Schulz	Vattenfall	Industry
Sigurd Pedersen	DONG Energy	Industry
Dave Jones	Sandbag	NGO
Antonella Battaglini	Renewables Grid Initiative	NGO
Thorsten Lenck	Agora Energiewende	NGO
Mara Marthe Kleiner	Agora Energiewende	NGO
Rafael Muruais-Garcia	ACER	Policy
Marcus Mittendorf	EEX	Power exchange & data service provider
Katrin Petri	EEX	Power exchange & data service provider
Filippo Pirovano	EDF Trading	Trading

Notes: One interviewee did not consent to being identified by name; thus, 22 names are listed.

During the project, a workshop with members of DG ENER—Balazs Josza, Andras Hujber and Mathilde Carbonnelle—and ENTSO-E—Mark Csete, Dalius Sulga, Tomas Sumskas and Cris Cotino—was held with the intention of receiving feedback on our preliminary findings. The discussions further informed this article.

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