elec-sys-data

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README

Welcome to the ml-elec-model wiki!

by nmstreethran at gmail dot com

This project is a work-in-progress. Feedback and suggestions are always welcome. Please open an issue or refer to the contributing guidelines in the main repository if you would like to contribute.

Machine learning-based electricity system model.

Requirements

- Python 3
- Git
- ENTSO-E API Python client

Documentation

Documentation is written in the repository's GitHub Wiki. The files can also be found in the folder.

Cloning the repository

To clone the latest version of this repository, including the contents of the submodule:

Using HTTPS

```
git clone --recurse-submodules https://github.com/nmstreethran/ml-elec-model.git
```

Using SSH

```
git clone --recurse-submodules git@github.com:nmstreethran/ml-elec-model.git
```

The GitHub wiki has been included in this repository as a submodule. Once changes to the wiki within the submodule are made (e.g., new markdown files, images), these changes are first committed and pushed to the wiki's branch, before committing and pushing to the main repository's branch.

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This repository is a continuation and improvement of the work done by nmstreethran in ENSYSTRA/short-term-forecasting.

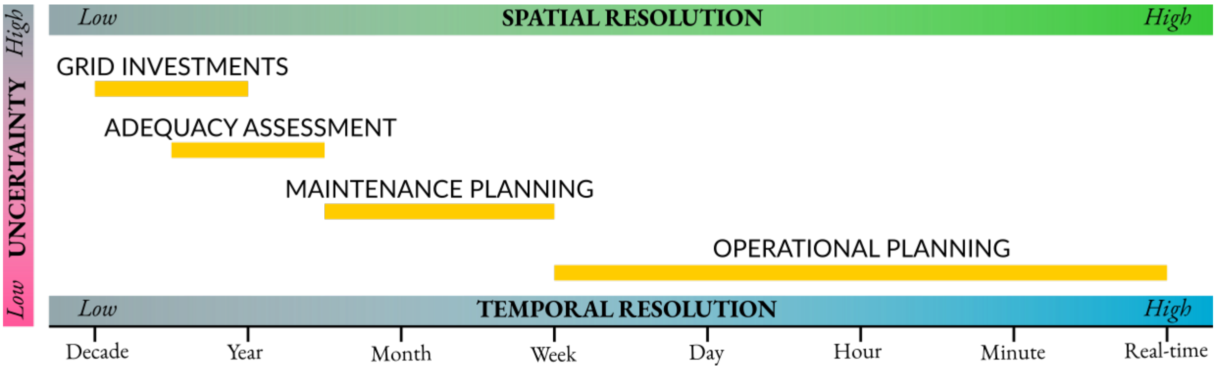
Contributing guidelines is adapted from the Open Science MOOC. The contents of the MOOC are licensed under a Creative Commons Zero v1.0 Universal License.

Background

Electricity system

The electricity system can be seen as having two components; the physical grid consisting of generators and transmission and distribution systems, and the electricity market consisting of a number of actors.

Electricity systems exist in different resolutions and levels of uncertainty. The figure below represents the different scales of electricity systems, mainly in terms of temporal resolution, but also uncertainty and spatial resolution. Temporally, "real-time" is referred to as the time of dispatch. It can be observed that the operational planning scale has high spatial and temporal resolution, and relatively low uncertainty. Operational planning includes dispatch planning and plant scheduling (i.e., unit commitment), which ranges from a few minutes to a week before dispatch. Maintenance planning can take a few weeks to years, as it involves upgrade and maintenance work which may require shut-down of units or assets, in turn affecting the availability of generation units and grid infrastructure. Adequacy assessments, which takes years, involve assessing the existing generation and storage capacities and planning for new installations based on demand projections, to ensure this demand will be met in the future. Finally, grid investment decisions, including planning transmission and distribution grid networks, cross-border and regional interconnections and grid capacity expansions, take many years to decades and have very high uncertainty as a result.



The various scales of electricity systems in terms of their approximate temporal resolution, as well as spatial resolution and uncertainty, adapted from Glismann 2018 and Pfenninger, et al. 2014.

Generation technologies

The table below shows the characteristics of the main energy generation technologies, including their costs. These generation sources have different variabilities, fuel types, flexibilities, costs and carbon emissions. According to the EU reference scenario 2016, wind and solar energy resources, which are variable renewable energy (VRE) resources, are expected to generate a total of 35 % of EU's electricity by 2050, which is a significant increase (23 %) from 2015 levels. Conversely, generation from nuclear and solids, which are not variable and provide base load generation, are expected to decrease significantly. Unlike conventional generators, VRE are intermittent as they are dependent on atmospheric conditions, such as wind speed and cloud cover, and they vary both spatially (i.e., location-dependent) and temporally. Therefore, VRE generation cannot be controlled to meet the demand patterns and needs of the energy system, which is a challenge to electricity and energy system operators in general. The costs listed in this table are derived based on National Renewable Energy Laboratory (NREL)'s NREL-SEAC 2008 Data Set. VRE generation technologies have high capital expenditure (CAPEX) compared to conventional fossil-powered and biomass generation. Conversely, the operational expenditure (OPEX), which includes fuel and fixed operational and maintenance (O&M) costs, is low for VRE generation technologies, as they have no fuel costs unlike conventional generators.

Characteristics of the main energy generation technologies, adapted from Erbach 2016 and Tidball, et al. 2010.

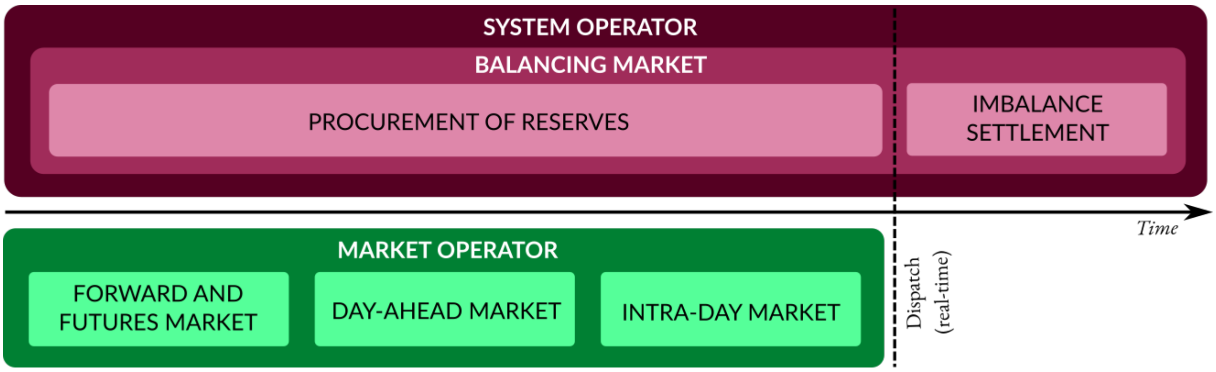
Type[1]	**Variable**	**Fuel type**	**Flexibility**	**Low carbon**	**CAPEX**	**OPEX**	**LCOE**[2]
Coal	no	fossil	medium	no	low	high	very low
Natural gas	no	fossil	high	no	very low	very high	low
Biomass	no	renewable	medium	yes[3]	low	very high	very high
Nuclear	no	nuclear	low	zero-emission	medium	medium	medium
Hydro	no	renewable	very high	zero-emission			
Solar	yes	renewable	very low	zero-emission	very high	very low	very high
Wind	yes	renewable	very low	zero-emission			

Type[1]	Variable	Fuel type	Flexibility	Low carbon	CAPEX	OPEX	LCOE[2]
Onshore wind					high	very low	very low
Offshore wind					very high	low	high
Geothermal	no	renewable	high	zero-emission	high	medium	high

Electricity market

The actors in the electricity market include generators, retailers, large and small consumers, transmission system operators (TSOs), distribution network operators (DNOs), balance responsible parties (BRPs), aggregators, regulators, and market operators.

There are two types of electricity markets; the retail market and the wholesale market. The retail market involves the retailers buying electricity from generators and selling it to consumers. The wholesale market involves generators, retailers and (large) consumers, who buy and sell electricity. Energy-only transactions in the wholesale market have different temporal resolutions and take place before dispatch, shown in green in the figure below. Balancing markets, shown in pink in the figure, which involve both energy and services, operate both before and after dispatch. The energy-only markets are operated by the market operator or power exchanges, while the balancing market is operated by the system operator. The day-ahead and intra-day markets can be considered short-term electricity markets, as the former takes place 24 hours in advance of dispatch, while the latter takes place continuously after the day-ahead market, up to minutes before dispatch.



The various electricity markets in terms of operator and temporal resolution, before and after dispatch, adapted from KU Leuven Energy Institute 2015 and Pinson 2018.

In short-term electricity market auctions, such as the day-ahead market auction, generating companies have the incentive to bid as low as possible, as the supply bids are ranked in ascending order of price. Conversely, on the demand side, consumers have the incentive to bid as high as possible, as the demand bids are ranked in descending order of price. These two curves form a so called merit order, and the intersection between these two curves is the equilibrium point. The price at this equilibrium point is the market clearing price, which is what all accepted bids will receive, regardless of their initial bid. All supply and demand bids to the left of the equilibrium point will be accepted, and those to the right are rejected.

In the case of generating companies, the OPEX of their generators determine the price at which it is bid. For conventional power plants, this OPEX includes fuel costs and carbon costs (except nuclear power plants). For solar and wind power plants, the OPEX is close to zero, as they do not require fuel to run. The revenue received by generating companies in the day-ahead market for each power plant contributes towards their CAPEX. Since conventional power plants have relatively low CAPEX, and fuel costs are high, the main decision generating companies have to make in short-term electricity markets is whether it is economical to run these power plants. For solar and wind power plants, which have relatively high CAPEX, companies are interested in getting as many bids accepted and as much of the electricity generated sold as possible.

References

1. G. Erbach, "Understanding electricity markets in the EU," European Union, Briefing, November 2016.
2. S. Glismann, "Modelling from a TSO Perspective - TenneT NL," 6 September 2018.

[1] *Costs for natural gas, biomass, solar and geothermal are that of advanced combustion turbine, biomass gasification plant, utility-scale photovoltaic and hydrothermal plant respectively.*
[2] *LCOE - levelised cost of electricity.*
[3] *Regrowth of biomass compensates emissions.*

3. S. Pfenninger, A. Hawkes, and J. Keirstead, "Energy systems modeling for twenty-first century energy challenges," Renewable and Sustainable Energy Reviews, vol. 33, pp. 74–86, May 2014.
4. "Energy modelling - EU Reference Scenario 2016."
5. P. L. Joskow, "Comparing the Costs of Intermittent and Dispatchable Electricity Generating Technologies," American Economic Review, vol. 101, no. 3, pp. 238–241, May 2011.
6. R. Tidball, J. Bluestein, N. Rodriguez, S. Knoke, and J. Macknick, "Cost and Performance Assumptions for Modeling Electricity Generation Technologies," National Renewable Energy Laboratory, Subcontract Report NREL/SR-6A20-48595, 2010.
7. P. Pinson, "Renewables in Electricity Markets."
8. "The current electricity market design in Europe," KU Leuven Energy Institute, Heverlee, Belgium, January 2015.
9. "Overview of European Electricity Markets," European Union, Brussels, Belgium, February 2016.

Regions

Territories

The nomenclature of territorial units for statistics (NUTS) classifies territorial units in Europe in different levels:

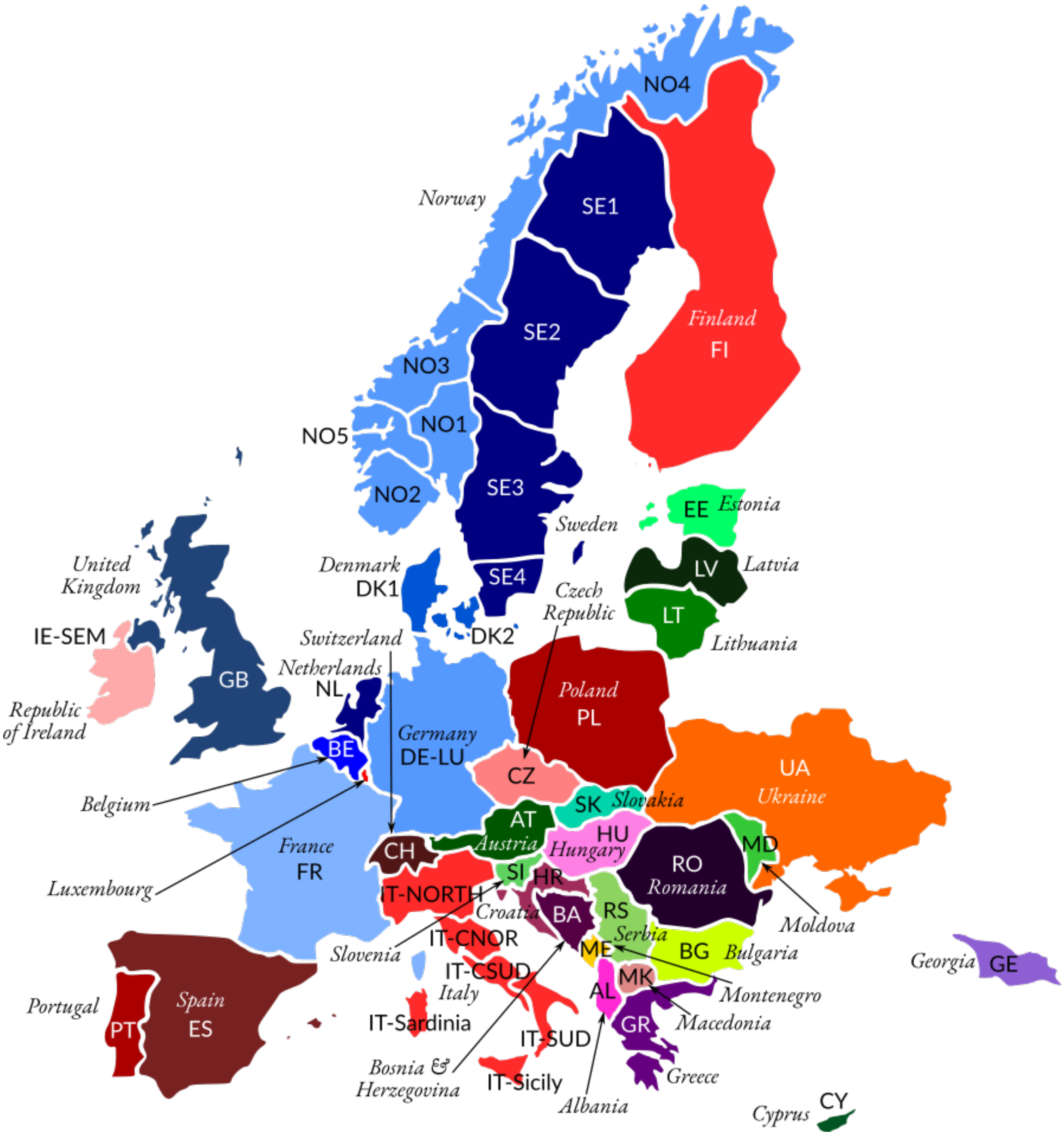
- NUTS 0: country-level
- NUTS 1: major socio-economic regions
- NUTS 2: basic regions for the application of regional policies
- NUTS 3: small regions for specific diagnoses

Bidding zones

A bidding zone is the largest geographical area within which market participants are able to exchange energy without capacity allocation. There are three types of bidding zones:

1. national borders (e.g., France or the Netherlands) - majority of bidding zones in Europe
2. larger than national borders (e.g., Germany and Luxembourg or the Single Electricity Market for the island of Ireland)
3. smaller zones within individual countries (e.g., Italy, Norway or Sweden)

The bidding zones in European electricity markets and surrounding regions are illustrated in the map below.



Bidding zones in Europe. This map is created using the base map with bidding zone borders from ENTSO-E Transparency Platform's cross-border physical flow map as a guide.

The table below below lists bidding zones in Europe by country and market operator.

Bidding zones and market operators in Europe. Country codes in brackets are according to ISO_3166-1 alpha-2.

Country	Markets	Zones
Albania (AL)		AL
Bosnia and Herzegovina (BA)		BA
Belgium (BE)	Belpex	BE
Bulgaria (BG)		BG
Switzerland (CH)		CH
Cyprus (CY)		CY
Czech Republic (CZ)		CZ
Germany (DE)	EEX, EPEX	DE-LU
Denmark (DK)	EEX, Nord Pool	DK1, DK2
Estonia (EE)		EE
Spain (ES)		ES
Finland (FI)		FI
France (FR)	EEX, EPEX	FR
Georgia (GE)		GE
Greece (GR)		GR

Country	Markets	Zones
Croatia (HR)		HR
Hungary (HU)		HU
Republic of Ireland (IE)		IE-SEM
Italy (IT)		IT-CNOR, IT-CSUD, IT-NORTH, IT-Sardinia, IT-Sicily, IT-SUD
Lithuania (LT)		LT
Luxembourg (LU)		DE-LU
Latvia (LV)		LV
Moldova (MD)		MD
Montenegro (ME)		ME
North Macedonia (MK)		MK
Netherlands (NL)	APX	NL
Norway (NO)	EEX, Nord Pool	NO1, NO2, NO3, NO4, NO5
Poland (PL)		PL
Portugal (PT)		PT
Romania (RO)		RO
Serbia (RS)		RS
Sweden (SE)	EEX, Nord Pool	SE1, SE2, SE3, SE4
Slovenia (SI)		SI
Slovakia (SK)		SK
Ukraine (UA)		
United Kingdom (UK)	APX, N2EX	GB, IE-SEM

The United Kingdom is comprised of Great Britain (GB) and Northern Ireland. Northern Ireland is part of the Single Electricity Market of the island of Ireland (IE-SEM), which it shares with the Republic of Ireland (IE). Prior to 01/10/2018, Germany was part of the DE-AT-LU bidding zone, together with Austria (AT) and Luxembourg (LU), which had split into the DE-LU and AT bidding zones, as reported by European Network of Transmission Systems Operators for Electricity (ENTSO-E) below:

> *[...] DE-AT-LU bidding zone split on the 23rd of August. BZN|DE-AT-LU will be separated into 2 new bidding zones BZN|DE-LU and BZN|AT.*
>
> *New bidding zones will be active from the 1st of October, however, first data submissions, like month ahead forecasts, are expected from the 1st of September.*
>
> *Validity end date for BZN|DE-AT-LU is the end of September 2018. [...]*

Mapping bidding zones to NUTS 3 territories is straightforward for Belgium, Germany, France and Netherlands (bidding zone type 1 or 2) – all NUTS 3 territories in these countries have the same bidding zone.

Denmark and United Kingdom are both conveniently separated into two zones that are easily distinguishable. For Denmark, these are Western Denmark (NUTS IDs containing DK03-DK05) and Southern Denmark (NUTS IDs containing DK01-DK02). For United Kingdom, these are Great Britain (NUTS IDs containing UKC-UKM) and Northern Ireland (NUTS IDs containing UKN).

There is no clear indication of the bidding zone boundaries for Norway and Sweden, so some assumptions were made. Both countries have multiple smaller bidding zones (type 3) with flexible borders. This was done to optimise allocation of resources and reduce the overall price of electricity. Norway has five zones and Sweden has four zones. By cross-referencing Nord Pool market data, NUTS 3 data and county maps of Norway and Sweden, the territories are split into the bidding zones as shown in the table below. Nord Pool associates each bidding zone with a major reference city in that zone. However, there were six cities for Norway instead of the expected five. Historical Nord Pool market data for Norway suggests that two cities, Trondheim and Molde, have had the same system price since 2003. The ELSPOT area change log also confirms that Trondheim and Molde are city references for the NO3 bidding zone. Therefore, these two cities are grouped into the same bidding zone, which also satisfies what the maps suggest.

Bidding zones and their territories for Norway and Sweden, approximated based on Nord Pool market data, NUTS 3 data and county maps of Norway and Sweden.

Bidding zone	Reference cities	Counties	NUTS 3 IDs
NO1	Oslo	Oslo, Akershus, Hedmark, Oppland, Østfold, Buskerud, Vestfold, Telemark	NO011-034
NO2	Kristiansand	Aust-Agder, Vest-Agder, Rogaland	NO041-043
NO3	Trondheim, Molde	Sogn og Fjordane, Møre og Romsdal, Trøndelag	NO052-060
NO4	Tromsø	Nordland, Troms, Finnmark	NO071-073
NO5	Bergen	Hordaland	NO051
SE1	Luleå	Norrbotten	SE332

Bidding zone	Reference cities	Counties	NUTS 3 IDs
SE2	Sundsvall	Gävleborg, Västernorrland, Jämtland, Västerbotten	SE313-331
SE3	Stockholm	Stockholm, Uppsala, Södermanland, Östergötland, Örebro, Västmanland, Jönköping, Gotland, Västra Götaland, Värmland, Dalarna	SE110-211, SE214, SE232-312
SE4	Malmö	Kronoberg, Kalmar, Blekinge, Halland, Skåne	SE212-213, SE221-231

Transmission system operators and interconnections

Europe has multiple TSOs and cross-border interconnections. These are listed, along with the bidding zones, in the table below.

TSOs and cross-border interconnections in Europe. Data: European Network of Transmission System Operators for Electricity.

Country	TSOs	Cross-border interconnections	Bidding zones
BE	Elia System Operator	FR, LU, NL, UK	BE
DK	Energinet	DE, NO, SE	DK1, DK2
DE	TransnetBW, TenneT TSO, Amprion, 50Hertz Transmission	AT, CH, CZ, DK, FR, LU, NL, PL, SE	DE-LU
FR	Réseau de Transport d'Electricité	BE, CH, DE, ES, IT, UK	FR
NL	TenneT TSO	BE, DE, NO, UK	NL
NO	Statnett	DK, FI, NL, SE	NO1, NO2, NO3, NO4, NO5
SE	Svenska Kraftnät	DK, FI, DE, LT, NO, PL	SE1, SE2, SE3, SE4
UK	National Grid Electricity Transmission, System Operator for Northern Ireland, Scottish Hydro Electric Transmission, ScottishPower Transmission	BE, FR, IE, NL	GB, IE-SEM

References

1. "NUTS - Nomenclature of territorial units for statistics - Eurostat."
2. "Bidding Zones Literature Review," Ofgem, July 2014.
3. "Data view - Cross-Border Physical Flow - ENTSO-E Transparency Platform."
4. "Power | Statkraft."
5. "See market data for all areas | Nord Pool."
6. "EPEX SPOT SE: About EPEX SPOT."
7. "DE-AT-LU Bidding zone split - News - ENTSO-E Transparency Platform."
8. "European Commission - PRESS RELEASES - Press release - Antitrust: Commission increaseselectricity trading capacity on the Swedish borders," 14 April 2010.
9. "List of changes in day-ahead and intraday areas," Nord Pool.
10. "Counties of Norway," Wikipedia. 2 April 2019.
11. "Counties of Sweden," Wikipedia. 11 February 2019.
12. "ENTSO-E Transparency Platform."
13. "Regional Security Coordinators FAQ."
14. "Overview of European Electricity Markets," European Union, Brussels, Belgium, February 2016.

ENTSO-E data

Generation and load data

Generation and load data for each bidding zone are downloaded from the ENTSO-E Transparency Platform (ENTSO-E TP). The descriptions of the data are adapted from ENTSO-E Transparency Platform's Knowledge Base. ENTSO-E TP aggregates data by following electricity production types:

- Biomass
- Fossil brown coal/lignite
- Fossil gas
- Fossil hard coal
- Fossil oil

- Geothermal
- Hydro pumped storage
- Hydro run-of-river and poundage
- Hydro water reservoir
- Nuclear
- Other
- Other renewable
- Solar
- Waste
- Wind offshore
- Wind onshore

Actual generation per production type

This dataset is the actual net electricity generation output in MW, aggregated by production type for each bidding zone per market time unit. These are available at different resolutions depending on the country, which is summarised below.

Temporal resolution of actual generation per production type dataset by country:

- 15 minutes: AT, DE, HU, LU, NL
- 30 minutes: CY, IE, UK
- 1 hour: BA, BE, BG, CH, CZ, DK, EE, ES, FI, FR, GE, GR, HR, IT, LT, LV, ME, MK, NO, PL, PT, RO, RS, SE, SI, SK

Each data point represents the average of all available instantaneous net generation output values on each market time unit. The values are estimated if unknown. The actual outputs of small-scale generating units may be estimated if there are no real-time measurements from these units. The data are published on ENTSO-E TP no later than one hour after the operational period.

Installed capacity per production unit

This dataset contains information about production units (existing and planned) with an installed generation capacity of at least 100 MW, which includes the following:

- unit name
- code
- installed net generation capacity (MW)
- voltage connection level (kV)
- bidding zone (denoted using Energy Identification Codes (EICs))
- production type (e.g., fossil gas, wind offshore)

This information is published annually on ENTSO-E TP at the start of the year and is valid for the three following years.

Load

This dataset represents the actual total load in MW per bidding zone per market time unit. These are available at different resolutions depending on the country, which is summarised in below.

Temporal resolution of electricity load dataset by country:

- 15 minutes: AL, BE, DE, HU, LU, NL
- 30 minutes: CY, IE, UK
- 1 hour: AT, BA, BG, CH, CZ, DK, EE, ES, FI, FR, GE, GR, HR, IT, LT, LV, MD, ME, MK, NO, PL, PT, RO, RS, SI, SK, SE, UA

The total load is defined as equal to the sum of power generated by plants on both TSO and DNO networks, from which the following are deduced:

- the balance (export-import) of exchanges on interconnections between neighbouring bidding zones
- the power absorbed by energy storage resources

The load is calculated using the average of real-time load values per bidding zone per market time unit.

```
Actual total load (including losses without stored energy)
= Net generation – Exports + Imports – Absorbed energy
```

For these calculations, the net generation is preferred. However, gross generation may be used if it is available with the better precision. The TSOs responsible for each area decide whether to use gross or net generation, but they are required to keep their choice consistent per bidding zone. Absorbed energy is also provided as separate information with the aggregated generation output of the hydro pumped storage. The physical flow on the tie line is measured as agreed by neighbouring TSOs or bidding zones, where applicable. This dataset is published on ENTSO-E TP no later than one hour after the end of the operating period.

Automating the data extraction process

The ENTSO-E TP has a dashboard with various electricity system data tables and visualisations available to the public. All users must first accept the platform's terms and conditions and privacy policy before gaining access to the dashboard. However, in order to export datasets in various formats (such as `.csv` and `.xml`), as well as gain additional functionalities, it is required to register for a free account on ENTSO-E TP. ENTSO-E TP's Restful application programming interface (API) can then be used to automate the data extraction process (see the API implementation and user guides for more info). Once a free account has been created, request for a security token to access the API by sending an email to the ENTSO-E TP Helpdesk (transparency at entsoe dot eu), stating 'Restful API access' in the subject and the email address used to register for the account. Once granted, the security token can be viewed via account settings.

The ENTSO-E API Python client is used to easily query the required data and return them as Pandas dataframes or series. The queries for generation and installed generation capacity per unit return dataframes, while the query for load returns a series. `entsoe-api.py` is the script used to perform this.

```python
import pandas as pd
from entsoe import EntsoePandasClient
from entsoe.mappings import DOMAIN_MAPPINGS, BIDDING_ZONES
# combine domain and bidding zone keys and values into the
# DOMAIN_MAPPINGS dictionary
DOMAIN_MAPPINGS.update(BIDDING_ZONES)
```

The bidding zones in Europe, mapped to their corresponding EICs as shown in the table below, are used when querying using the Pandas client. Note that `DE-LU` only works for timestamps starting 01/10/2018. Use `DE-AT-LU` for timestamps prior to this date.

Bidding zones in Europe and their corresponding EICs.

Zone name	Bidding zone	EIC
Albania	AL	10YAL-KESH—-5
Belgium	BE	10YBE———-2
Bosnia and Herzegovina	BA	10YBA-JPCC—-D
Bulgaria	BG	10YCA-BULGARIA-R
Switzerland	CH	10YCH-SWISSGRIDZ
Cyprus	CY	10YCY-1001A0003J
Czech Republic	CZ	10YCZ-CEPS—-N
Germany and Luxembourg	DE-LU	10Y1001A1001A82H
Western Denmark	DK-1	10YDK-1——-W
Eastern Denmark	DK-2	10YDK-2——-M
Estonia	EE	10Y1001A1001A39I
Spain	ES	10YES-REE——0
Finland	FI	10YFI-1——-U
France	FR	10YFR-RTE——C
Georgia	GE	
Great Britain	GB	10YGB———-A
Greece	GR	10YGR-HTSO—-Y
Croatia	HR	10YHR-HEP——M
Hungary	HU	10YHU-MAVIR—-U
Ireland (Single Electricity Market)	IE-SEM	10Y1001A1001A59C
Centre-North, Italy	IT-CNOR	10Y1001A1001A70O
Centre-South, Italy	IT-CSUD	10Y1001A1001A71M
North, Italy	IT-NORTH	10Y1001A1001A73I
Sardinia, Italy	IT-Sardinia	10Y1001A1001A74G
Sicily, Italy	IT-Sicily	10Y1001A1001A75E
South, Italy	IT-SUD	10Y1001A1001A788

Zone name	Bidding zone	EIC
Lithuania	LT	10YLT-1001A0008Q
Latvia	LV	10YLV-1001A00074
Moldova	MD	
Montenegro	ME	10YCS-CG-TSO—S
North Macedonia	MK	10YMK-MEPSO—-8
Netherlands	NL	10YNL———-L
Oslo, Norway	NO-1	10YNO-1——–2
Kristiansand, Norway	NO-2	10YNO-2——–T
Trondheim and Molde, Norway	NO-3	10YNO-3——–J
Tromsø, Norway	NO-4	10YNO-4——–9
Bergen, Norway	NO-5	10Y1001A1001A48H
Poland	PL	10YPL-AREA—–S
Portugal	PT	10YPT-REN——W
Romania	RO	10YRO-TEL——P
Serbia	RS	10YCS-SERBIATSOV
Luleå, Sweden	SE-1	10Y1001A1001A44P
Sundsvall, Sweden	SE-2	10Y1001A1001A45N
Stockholm, Sweden	SE-3	10Y1001A1001A46L
Malmö, Sweden	SE-4	10Y1001A1001A47
Slovenia	SI	10YSI-ELES—–O
Slovakia	SK	10YSK-SEPS—–K
Ukraine	UA	10YUA-WEPS—–0

Terms of use

- GENERAL TERMS AND CONDITIONS FOR THE USE OF THE ENTSO-E TRANSPARENCY PLATFORM
- LIST OF DATA AVAILABLE FOR FREE RE-USE

References

1. "Help Page - ENTSO-E Transparency Platform."
2. "ENTSO-E Transparency Platform Data Extraction Process Implementation Guide," ENTSO-E AISBL, Brussels, Belgium, July 2016.
3. "Transparency Platform restful API - user guide."
4. EnergieID/entsoe-py. EnergieID cvba-so, 2019.
5. "ENTSO-E Transparency Platform."
6. "Energy Identification Codes (EICs)."

Market data: Nord Pool

Nord Pool

Historical market data from Nord Pool is stored as `.xls` files can be accessed in their historical market data site.

- Membership list - Nord Pool

Terms of use

- Terms and conditions for use

Meteorological data: Germany

Weather data for Germany is extracted from Deutscher Wetterdienst's Climate Data Center (CDC) OpenData. `windHourly_de.py` and `solarHourly_de.py` are the scripts used to extract hourly wind and solar data respectively.

Automating the data extraction process

Terms of use

- Terms of use for data on the CDC ftp server

References

1. "Wetter und Klima - Deutscher Wetterdienst - CDC (Climate Data Center)."