EMBER

Europe Electricity Interconnection Data Tool

Sources and methodology documentation

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About Ember

Ember is an independent, not-for-profit energy think tank that aims to shift the world to clean electricity using data. It gathers, curates and analyses data on the global power sector and its impact on the climate, using cutting edge technologies and making data and research as open as possible. It uses data-driven insights to shift the conversation towards high impact policies and empower other advocates to do the same. Founded in 2008 as Sandbag, it formerly focused on analysing, monitoring and reforming the EU carbon market, before rebranding as Ember in 2020. Its team of electricity analysts and other support staff are based around the world in the EU, UK, Turkey, India, China and Indonesia.

Glossary

BOGI: Baltic Offshore Grid Initiative
BZ: Bidding Zone
CY: Climate Year
CCR: Capacity Calculation Region
ENTSO-E: European Network of Transmission System Operators for Electricity
FBMC: Flow-Based Market Coupling
MED-TSO: Mediterranean Transmission System Operators
NET-P: Net Position (export)
NT+: National Trends+
NTC: Net Transfer Capacity
PCI: Project of Common Interest
RES: Renewable Energy Source
RES-E: Variable RES share of Electricity generation
SOR: Summer Outlook Report
TEASIMED: Towards an Efficient, Adequate, Sustainable and Interconnected MEDiterranean (power system)
TP: Transparency Platform
TRM: Transmission Reliability Margin
TSO: Transmission System Operator (for Electricity)
TTC: Total Transfer Capacity
TYNDP: Ten-Year Network Development Plan
WOR: Winter Outlook Report

Sources

List of key reference materials used for data collection

1. Ember hourly electricity dataset (from analysis of ENTSO-E's TP)
2. ENTSO-E - Winter Outlook Report 2024/2025
3. ENTSO-E - Summer Outlook Report 2024
4. ENTSO-E - TYNDP Scenarios 2024
5. ENTSO-E - TYNDP System Needs 2024
6. ENTSO-E - TYNDP CBA 2024
7. Med-TSO - Mediterranean Master Plan 2022
8. 50Hertz - BOGI roadmap press release

Metrics

Detailed description of information reported in the various views of the tool, including related sources, data consolidation methodology, high-level meaning explanations

0.0 Geographical mapping

In the context of grids, *Bidding Zones* are defined as the largest geographical areas within which market participants can exchange energy without capacity allocation, as defined in the regulation on the internal market for electricity (recast) (EU) 2019/943.

Since power system models are generally geographically defined through Bidding Zones, which cover the administrative area of a country or a portion of it, representing cross-border transmission lines requires the definition of a convention to map BZs to countries. The mapping adopted for the development of the data tool is reported in Table 1.

Within the scope of the data tool, some BZs for offshore wind have been grouped into 3 notional countries, named *"Baltic Hub"* (BW), *"Celtic Hub"* (CW) and *"North Hub"* (NW). This aggregation was chosen to provide a more intuitive visualization of connections and flows around such hubs on the map, also considering the potential complications arising from the radial connections expected for various offshore nodes.

Bidding Zone	Country code	Country name
AL00	AL	Albania
AT00	AT	Austria
BA00	BA	Bosnia and Herzegovina
BE00	BE	Belgium
BG00	BG	Bulgaria
EEOF	BW	*Baltic Hub*
CH00	CH	Switzerland
CW00	CW	*Celtic Hub*
CY00	CY	Cyprus
CZ00	CZ	Czechia
DE00	DE	Germany
DEKF	DE	Germany
DKBH	DK	Denmark
DKE1	DK	Denmark
DKKF	DK	Denmark
DKW1	DK	Denmark
DZ00	DZ	Algeria
EE00	EE	Estonia
EG00	EG	Egypt
ES00	ES	Spain
FI00	FI	Finland
FR00	FR	France
FR15	FR	France
GR00	GR	Greece
GR03	GR	Greece
HR00	HR	Croatia
HU00	HU	Hungary
IE00	IE	Ireland
IL00	IL	Israel
ITCA	IT	Italy
ITCN	IT	Italy
ITCO	IT	Italy
ITCS	IT	Italy
ITN1	IT	Italy
ITS1	IT	Italy
ITSA	IT	Italy
ITSI	IT	Italy
ITVI	IT	Italy
LT00	LT	Lithuania
LTOF	LT	Lithuania
LUB1	LU	Luxembourg
LUF1	LU	Luxembourg
LUG1	LU	Luxembourg
LUV1	LU	Luxembourg
LV00	LV	Latvia
LY00	LY	Libya
MA00	MA	Morocco
MD00	MD	Moldova

Bidding Zone	Country code	Country name
ME00	ME	Montenegro
MK00	MK	North Macedonia
MT00	MT	Malta
NL00	NL	Netherlands
NL6H	NL	Netherlands
NLA0	NL	Netherlands
NLBH	NL	Netherlands
NLLL	NL	Netherlands
NOM1	NO	Norway
NON1	NO	Norway
NOS0	NO	Norway
BEOF	NW	*North Hub*
DKNS	NW	*North Hub*
NL60	NW	*North Hub*
PL00	PL	Poland
PLE0	PL	Poland
PLI0	PL	Poland
PS00	PS	Palestine
PT00	PT	Portugal
RO00	RO	Romania
RS00	RS	Serbia
XRU00	RU	Russia
XSA00	SA	Saudi Arabia
SE01	SE	Sweden
SE02	SE	Sweden
SE03	SE	Sweden
SE04	SE	Sweden
SI00	SI	Slovenia
SK00	SK	Slovakia
TN00	TN	Tunisia
TR00	TR	Turkyie
UA00	UA	Ukraine
UK00	UK	United Kingdom
UKNI	UK	United Kingdom
XK00	XK	Kosovo

Table 1 - Mapping of BZs to countries.

A convention in associating BZs to countries, in the particular scope of this data tool, translates into the need to associate links between BZs to the respective international lines (interconnectors). The mapping adopted for these elements, which here are relevant only in the case a transmission line crosses a national border, is reported in Table 2.

BZ line	BZ from	BZ to	Country from	Country to	Country line
AL00-GR00	AL00	GR00	AL	GR	AL-GR
AL00-ME00	AL00	ME00	AL	ME	AL-ME
AL00-MK00	AL00	MK00	AL	MK	AL-MK
AL00-RS00	AL00	RS00	AL	RS	AL-RS
AL00-XK00	AL00	XK00	AL	XK	AL-XK
AT00-CH00	AT00	CH00	AT	CH	AT-CH
AT00-CZ00	AT00	CZ00	AT	CZ	AT-CZ
AT00-DE00	AT00	DE00	AT	DE	AT-DE
AT00-HU00	AT00	HU00	AT	HU	AT-HU
AT00-ITN1	AT00	ITN1	AT	IT	AT-IT
AT00-SI00	AT00	SI00	AT	SI	AT-SI
AT00-SK00	AT00	SK00	AT	SK	AT-SK
BA00-HR00	BA00	HR00	BA	HR	BA-HR
BA00-ME00	BA00	ME00	BA	ME	BA-ME
BA00-RS00	BA00	RS00	BA	RS	BA-RS
BE00-DE00	BE00	DE00	BE	DE	BE-DE
BE00-FR00	BE00	FR00	BE	FR	BE-FR
BE00-LUB1	BE00	LUB1	BE	LU	BE-LU
BE00-LUG1	BE00	LUG1	BE	LU	BE-LU
BE00-NL00	BE00	NL00	BE	NL	BE-NL
BE00-BEOF	BE00	BEOF	BE	NW	BE-NW
BE00-NL60	BE00	NL60	BE	NW	BE-NW
BE00-UK00	BE00	UK00	BE	UK	BE-UK
BG00-GR00	BG00	GR00	BG	GR	BG-GR
BG00-MK00	BG00	MK00	BG	MK	BG-MK
BG00-RO00	BG00	RO00	BG	RO	BG-RO
BG00-RS00	BG00	RS00	BG	RS	BG-RS
BG00-TR00	BG00	TR00	BG	TR	BG-TR
DE00-EEOF	DE00	EEOF	DE	BW	BW-DE
EE00-EEOF	EE00	EEOF	EE	BW	BW-EE
EEOF-LV00	EEOF	LV00	BW	LV	BW-LV
CH00-DE00	CH00	DE00	CH	DE	CH-DE
CH00-FR00	CH00	FR00	CH	FR	CH-FR
CH00-ITN1	CH00	ITN1	CH	IT	CH-IT
CW00-UK00	CW00	UK00	CW	UK	CW-UK
CY00-EG00	CY00	EG00	CY	EG	CY-EG
CY00-GR03	CY00	GR03	CY	GR	CY-GR
CY00-IL00	CY00	IL00	CY	IL	CY-IL
CZ00-DE00	CZ00	DE00	CZ	DE	CZ-DE
CZ00-PL00	CZ00	PL00	CZ	PL	CZ-PL
CZ00-SK00	CZ00	SK00	CZ	SK	CZ-SK
DE00-DKBH	DE00	DKBH	DE	DK	DE-DK
DE00-DKE1	DE00	DKE1	DE	DK	DE-DK
DE00-DKW1	DE00	DKW1	DE	DK	DE-DK
DEKF-DKKF	DEKF	DKKF	DE	DK	DE-DK
DE00-FR00	DE00	FR00	DE	FR	DE-FR
DE00-GR00	DE00	GR00	DE	GR	DE-GR
DE00-LUG1	DE00	LUG1	DE	LU	DE-LU

BZ line	BZ from	BZ to	Country from	Country to	Country line
DE00-LUV1	DE00	LUV1	DE	LU	DE-LU
DE00-MA00	DE00	MA00	DE	MA	DE-MA
DE00-NL00	DE00	NL00	DE	NL	DE-NL
DE00-NOS0	DE00	NOS0	DE	NO	DE-NO
DE00-PL00	DE00	PL00	DE	PL	DE-PL
DE00-SE04	DE00	SE04	DE	SE	DE-SE
DE00-UK00	DE00	UK00	DE	UK	DE-UK
DKW1-NL00	DKW1	NL00	DK	NL	DK-NL
DKW1-NOS0	DKW1	NOS0	DK	NO	DK-NO
DKNS-DKW1	DKNS	DKW1	NW	DK	DK-NW
DKE1-PL00	DKE1	PL00	DK	PL	DK-PL
DKE1-SE04	DKE1	SE04	DK	SE	DK-SE
DKW1-SE03	DKW1	SE03	DK	SE	DK-SE
DKW1-UK00	DKW1	UK00	DK	UK	DK-UK
DZ00-ITN1	DZ00	ITN1	DZ	IT	DZ-IT
DZ00-MA00	DZ00	MA00	DZ	MA	DZ-MA
DZ00-TN00	DZ00	TN00	DZ	TN	DZ-TN
EE00-FI00	EE00	FI00	EE	FI	EE-FI
EE00-LV00	EE00	LV00	EE	LV	EE-LV
XRU00-EE00	XRU00	EE00	RU	EE	EE-RU
EG00-GR00	EG00	GR00	EG	GR	EG-GR
EG00-GR03	EG00	GR03	EG	GR	EG-GR
EG00-LY00	EG00	LY00	EG	LY	EG-LY
XSA00-EG00	XSA00	EG00	SA	EG	EG-SA
ES00-FR00	ES00	FR00	ES	FR	ES-FR
ES00-ITN1	ES00	ITN1	ES	IT	ES-IT
ES00-MA00	ES00	MA00	ES	MA	ES-MA
ES00-PT00	ES00	PT00	ES	PT	ES-PT
FI00-NON1	FI00	NON1	FI	NO	FI-NO
XRU00-FI00	XRU00	FI00	RU	FI	FI-RU
FI00-SE01	FI00	SE01	FI	SE	FI-SE
FI00-SE02	FI00	SE02	FI	SE	FI-SE
FI00-SE03	FI00	SE03	FI	SE	FI-SE
FR00-IE00	FR00	IE00	FR	IE	FR-IE
FR00-ITN1	FR00	ITN1	FR	IT	FR-IT
FR15-ITCO	FR15	ITCO	FR	IT	FR-IT
FR00-LUF1	FR00	LUF1	FR	LU	FR-LU
FR00-UK00	FR00	UK00	FR	UK	FR-UK
GR00-ITS1	GR00	ITS1	GR	IT	GR-IT
GR00-LY00	GR00	LY00	GR	LY	GR-LY
GR03-LY00	GR03	LY00	GR	LY	GR-LY
GR00-MK00	GR00	MK00	GR	MK	GR-MK
GR00-TR00	GR00	TR00	GR	TR	GR-TR
HR00-HU00	HR00	HU00	HR	HU	HR-HU
HR00-RS00	HR00	RS00	HR	RS	HR-RS
HR00-SI00	HR00	SI00	HR	SI	HR-SI
HU00-RO00	HU00	RO00	HU	RO	HU-RO
HU00-RS00	HU00	RS00	HU	RS	HU-RS

BZ line	BZ from	BZ to	Country from	Country to	Country line
HU00-SI00	HU00	SI00	HU	SI	HU-SI
HU00-SK00	HU00	SK00	HU	SK	HU-SK
HU00-UA00	HU00	UA00	HU	UA	HU-UA
IE00-UK00	IE00	UK00	IE	UK	IE-UK
IE00-UKNI	IE00	UKNI	IE	UK	IE-UK
IL00-PS00	IL00	PS00	IL	PS	IL-PS
ITCS-ME00	ITCS	ME00	IT	ME	IT-ME
ITSI-MT00	ITSI	MT00	IT	MT	IT-MT
ITN1-SI00	ITN1	SI00	IT	SI	IT-SI
ITCN-TN00	ITCN	TN00	IT	TN	IT-TN
ITCS-TN00	ITCS	TN00	IT	TN	IT-TN
ITSI-TN00	ITSI	TN00	IT	TN	IT-TN
TN00-ITSI	XTN00	ITSI	TN	IT	IT-TN
LT00-LV00	LT00	LV00	LT	LV	LT-LV
LT00-PL00	LT00	PL00	LT	PL	LT-PL
XRU00-LT00	XRU00	LT00	RU	LT	LT-RU
LT00-SE04	LT00	SE04	LT	SE	LT-SE
XRU00-LV00	XRU00	LV00	RU	LV	LV-RU
LV00-SE03	LV00	SE03	LV	SE	LV-SE
LY00-TN00	LY00	TN00	LY	TN	LY-TN
MD00-RO00	MD00	RO00	MD	RO	MD-RO
MD00-RO00	XMD00	RO00	MD	RO	MD-RO
MD00-UA00	MD00	UA00	MD	UA	MD-UA
ME00-RS00	ME00	RS00	ME	RS	ME-RS
ME00-XK00	ME00	XK00	ME	XK	ME-XK
MK00-RS00	MK00	RS00	MK	RS	MK-RS
MK00-XK00	MK00	XK00	MK	XK	MK-XK
MT00-TN00	MT00	TN00	MT	TN	MT-TN
NL00-NOS0	NL00	NOS0	NL	NO	NL-NO
NL00-NL60	NL00	NL60	NL	NW	NL-NW
NL00-UK00	NL00	UK00	NL	UK	NL-UK
NLLL-UK00	NLLL	UK00	NL	UK	NL-UK
XRU00-NON1	XRU00	NON1	RU	NO	NO-RU
NOM1-SE02	NOM1	SE02	NO	SE	NO-SE
NON1-SE01	NON1	SE01	NO	SE	NO-SE
NON1-SE02	NON1	SE02	NO	SE	NO-SE
NOS0-SE03	NOS0	SE03	NO	SE	NO-SE
NOS0-UK00	NOS0	UK00	NO	UK	NO-UK
BEOF-UK00	BEOF	UK00	NW	UK	NW-UK
PL00-SE04	PL00	SE04	PL	SE	PL-SE
PL00-SK00	PL00	SK00	PL	SK	PL-SK
PL00-UA00	PL00	UA00	PL	UA	PL-UA
RO00-RS00	RO00	RS00	RO	RS	RO-RS
RO00-UA00	RO00	UA00	RO	UA	RO-UA
RS00-XK00	RS00	XK00	RS	XK	RS-XK
XRU00-UA00	XRU00	UA00	RU	UA	RU-UA
SK00-UA00	SK00	UA00	SK	UA	SK-UA

Table 2 - Mapping of BZ lines to country lines.

1.1 Capacity view

The *Capacity* view of the dashboard includes information that doesn't change over the course of the year in focus, such as capacity and potentials.

Metrics reported here are divided into 4 categories:

- *2024*: best-estimate of grid characteristics as of 2024. This forms the basis of the *Flows* view for 2024.
- *Reference*: best-estimate of grid characteristics according to realistically achievable targets. It applies to 2030 and 2040 and forms the basis of the respective *Flows* views.
- *Projects*: expanded grid corresponding to the realization of all transmission projects with commissioning date prior to the year in focus. It applies to 2030 and 2040.
- *Needs*: expanded grid whose realization would be economically viable and minimize power system costs. It applies to 2030 and 2040.

1.1.1 Interconnection capacity

- **Unit of measure:** MW
- **Granularity:** year
- **Description:** size of an interconnector, expressed as an estimate of its Net Transfer Capacity (NTC). This value is typically computed by derating the Total Transfer Capacity (TTC) by a Transmission Reliability Margin (TRM), so as to implicitly include planned outage events.
  Interconnection capacity is directional, meaning that the NTC of a line from country *A* to *B* can be different from the NTC of the line from country *B* to *A*. The width of interconnector lines on the map is parametrized based on the maximum value of each pair of directions, but direction-specific values are available in the side charts.
  NTC is chosen as the convention in the data tool because it allows for a more comprehensive and consistent overview of both capacity and flow

metrics over the represented years and geographies. At the same time, it is important to note that in real market operations, cross-zonal transfer capacity can be computed differently within a CCR with respect to another. The most relevant examples of potential divergence are the Core (involving Austria, Belgium, Croatia, Czechia, France, Germany, Hungary, Luxembourg, Netherlands, Poland, Romania, Slovakia and Slovenia) and the Nordics (involving Denmark, Finland, Norway and Sweden) CCRs: both, the former since June 2022 and the latter since October 2024, implement Flow-Based Market Coupling (FBMC), whose optimization of transfer capacity calculation allows for higher exchange levels than in the case of the bilateral NTC computation.
Therefore, the convention used for the data tool – at least for the *2024* and *Reference* categories – can be seen as a conservative representation of the actual physical capacity of European interconnectors.

- **Collection and consolidation methodology:** the process for collection and consolidation varies by target year.
    - 2024: the *2024* NTC starting dataset is extracted by taking, for each available cross-zonal line, the absolute maximum and absolute minimum value of the "Transfer Capacity" timeseries obtained by combining the most recent WOR and SOR publications from ENTSO-E, so that both forward and backward capacity are taken into account. The aggregation from cross-zonal to cross-border is performed per direction according to the mapping reported in the previous section. These intermediate NTCs are then benchmarked with extreme values of historical 2024 cross-border flow hourly timeseries, previously extracted from the ENTSO-E's TP, and adjusted upward (only in cases where there's a net gap, with particular caution for Core countries) or validated. The same hourly flow timeseries are also used to estimate NTCs for borders which are not modelled in Seasonal Outlooks, but are known to have an interconnector (mainly lines to/from Russia, Ukraine and Kosovo). Dedicated research (Med-TSO regions) is conducted for relevant lines whose existence is known but for which neither NTC nor hourly flow data is available. In exceptional cases, TSOs are contacted directly for clarifications on ambiguities.

- 2030: the *Reference* NTC starting dataset is taken directly from the 2030 "Reference Grid" published input dataset of the TYNDP 2024 Scenarios, where both forward and backward yearly figures at cross-zonal level are reported.
  These intermediate NTCs are then benchmarked with extreme values of optimized 2030 cross-border flow hourly timeseries, limited to the "National Trends+" scenario (designed to align with national energy and climate policies derived from European targets, only modelled for CY 2009), and adjusted upward (only in cases where there's a net gap) or validated.
  For European interconnectors that are currently in operation but are not modelled within the TYNDP 2024 Scenarios exercise (mainly lines from/to Ukraine and Kosovo), a no-decommissioning assumption is made throughout the time horizon covered by the data tool. This means that if no projections are found for 2030, the lifetime of transmission lines is assumed to be long enough for the interconnection to remain the same as in 2024. In exceptional cases, TSOs are contacted directly for clarifications on ambiguities.
  The *Projects* NTC dataset is created by checking out all single transmission PCI candidates with expected commissioning date prior to 2030 that are not included in the respective "Reference Grid", as published as part of the TYNDP 2024 CBA exercise, and by adding their NTC on top of the *Reference* base values. The same approach is adopted for infrastructure within the BOGI roadmap and for the TEASIMED projects #2, #4 and #12 (only ones under development at the time of data collection).
  The TYNDP 2024 System Needs study reports transmission infrastructure gaps expressed only as ranges on a map, without providing border-specific values. However, the exercise estimates for 2030 a total capacity of 88 GW on top of the 2030 "Reference Grid".
  The *Needs* NTC dataset is therefore derived by distributing the additional capacity linearly among all borders covered by the study, with weights being the midpoint between the lower and upper bracket of the respectively assigned range, and the final value being capped to the upper bracket. This approach – chosen as the

simplest and most neutral – still makes it possible for capacities in this category to deviate (on average downwards) from actual model outputs.
For all the three categories listed here, aggregation from cross-zonal to cross-border is then performed per direction according to the mapping reported in the previous section.

- 2040: the *Reference* NTC starting dataset is taken by combining the consolidated cross-zonal values from 2030 with the capacity of all transmission PCI candidates with expected commissioning date prior to 2040 that are flagged as included in the 2035 "Reference Grid", which is the one used in the respective Scenarios model.
  These intermediate NTCs are then benchmarked with extreme values of optimized 2040 cross-border flow hourly timeseries, limited to the "National Trends+" scenario (designed to align with national energy and climate policies derived from European targets, only modelled for CY 2009), and adjusted upwards (only in cases where there's a net gap) or validated.
  For European interconnectors that are currently in operation but are not modelled within the TYNDP 2024 Scenarios exercise (mainly lines from/to Ukraine and Kosovo), a no-decommissioning assumption is made throughout the time horizon covered by the data tool. This means that if no projections are found for 2040, the lifetime of transmission lines is assumed to be long enough for the interconnection to remain the same as in 2024/2030. In exceptional cases, TSOs are contacted directly for clarifications on ambiguities.
  The *Projects* NTC dataset is created by checking out all single transmission PCI candidates with expected commissioning date prior to 2040 that are not included in the respective "Reference Grid", as published as part of the TYNDP 2024 CBA exercise, and by adding their NTC on top of the *Reference* base values. The same approach is adopted for infrastructure within the BOGI roadmap and for the TEASIMED projects #2, #4 and #12 (only ones under development at the time of data collection).
  The TYNDP 2024 System Needs study reports transmission infrastructure gaps expressed only as ranges on a map, without

providing border-specific values. However, the exercise estimates for 2040 a total capacity of 108 GW on top of the 2030 "Reference Grid". The *Needs* NTC dataset is therefore derived by distributing the additional capacity linearly among all borders covered by the study, with weights being the midpoint between the lower and upper bracket of the respectively assigned range, and the final value being capped to the upper bracket. This approach, chosen as the simplest and most neutral, still makes it possible for capacities in this category to deviate (on average downwards) from actual model outputs.
For all three categories listed here, aggregation from cross-zonal to cross-border is then performed per direction according to the mapping reported in the previous section.

1.1.2 Import potential

- **Unit of measure:** %
- **Granularity:** year
- **Description:** the portion of a country's peak demand that can theoretically be satisfied if all entering interconnectors import at full capacity simultaneously.
- **Collection and consolidation methodology:** the indicator is computed as the ratio of the sum of the NTC from all importing interconnectors to the country-level peak demand (excluding storage load). This metric is expressed by category (*2024, Reference, Projects, Needs*) for 2030 and 2040. The process for collection and consolidation of peak demand varies by target year.
    - 2024: the zonal peak demand is computed as the maximum value of the historical hourly timeseries extracted from ENTSO-E's TP. When information from this source is lacking for a BZ, the first fallback option is the maximum of the combined Seasonal Outlook demand timeseries (across all CYs). If the information is still lacking for a BZ, the second fallback option is a backscaling of the peak value from the closest future target year, using the proportion between yearly load figures as a linear derating factor.

The aggregation from zones to countries is then performed according to the mapping reported in the previous section.

- 2030/2040: the zonal peak demand is computed here as the maximum value of the respective hourly timeseries out of the TYNDP 2024 Scenarios model, limited to the "NT+" scenario..
  The aggregation from zones to countries is then performed according to the mapping reported in the previous section.

1.2 Flows view

The *Flows* view of the dashboard includes information whose changes can be relevant at hourly or monthly granularity within a year in focus, such as renewable penetration in the generation mix, net position, exchanges with neighboring countries.

Metrics reported here refer exclusively to the *2024* and *Reference* categories, which are the only ones for which historical or modelled data is currently available at the necessary granularity.

1.2.1 NET-P / Net exports

- **Unit of measure:** %
- **Granularity:** year, month, hour
- **Description:** net import (indicated by a negative sign) or net export (indicated by a positive sign) of a country with respect to its demand (excluding storage load). It indicates how much of the load is supplied by power from neighboring power systems or how much of it is the equivalent of electricity being transferred elsewhere.
- **Collection and consolidation methodology:** hourly demand timeseries data treatment is described in the previous section; the process for

collection and consolidation of absolute net position data varies by target year.

- 2024: the historical hourly net position timeseries of a BZ is extracted from ENTSO-E's TP. After an aggregation from zones to countries is performed according to the mapping reported in the previous section, all net position granularities are derived by averaging over the year, month and hour of the day the instantaneous values of the ratio between net position and demand (excluding storage load). When information from this source is lacking for a country, aggregated monthly demand and net position data is used as a fallback option, allowing for a high-level approximation of yearly and monthly granularities of the indicator.
- 2030/2040: the hourly flows from and to each BZ are extracted from the TYNDP 2024 Scenarios model outputs, limited to the "NT+" scenario, and aggregated from zones to countries according to the mapping reported in the previous section. To express the metric at country level, instantaneous entering or exiting flows are summed (following the sign convention described above) to compute a net position timeseries, whose instantaneous values are divided by the respective country-level demand (excluding storage load), and finally averaged over the year, month and hour of the day.

1.2.2 Variable RES penetration

- **Unit of measure:** %
- **Granularity:** year, month, hour
- **Description:** share of generation supplied by PV solar, thermal solar (CSP), onshore wind and offshore wind. Does not include behind-the-meter contributions such as rooftop PV.
- **Collection and consolidation methodology:** the process for collection and consolidation of generation data varies by target year.
    - 2024: the zonal hourly generation by technology is extracted from ENTSO-E's TP, when available.
      The aggregation from zones to countries is then performed

according to the mapping reported in the previous section.
All variable RES penetration granularities are derived by averaging over the year, month and hour of the day the instantaneous values of the ratio between solar+wind and total generation.

- 2030/2040: hourly generation by technology for each BZ is extracted from the TYNDP 2024 Scenarios model outputs, limited to the "NT+" scenario, and aggregated from zones to countries according to the mapping reported in the previous section. Solar+wind instantaneous values are divided by the respective total generation, and finally averaged over the year, month and hour of the day.

1.2.3 Cross-border flows

- **Unit of measure:** %
- **Granularity:** year, month, hour
- **Description:** the share of total interconnection capacity – measured either as an interconnector NTC (for a given year) or as the maximum between importing and exporting NTC (for a given month or hour) – that is being used for flows to or from a neighboring country.
- **Collection and consolidation methodology:** interconnection capacity data treatment is described in the previous section; the process for collection and consolidation of flows data varies by target year.
    - 2024: the historical hourly flows from and to a BZ are extracted from ENTSO-E's TP. After an aggregation from cross-zonal to cross-border is performed according to the mapping reported in the previous section, month and hour granularities are derived by averaging over the month and hour of the day the instantaneous values of the ratio between flows (categorized by destination country, and following the same sign convention as for net position figures) and total interconnection capacity. For the yearly granularity, which is relevant only for graphic representations, the dividend of each cross-border ratio is simply the respective interconnection NTC.
    - 2030/2040: hourly cross-zonal flows for each BZ are extracted from the TYNDP 2024 Scenarios model outputs, limited to the "NT+"

scenario. After an aggregation from cross-zonal to cross-border is performed according to the mapping reported in the previous section, month and hour granularities are derived by averaging over the month and hour of the day the instantaneous values of the ratio between flows (categorized by destination country, and following the same sign convention as for net position figures) and total interconnection capacity. For the yearly granularity, which is relevant only for graphic representations, the dividend of each cross-border ratio is simply the respective interconnection NTC.

Published material

Index and content of published material

- *peak_demand.csv*: peak demand (MW) per country-year, as considered in the analysis behind the data tool.
- *REF_NTC.csv*: *2024* or *Reference* interconnector capacity (MW) per border-year. Includes both forward and backward NTC.
- *PROJ_NTC.csv*: *Projects* interconnector capacity (MW) per border-year. Includes both forward and backward NTC, for 2030 and 2040 only.
- *NEEDS_NTC.csv*: *Needs* interconnector capacity (MW) per border-year. Includes both forward and backward NTC, for 2030 and 2040 only.
- *imp_pot_chart_YYYY.csv*: Import Potential (%) for year *YYYY*, per country-category.
- *country_hourly_chart_YYYY.csv*: hour-of-day averages of Net Position and Variable RES Penetration indicators (%) for year *YYYY*, per country.
- *country_monthly_chart_YYYY.csv*: monthly averages of Net Position and Variable RES Penetration indicators (%) for year *YYYY*, per country.
- *flows_hourly_chart_YYYY.csv*: hour-of-day averages of the Cross-border Flows indicators (%) for year *YYYY*, per country-line.
- *flows_monthly_chart_YYYY.csv*: hour-of-day averages of the Cross-border Flows indicators (%) for year *YYYY*, per country-line.