WHITEPAPER

Methodology for the electricity mix and derived signals

A validation of Electricity Maps methodology for electricity mix, carbon intensity, renewable energy percentage, and carbon-free energy percentage data

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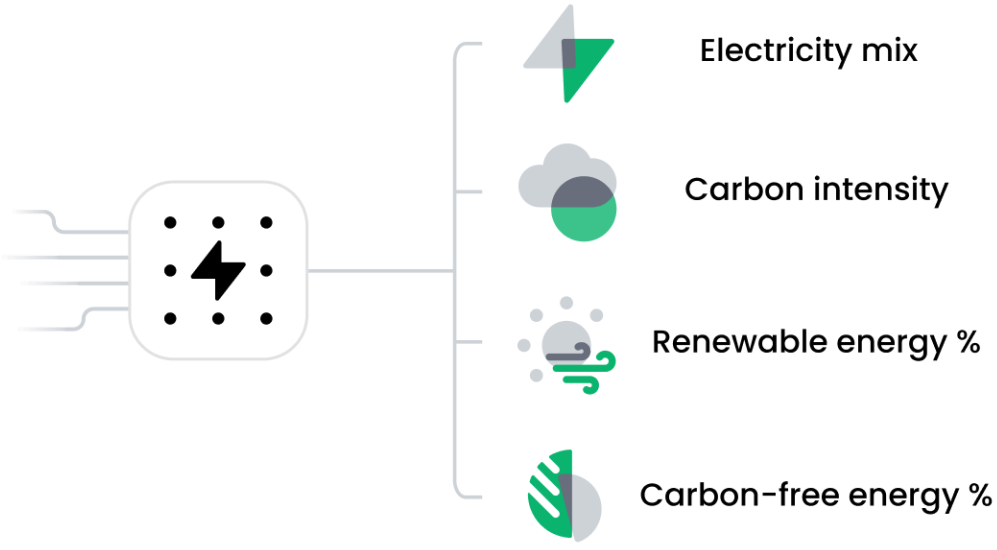

ELECTRICITY MAPS

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Executive summary

Electricity Maps provides a range of data for electricity grids worldwide with high spatial and temporal granularity. Besides a high granularity, Electricity Maps leverages the flow-tracing method to account for electricity flows across power grids and provide data with the highest accuracy. In particular, Electricity Maps' carbon intensity, renewable energy percentage, and carbon-free energy percentage data can be used to calculate location-based emissions for scope 2 reporting.

This whitepaper introduces Electricity Maps' methodology for electricity mix data, carbon intensity, renewable energy percentage, and carbon-free energy percentage signals. In particular, it introduces the flow-tracing method used by Electricity Maps, which is the main distinction from alternative data sources besides data granularity. The flow-tracing method traces back all electricity flows across interconnected grids to calculate the electricity mix available in each grid considering local electricity generation as well as electricity flows. Flow-traced data with high spatial and temporal granularity provided by Electricity Maps is more accurate for emissions accounting and reporting compared to data sources such as the International Energy Agency.

Electricity Maps data is validated against alternative sources, including worldwide sources (Ember, IEA), and authoritative regional sources (Eurostat). The validation is run on production-based yearly-aggregated data. On average, the difference between Electricity Maps data and these datasets remains below 3 percentage points for the renewable energy and carbon-free energy percentage data worldwide. This demonstrates the validity of Electricity Maps data.

Finally, this whitepaper clarifies the process used by Electricity Maps for data updates as well as data publication through the publicly available datasets and the API. Electricity Maps data is regularly updated to leverage consolidated data available from primary data sources. In 90% of zones, renewable energy percentage data will update by less than 2 percentage points and carbon intensity data will update by less than 3% after 3 months. These updates enable Electricity Maps to provide the most up-to-date and accurate historical and real-time data while remaining compatible with accounting and reporting use cases.

Customers & scientific references

Electricity Maps' data is used today by leading companies worldwide, including Google, Microsoft, Cisco, Samsung, and Schneider Electric for purposes such as accounting and reporting their emissions both internally, and externally for their customers and end-users.

Publicly available datasets from Electricity Maps were downloaded 20,000 times in 2024 for a wide range of use cases, among which are carbon accounting calculations. The Electricity Maps API also serves an average of 15 million requests per day with 0 downtime since 2021.

Finally, Electricity Maps is a trusted partner in the academic world, collaborating with leading research institutions and providing its data for free to researchers worldwide. At the end of 2024, Electricity Maps had provided data or been cited by more than 100 scientific publications. The publication [1] co-authored by Electricity Maps in 2017 that introduces the flow tracing method used by Electricity Maps and applies it to the European grid has received more than 100 citations.

Used by more than 300M users worldwide. Trusted by 40+ companies, including:

Concepts, scope, and definitions

When measuring the environmental impact of human activity, some fundamental methodological choices have to be made. This is also the case when measuring the climate impact of electricity consumption, which is at the core of Electricity Maps' data. This section aims to introduce the most important concepts and definitions that are relevant for understanding Electricity Maps' data offering as well as its scope.

Attributional vs consequential approach

The first and most important choice that has to be made is to define and select what kind of method should be used for assessing climate impacts. **Inventory accounting** (also called **attributional accounting**) is used by companies and organizations to report greenhouse gas (GHG) emissions and removals over time. **Project-based accounting** (also called **consequential accounting**) is used to quantify changes in GHG emissions and removals of a specific project compared to a counterfactual baseline scenario. Read more about the key differences between these two methodologies in the comparative review[1] from the GHG Protocol.

Leading standards for carbon accounting and reporting worldwide, such as the Greenhouse Gas Protocol Scope 2 Guidance[2] and the SBTi Corporate Near-term Criteria[3], require the use of an attributional approach. Additionally, a number of climate-related disclosure rules worldwide reference the GHG Protocol Scope 2 Guidance and, by extension, also require an attributional approach[4]. Electricity Maps' data is suited for calculations following an attributional approach.

Location-based vs market-based

Two different approaches exist for calculating GHG emissions from electricity consumption within the attributional method, and numbers for both of them must be reported. As described by the GHG Protocol Scope 2 Guidance in section 4.1 on "Approaches to accounting scope 2"[2], *"the market-based method reflects emissions from electricity that companies have purposefully chosen (or their lack of choice), while the location-based method reflects the average emissions intensity of grids on which energy consumption occurs"*. Electricity Maps' data represents emissions following a **location-based approach** where electricity from different sources, such as wind, solar, coal, and others, gets mixed in the electricity grid and cannot be unmixed anymore. This is the closest representation of the actual electricity mix consumed from the grid, and the associated emissions. On the other hand, it does not reflect electricity purchases or investments made by companies. Location-based data can also be used in market-based calculation, in place of residual mix data, according to Table 6.3 of the Scope 2 Guidance[2].

[1] Inventory and Project Accounting: A Comparative Review | GHG Protocol
[2] Scope 2 Guidance.pdf
[3] Corporate Near-term criteria V5.2
[4] GHG-Protocol-Integration.pdf

Spatial granularity

At Electricity Maps, spatial units are called **zones**. A zone represents a physical network where power lines connect power plants generating electricity to consumers. Most zones represent an **electricity grid,** where an operator is responsible for the network's reliability which might involve transmitting electricity to neighboring grids. Accounting for these electricity flows between grids is crucial to accurately represent the physical reality. Electricity Maps aims to display the smallest subdivision of electricity grids within the limits of data availability. A zone might not always exactly overlap with political entities such as countries or federal states, but often does.

Temporal granularity

Electricity Maps gathers data with different levels of **temporal granularity** (from a 5-minute to a yearly granularity) and harmonizes all data to the same level of granularity. Electricity Maps aims to display the highest level of temporal granularity within the limits of data availability. In 2024, Electricity Maps uses an hourly granularity, which means that all data is available at a resolution of one hour for all zones covered worldwide. This granularity is expected to increase in the upcoming years. Electricity Maps also provides **aggregation** of its data both on the temporal level (from hours to days, months, and years) and the spatial level (from zones to countries).

Electricity mix

Electricity Maps operates with a harmonized subdivision of **electricity production technologies**, all gathered in Table 1. The **electricity mix** can be expressed as a relative share of each technology or as their absolute power or energy output. The power output is expressed in **megawatts (MW)** and represents the instantaneous output of a power plant or technology. The energy output is expressed in **megawatt hours (MWh)** and represents the output of a power plant or technology over time. A power plant generating 500MW of power over 1 hour will generate 500MWh of energy. For larger amounts of power and energy, Electricity Maps also uses gigawatts (GW), gigawatt hours (GWh), terawatts (TW), and terawatt hours (TWh); for smaller amounts, kilowatt (kW) and kilowatt hours (kWh) are used.

Flow-tracing

As described in the above section on spatial definition and granularity, electricity grids can transmit electricity with neighboring grids via so-called **interconnectors**. The **electricity production mix,** which ignores the electricity flows through these interconnectors, in most cases does not accurately represent the mix of electricity available to consumers on the grid, also called the **flow-traced electricity mix** (or electricity consumption mix). To calculate the flow-traced electricity mix in a given zone, Electricity Maps uses a flow-tracing method. This peer-reviewed scientific approach [1, 2, 3] is used to trace back the flows of electricity across all interconnected grids, even in the presence of loop flows, to accurately represent the mix of electricity available in a given zone.

Emission factors

Emission factors (also called fuel emission factors) quantify the emissions induced when generating a unit of electricity using a specific technology (e.g. wind, solar, or coal). The technology used, the facilities' age, and the geographical location are some parameters that influence these factors. They are a ratio usually expressed in grams of CO_2 equivalent per kilowatt hour of electricity generated (gCO_2/kWh).

There are two main types of emission factors, each of them relying on a different methodology and capturing a different scope: direct emission factors (also called operational or combustion emission factors) and lifecycle emission factors. **Direct emission factors** include only the emissions that occur from combusting the fuel while **lifecycle emission factors** include not only the emissions that occur from combusting the fuel, but all other emissions that occur in the life cycle of the fuel such as emissions from extraction, processing, and transportation of fuels. Combustion emission factors are used in the GHG Protocol Corporate Standard to calculate scope 2 emissions[5]. Both types of emission factors are supported by Electricity Maps.

Signals

Based on the flow-traced electricity mix, Electricity Maps calculates different indicators, also referred to as **signals**. A signal is an easy-to-interpret indicator that gives insights into the impacts of electricity consumption and allows comparison across space and time.

The first signal is called **carbon intensity (CI),** which represents the amount of greenhouse gas emitted per kWh of electricity consumed. It can be calculated for each hour in each zone by combining power mix data with technology-specific emission factors.

Besides carbon intensity, other indicators can represent the impact of electricity consumption, such as the share of low-carbon technologies, referred to as the **carbon-free energy percentage (CFE%)**, and the share of renewable technologies, referred to as the **renewable energy percentage (RE%)**. The classification of each electricity production technology as either low-carbon and/or renewable is summarized in Table 1.

[5] Corporate Standard Frequently Asked Questions | GHG Protocol

Table 1: Categorization of different electricity production technologies regarding Carbon-Free Energy and Renewable energy.

Technology	Carbon-Free Energy (CFE%)	Renewable Energy (RE%)
Coal		
Gas		
Oil		
Unknown	Zone-specific	
Nuclear	X	
Wind	X	X
Solar	X	X
Hydro	X	X
Geothermal	X	X
Biomass[6]	X	X
Hydro storage	Zone-specific	
Battery storage		

[6] The distinction between biomass and sustainable biomass is not made as it is not available in the primary data sources

Methodology

This section explains the Electricity Maps methodology, building on the concepts and definitions introduced above and using the data processing pipeline as a point of reference.

Simplified overview of the data processing pipeline

Figure 1 represents a simplified version of Electricity Maps' data processing pipeline for the electricity mix, carbon intensity (CI), renewable energy percentage (RE%), and carbon-free energy percentage (CFE%) calculations. The paragraph below describes this pipeline high-level and the next sections dive into the methodology used at each step of the pipeline.

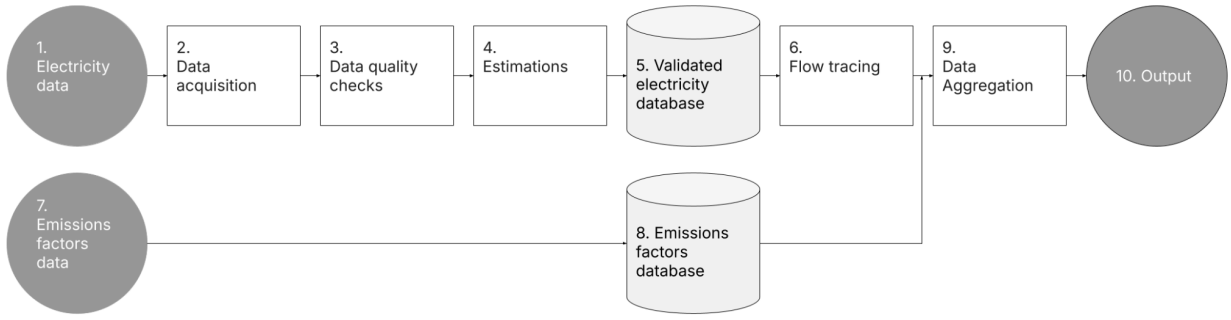

Figure 1: Simplified representation of Electricity Maps pipeline for carbon intensity, carbon-free energy percentage, and renewable energy percentage calculation.

All Electricity Maps data is calculated based on the highest-quality data available (**step 1**). The pipeline starts by ingesting this electricity data using data integrations (**step 2**) that collect and transform it into a standardized format. This includes data on production mix and electricity flows. Quality tests are performed before the data is ingested in Electricity Maps' systems (**step 3**). All invalid data points detected are removed, and estimation models are used to replace missing data (removed invalid data points, data gaps, data delays...) (**step 4**). The now complete and quality-guaranteed data is stored (**step 5**). The next step consists of applying the flow-tracing algorithm, which computes the electricity consumption mix based on the electricity production mix and electricity flows (**step 6**). Once the flow-traced mix is obtained, it can be used to calculate the following signals: CI, RE%, and CFE%intensity (CI), renewable energy percentage (RE%), and carbon-free energy percentage (CFE%). The carbon-intensity signal also requires emission factors to be sourced (**step 7**) and stored in a separate database (**step 8**). All data is aggregated at different time granularities (hourly, daily, monthly, yearly, etc.) (**step 9**) and delivered through Electricity Maps' platforms (**step 10**): App, API, and Data portal.

Input data & data parsers (steps 1 & 2)

Data sources

Electricity Maps collects electricity data from a range of data sources. This data includes:

- Electricity production mix
- Electricity flows between zones
- Electricity load (also called electricity demand)

Electricity Maps uses a list of criteria (authoritative data sources, primary data sources, regulations, data accuracy, data confirmability, and rigorous and transparent methodology) to only ingest accurate and high-quality data from credible and trustworthy data sources.

Data sources with a high degree of credibility include authoritative data sources (internationally or regionally), data sources publishing data validated against supranational trusted data sources, and data sources under legal requirements regarding the quality and provision of this data. This entails government sources like energy ministries, government-affiliated sources such as official statistical bureaus, transmission system operators, and utility companies directly generating electricity. Examples of data sources integrated by Electricity Maps are the EIA in the US, the ENTSO-E in Europe, the Grid Controller of India, the Tokyo Electric Power Company Holdings in Japan, and the IEA or Ember for monthly and yearly-aggregated data worldwide. All data sources used by Electricity Maps are made publicly available.

Data acquisition

The fact that contributing to Electricity Maps' product is open to the public comes with many benefits, such as contributions from experts and increased scrutiny. Contributions, feedback, and reviews from experts have enabled the development of regional emissions factors, and the identification of high-quality electricity data sources in several regions.

The data is acquired from many sources through data integrations called **parsers** that convert it to a standardized format. Contributing to building new parsers and updating current ones is open to the public. To ensure these parsers fulfill certain quality criteria, several guidelines[7,8,9] are used and enforced to control quality.

In addition to these guidelines, all contributions to the Electricity Maps open-source project follow a thorough contribution lifecycle described here that includes automated tests and multi-stage approval from Electricity Maps' employees before acceptance.

[7] https://github.com/electricitymaps/electricitymaps-contrib/blob/master/CONTRIBUTING.md
[8] https://github.com/electricitymaps/electricitymaps-contrib/blob/master/parsers/README.md
[9] https://github.com/electricitymaps/electricitymaps-contrib/wiki/Building-a-new-parser

Data quality checks & estimation (steps 3 & 4)

Data quality checks

All data collected by parsers is continuously and automatically validated according to a list of quality checks. These checks are regularly enriched and improved over time, and, for all data worldwide, consist of rules such as:

- The *exceeded-capacity rule*: detects if, within a certain time interval, the maximum capacity of a zone is exceeded for a production mode or an exchange. For example, if a data source reports 15GW of wind generation in a zone with 10GW of installed wind capacity, the data will be flagged as invalid.
- The *expected mode rule*: detects if, within a certain time interval, an expected production mode is not reported. For example, if a data source reports no gas generation in a zone with only gas generators, the data will be flagged as invalid.

All events flagged as invalid by one of the quality checks are removed and replaced by estimated data (also known as imputation). If the data source later returns an updated data point that is no longer flagged as invalid, Electricity Maps' data is updated with the newest data available. Electricity Maps keeps track of all data points removed and replaced in all zones, as well as all data updates.

Estimation models

Electricity Maps uses a range of estimation models to generate synthetic data in the presence of invalid data, delays, or temporary or permanent data gaps. Electricity Maps uses different estimation methods for different grids depending on their level of data availability. In this regard, zones are divided into three tiers:

A. *Tier A* comprises all zones where hourly data is available for the full power mix with a delay below a few days. The Time Slicer Average estimation method is used in the event of data gaps and outliers and for so-called now-casting in cases where data is delayed. The model fills in gaps by using neighboring observations to guarantee data completeness.
B. *Tier B* comprises all zones where hourly data is partially available. Zone-specific estimation models are developed to leverage available hourly data and estimate the remaining. These models are validated against available hourly data.
C. *Tier C* comprises all zones where only monthly or yearly data is available. The General Purpose Zone Development model is used to estimate hourly data from the available data. It guarantees that aggregated hourly data sums up to available monthly and yearly data. The model is trained and validated on zones with the full power mix available.

An overview of all Electricity Maps' zones and the tier they belonged to in January 2025 is available in Table A1 of Appendix A. Documentation about the estimation methods is available in Appendix B. Advanced documentation and validation of these models, including performance metrics, are available on demand.

Validated electricity database (step 5)

Electricity Maps stores all collected and validated data for all zones worldwide. It includes data that passed all quality checks and data from proprietary estimation methods. In addition, Electricity Maps keeps a record of all updates made to each data point over time, including the values and where each data point originates from (data source, estimation model) for each update. Thus, Electricity Maps have a complete data lineage that ensures the traceability of all data updates.

Flow-tracing (step 6)

Flow-tracing is the methodology used to trace back the origin of consumed electricity. The concept was introduced in 1996 by J. Bialek [2]. It has been applied to the European [1] and US [3] electricity grids in scientific publications. It is a peer-reviewed and validated methodology to account for electricity exchanges in the grid mix.

The flow-tracing methodology calculates the electricity consumption mix to reflect what is available on a grid (as a mix of local generation and imports). It relies on two rules: (1) *Proportional mixing* assumes that all electricity produced from different local sources (i.e. the different production technologies) and imported from neighboring grids is mixed proportionally to their respective amount of energy; and (2) *Irreversibility* assumes that all electricity consumed in the grid has a mix of the same proportions of the grid mix, i.e., once mixed in the grid, electricity cannot be unmixed anymore. This implies that electricity exported by a zone is made of the same mix as the electricity available in that zone. This further implies that flow-traced data on a specific zone already considers the potential case that a zone imports electricity from a zone that also imports electricity, accounting for this ad infinitum. This is achieved by calculating the consumption mix for all zones simultaneously using matrix algebra. The flow-tracing algorithm traces back all flows on the grid, beyond the closest neighbors, and even in the presence of loop flows (A loop flow happens when three grids A, B, and C have the following exchange structure: A → B → C → A such as between Bulgaria, Serbia, and Romania in the example below).

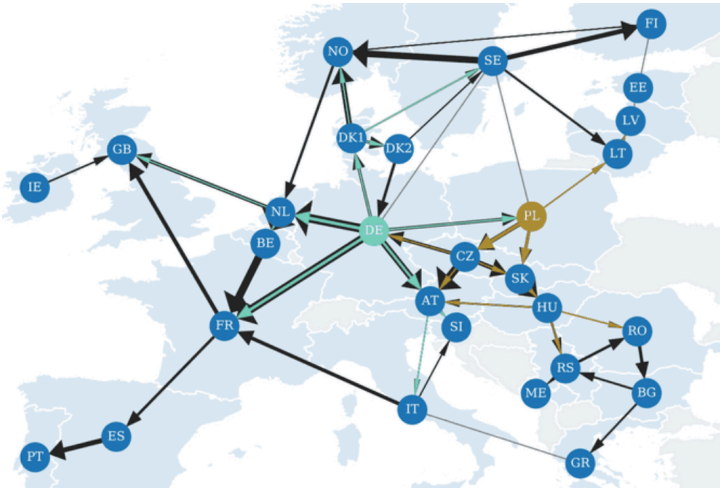

Figure 2: Graphical representation of electricity flows in Europe.

Figure 2 shows electricity flows in the European electricity grid for a specific hour. For simplicity, all zones are aggregated on the country level. The width of the arrows is proportional to the

electricity traded and transmitted between zones. The share of German wind production (turquoise) and Polish coal production (brown) have been highlighted in this example. The electricity mix from these two countries cascades to all interconnected countries through interconnectors. For the sake of representation, the arrow is not drawn anymore when the share becomes too small (even though the flow is still taken into account by the algorithm).

Overall, it is crucial to include exchanges in the electricity mix. More than 10% of electricity emissions come from imported electricity. Ignoring exchanges can cause a difference of up to twice the carbon emissions accounted for, with errors typically in the 10-15% range.

Emission factors (steps 7 & 8)

In parallel with the validated electricity database for electricity mix data, Electricity Maps also collects and stores technology-specific emission factors, with one direct and one lifecycle emission factor per technology and grid. Electricity Maps uses global values for all grids worldwide and, when possible, computes grid-specific factors.

Global emission factors used by Electricity Maps come, for most technologies, from Annex III of the IPCC (2014) Fifth Assessment Report [4] which contains carbon dioxide emission factors for electricity and heat. Global emission factors used by Electricity Maps are available in Table C1 of Appendix C.

In Europe, Electricity Maps computes grid-specific direct emission factors from the power-plant emissions data of the European Union's emissions trading scheme (EU-ETS) and the power-plant production data of ENTSO-E. Life cycle emission factors are calculated by adding upstream emission factors from widely acknowledged data sources, such as Annex III of the IPCC (2014) Fifth Assessment Report [4] and the UNECE 2022 report [5].

In the United States, Electricity Maps computes grid-specific direct emission factors from the power-plant emission and production data of the US Environmental Protection Agency's Emission & Generation Resource Integrated Database (eGRID). Life-cycle emission factors are calculated by adding upstream emission factors from widely acknowledged data sources.

Electricity Maps' methodology for regional emission factors with a higher granularity has been developed with the collaboration and review of leading experts in electricity emissions data and lifecycle analysis. A report describing the Electricity Maps methodology for emissions and validating it against the methodology from the IEA was also published in 2024.

Aggregation and output (steps 9 & 10)

Finally, all data is aggregated to the same temporal resolution. The data pipeline output consists of all signals per zone and aggregation period (e.g., hourly, daily, monthly). The carbon-free energy percentage and the renewable energy percentage are calculated according to the classification in Table 1, and the carbon intensity is calculated with the emission factors.

Data validation

This section aims to validate the renewable energy percentage and carbon-free energy percentage numbers of Electricity Maps by running a comparison with several data sources:

- the International Energy Agency (IEA) and Ember, both of which have a global focus,
- the statistical office of the European Union Eurostat, which has a regional focus and covers EU member states.

The following two subsections present the comparison results. The methodology used to source and compare data is available in Appendix D and Appendix E, with results for all geographies available in the respective datasets.

Comparison with IEA and Ember

This subsection compares Electricity Maps data to data provided by the International Energy Agency (IEA) and Ember for the renewable energy percentage (RE%) and the carbon-free energy percentage (CFE%).

The data from the IEA and Ember are compared to production-based Electricity Maps data, as the two sources do not include electricity flows in their calculations. The comparison focuses on yearly-aggregated data from 2023, the most recent year available for all three data sources. Detailed results for all available geographies can be found in Table D2.1 and Table D2.2 of Appendix D.

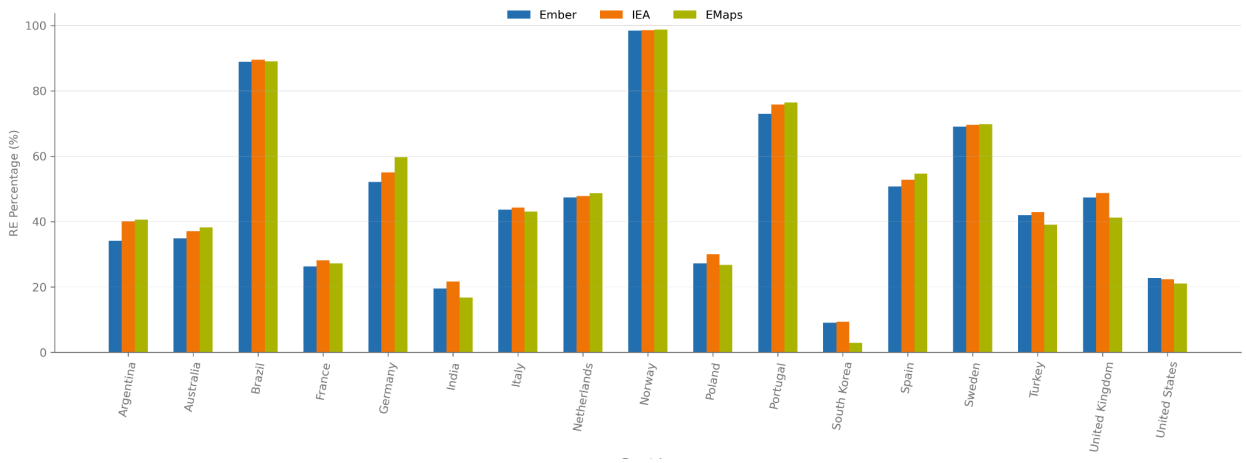

Figure 3: Comparison of the renewable energy percentage for different data sources across selected countries in 2023.

The comparison for the RE% in Figure 3 shows that the three datasets overall have consistent values for all geographies. In some countries, the Electricity Maps value can deviate slightly from one dataset but remain consistent with the other one, highlighting that these deviations are not only applicable to Electricity Maps data.

The median absolute differences between the data sources for the 59 countries considered are 1.8 percentage points (pp) between Ember and the IEA, 1.8 pp between Ember and Electricity Maps, and 3.2 pp between Electricity Maps and the IEA. All three datasets are highly correlated (0.99 correlation). Based on these values, Electricity Maps data for the RE% over 2023 is consistent with values provided by Ember and the IEA worldwide.

In addition to absolute differences between datasets, the median difference is also computed to analyze if the Electricity Maps dataset shows any bias compared to the other datasets, such as a consistently higher RE%. This reveals that, on average, Electricity Maps data is 0.1 percentage points higher than Ember data and 1.6 percentage points lower than the IEA data.

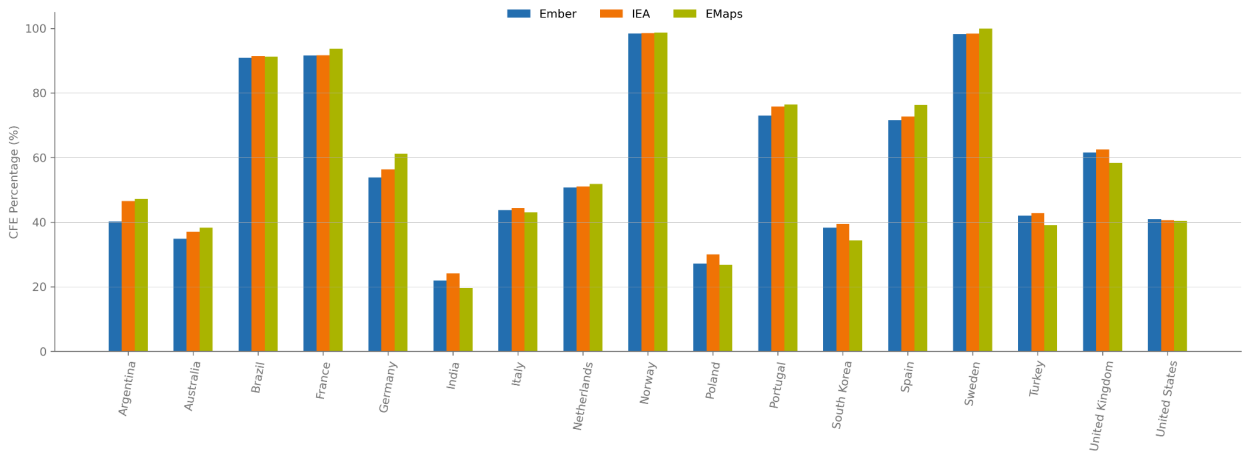

Figure 4: Comparison of the carbon-free energy percentage for different data sources across selected countries in 2023.

The comparison of CFE% shown in Figure 4 does not yield notably different results compared to the RE% presented above. The median absolute differences are of similar order with 2.1 pp between Ember and Electricity Maps and 2.9 pp between Electricity Maps and the IEA. The bias analysis also does not show any major differences, with the Electricity Maps value being, on average, 0.3 percentage points higher than the Ember value and 1.1 percentage points lower than the IEA. Electricity Maps value is thus, on average, comprised between the values of these two widely acknowledged data sources.

Comparison with Eurostat

This subsection compares Electricity Maps data to data provided by Eurostat, the statistical office of the European Union and an authoritative data source in Europe, for the renewable energy percentage (RE%) and the carbon-free energy percentage (CFE%).

As in the previous subsection, the data is compared to production-based Electricity Maps data, as Eurostat does not include exchanges between zones and countries in their calculations. The comparison uses yearly-aggregated data from 2022, the most recent year available from Eurostat. Detailed results for all available geographies can be found in Table E2.1 and Table E2.2 in Appendix E.

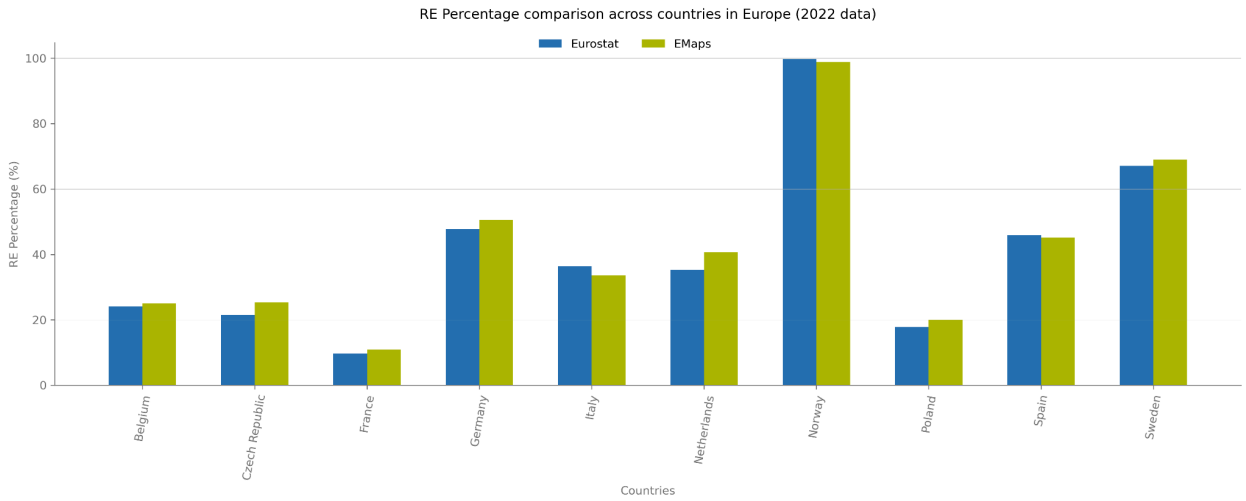

Figure 5: Comparison of the renewable energy percentage between Eurostat and Electricity Maps across selected countries in Europe in 2022.

Figure 5 shows a comparison between Eurostat and Electricity Maps RE% for the biggest electricity-producing countries in Europe in 2022. As for the previous subsection, the comparison for the renewable energy percentage over 2022 shows that Electricity Maps data is consistent with Eurostat data. The median absolute difference between the two data sources over the 33 countries is 2.4 pp. Electricity Maps data is also 1.5 pp lower than Eurostat data on average.

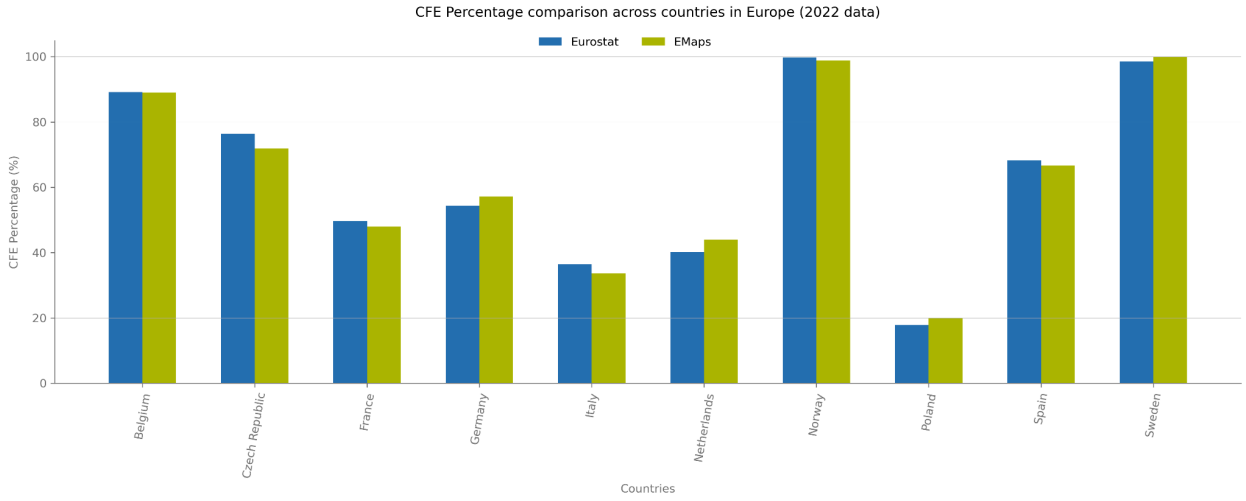

Figure 6: Comparison of the carbon-free energy percentage between Eurostat and Electricity Maps across selected countries in Europe in 2022.

Data publication and versioning

This section covers how data publication and data versioning work in Electricity Maps' freely available Datasets and Electricity Maps API.

The data points are marked according to the beginning of the time frame they are valid for, and all dates are in the UTC timezone. For example, with an hourly granularity, the data point marked with the date and time '2024-01-10T10:00:00Z' represents the timeframe spanning from 10 am to 11 am on the 10th of January 2024 in the UTC timezone.

Data portal

Electricity Maps allows for the free download of historical flow-traced signals (carbon intensity, renewable energy percentage, carbon-free energy percentage) via its Datasets. Data is available for 2021 and onwards, per zone and country, and can be retrieved on an hourly, daily, monthly, and yearly aggregation level.

Data for a given year is usually published in January of the following year under an ODb License. Under this license, Electricity Maps' data can be shared, used, and/or adapted for any purpose, including commercially, as long as the Attribution and Share Alike terms are followed.

In case of major data source or emission factor updates and changes, data for a given year can be updated more than once a year. To ensure that changes in data can be traced, snapshots of current and previous versions are stored in the Electricity Maps database and provided in the data portal.

API

Electricity Maps' data is also available through an API. The data is available historically, in real-time, and forecasted. Data provided can be updated over time for different reasons. An example is when data coming from external data sources is delayed and has been estimated in the meantime. Other reasons can also trigger an update of the data after weeks or even months, such as an outage of a data source or a data source publishing consolidated data after some time.

To cover all updates coming from external data sources, Electricity Maps applies an automatic data refetch policy that is available here. A refetch means retrieving (again) data for a data point already stored in the memory. Electricity Maps also keeps track of all changes made to any data point over time. Based on these updates, Electricity Maps provides premium customers with a data quality report indicating how many updates are made to data points in each zone over time and how large these updates are.

Table 2 gathers metrics about the updates made to data points in Electricity Maps' validated electricity database (see the Methodology section). A data point consists of all data for one zone and for one time. The results for all zones are available in Table F1 of Appendix F.

For half of the Electricity Maps zones, less than 50% of data points are updated after 24 hours. After 72 hours, updates to Electricity Maps' data points are much less frequent. For half of the zones, this concerns less than 21% of data points over the year. Finally, after 3 months, this number falls to 3%, with an average of 15% of data points updated after this time. The large difference between the median and average metrics for all periods greater than 48h shows that there are large differences from one zone to another.

Table 2: Share of data points that are updated after selected periods (aggregate statistics). These metrics are computed over all 2024 data for the 150 zones available commercially at that time.

Share of data points updated after...	6 hours	24 hours	48 hours	72 hours	7 days	30 days	3 months
Average	59%	43%	30%	28%	25%	22%	15%
Median	92%	48%	24%	21%	11%	8%	3%
75th percentile	100%	74%	52%	47%	44%	39%	25%
90th percentile	100%	90%	75%	74%	69%	58%	42%

The previous statistics indicated how many data points are expected to be updated after a certain period. However, this is not an indication of these updates' magnitude and their impact on the renewable energy percentage (RE%), carbon-free energy percentage (CFE%), and carbon intensity (CI) values provided by Electricity Maps. Table 3 and Table 4 respectively show, through aggregated statistics, how much the RE% and CI values provided by Electricity Maps get updated over time. The results for all zones for the RE%, the CFE%, and the CI are available in Table F2, Table F3, and Table F4 respectively, in Appendix F.

Table 3: Magnitude of updates to the renewable energy percentage after selected periods (aggregate statistics in percentage points). These metrics are computed over data from March 2024 to the end of the year for the 150 zones available commercially at that time.

Updates to RE% data	Before 6 hours	Between 6 and 24 hours	Between 24 and 72 hours	Between 72 hours and 7 days	Between 7 days and 30 days	Between 30 days and 3 months	After 3 months
Average	3.1	1.1	1.5	0.5	0.7	0.3	0.5
Median	2.0	0.3	0.4	0.2	0.3	0.1	0.1
75th percentile	4.4	1.6	1.5	0.6	0.9	0.4	0.7
90th percentile	6.8	3.4	3.7	1.2	1.4	0.8	1.8

Results show that data points can be largely updated within the first six hours after the time they are valid. On average, the RE% can be updated by 3 percentage points within this time frame. For 10% of zones, this increases to almost 7 percentage points. However, the magnitude of updates considerably decreases after six hours. Between 6 and 24 hours after the date time and between 24 and 72 hours, these updates are, on average, between 1 and 1.5 percentage points. For 50% of the zones, the RE% can already be considered definitive with updates of less than 0.5 percentage points. This becomes true for most ones after 72 hours with updates of less than 1 percentage point on average for 75% of zones and of less than 2 percentage points for 90% of the zones. Based on these statistics, and depending on the use case, we recommend refetching data once again after six hours to capture most of the updates. Another refetch after 72 hours is also recommended. After this date, data can be considered close to its definitive value. A refetch after 3 months ensures the highest data quality but is not essential.

As illustrated by Table 4, the updates to CI also happen in the majority within the first 72 hours after publication.

Table 4: Magnitude of relative updates to carbon intensity data after selected periods (aggregate statistics). These metrics are computed over data from March 2024 to the end of the year for the 150 zones available commercially at that time.

Updates to carbon intensity data	Before 6 hours	Between 6 and 24 hours	Between 24 and 72 hours	Between 72 hours and 7 days	Between 7 days and 30 days	Between 30 days and 1 month	After 3 months
Average	7%	2%	3%	1%	1%	1%	2%
Median	5%	1%	1%	1%	1%	0%	1%
75th percentile	9%	3%	4%	1%	2%	1%	2%
90th percentile	16%	6%	11%	2%	3%	2%	3%

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Appendix A - Zones and tiers

Table A1: Electricity Maps zones and zones' metadata

Zone identifier	Zone name	Country name	Tier
AE	United Arab Emirates	United Arab Emirates	Tier C
AF	Afghanistan	Afghanistan	Tier C
AG	Antigua and Barbuda	Antigua and Barbuda	Tier C
AL	Albania	Albania	Tier C
AM	Armenia	Armenia	Tier C
AO	Angola	Angola	Tier C
AT	Austria	Austria	Tier A
AU-NSW	New South Wales	Australia	Tier A
AU-NT	Northern Territory	Australia	Tier A
AU-QLD	Queensland	Australia	Tier A
AU-SA	South Australia	Australia	Tier A
AU-TAS	Tasmania	Australia	Tier A
AU-VIC	Victoria	Australia	Tier A
AU-WA	Western Australia	Australia	Tier A
AZ	Azerbaijan	Azerbaijan	Tier C
BA	Bosnia and Herzegovina	Bosnia and Herzegovina	Tier A
BB	Barbados	Barbados	Tier C
BD	Bangladesh	Bangladesh	Tier B
BE	Belgium	Belgium	Tier A
BF	Burkina Faso	Burkina Faso	Tier C
BG	Bulgaria	Bulgaria	Tier A
BH	Bahrain	Bahrain	Tier C
BI	Burundi	Burundi	Tier C
BJ	Benin	Benin	Tier C
BN	Brunei Darussalam	Brunei Darussalam	Tier C
BO	Bolivia	Bolivia	Tier A
BR-CS	Central Brazil	Brazil	Tier A
BR-N	North Brazil	Brazil	Tier A
BR-NE	North-East Brazil	Brazil	Tier A
BR-S	South Brazil	Brazil	Tier A
BS	Bahamas	Bahamas	Tier C
BT	Bhutan	Bhutan	Tier C
BW	Botswana	Botswana	Tier C
BY	Belarus	Belarus	Tier C
BZ	Belize	Belize	Tier C

CA-AB	Alberta	Canada	Tier A
CA-BC	British Columbia	Canada	Tier C
CA-MB	Manitoba	Canada	Tier C
CA-NB	New Brunswick	Canada	Tier C
CA-NL	Newfoundland & Labrador	Canada	Tier C
CA-NS	Nova Scotia	Canada	Tier C
CA-NT	Northwest Territories	Canada	Tier C
CA-NU	Nunavut	Canada	Tier C
CA-ON	Ontario	Canada	Tier A
CA-PE	Prince Edward Island	Canada	Tier C
CA-QC	Québec	Canada	Tier A
CA-SK	Saskatchewan	Canada	Tier C
CA-YT	Yukon	Canada	Tier C
CD	Democratic Republic of Congo	Democratic Republic of Congo	Tier C
CF	Central African Republic	Central African Republic	Tier C
CG	Congo	Congo	Tier C
CH	Switzerland	Switzerland	Tier C
CI	Côte d'Ivoire	Côte d'Ivoire	Tier C
CL-SEN	Sistema Eléctrico Nacional	Sistema Eléctrico Nacional	Tier A
CM	Cameroon	Cameroon	Tier C
CN	China	China	Tier C
CO	Colombia	Colombia	Tier B
CR	Costa Rica	Costa Rica	Tier A
CU	Cuba	Cuba	Tier C
CV	Cabo Verde	Cabo Verde	Tier C
CW	Curaçao	Curaçao	Tier C
CY	Cyprus	Cyprus	Tier A
CZ	Czechia	Czechia	Tier A
DE	Germany	Germany	Tier A
DJ	Djibouti	Djibouti	Tier C
DK-BHM	Bornholm	Denmark	Tier A
DK-DK1	West Denmark	Denmark	Tier A
DK-DK2	East Denmark	Denmark	Tier A
DM	Dominica	Dominica	Tier C
DO	Dominican Republic	Dominican Republic	Tier C
DZ	Algeria	Algeria	Tier C
EC	Ecuador	Ecuador	Tier C
EE	Estonia	Estonia	Tier A

EG	Egypt	Egypt	Tier C
ER	Eritrea	Eritrea	Tier C
ES	Spain	Spain	Tier A
ET	Ethiopia	Ethiopia	Tier C
FI	Finland	Finland	Tier A
FJ	Fiji	Fiji	Tier C
FK	Falkland Islands	Falkland Islands	Tier C
FR	France	France	Tier A
GA	Gabon	Gabon	Tier C
GB	Great Britain	Great Britain	Tier A
GB-NIR	Northern Ireland	Northern Ireland	Tier B
GE	Georgia	Georgia	Tier A
GF	French Guiana	French Guiana	Tier A
GH	Ghana	Ghana	Tier C
GI	Gibraltar	Gibraltar	Tier C
GL	Greenland	Greenland	Tier C
GM	Gambia	Gambia	Tier C
GN	Guinea	Guinea	Tier C
GQ	Equatorial Guinea	Equatorial Guinea	Tier C
GR	Greece	Greece	Tier A
GU	Guam	Guam	Tier C
GW	Guinea-Bissau	Guinea-Bissau	Tier C
GY	Guyana	Guyana	Tier C
HK	Hong Kong	Hong Kong	Tier C
HR	Croatia	Croatia	Tier A
HT	Haiti	Haiti	Tier C
HU	Hungary	Hungary	Tier A
ID	Indonesia	Indonesia	Tier C
IE	Ireland	Ireland	Tier B
IL	Israel	Israel	Tier B
IN-EA	Eastern India	India	Tier B
IN-NE	North Eastern India	India	Tier B
IN-NO	Northern India	India	Tier B
IN-SO	Southern India	India	Tier B
IN-WE	Western India	India	Tier B
IQ	Iraq	Iraq	Tier C
IR	Iran	Iran	Tier C
IS	Iceland	Iceland	Tier A
IT-CNO	Central North Italy	Italy	Tier A

IT-CSO	Central South Italy	Italy	Tier A
IT-NO	North Italy	Italy	Tier A
IT-SAR	Sardinia	Italy	Tier A
IT-SIC	Sicily	Italy	Tier A
IT-SO	South Italy	Italy	Tier A
JM	Jamaica	Jamaica	Tier C
JO	Jordan	Jordan	Tier C
JP-CB	Chūbu	Japan	Tier B
JP-CG	Chūgoku	Japan	Tier B
JP-HKD	Hokkaidō	Japan	Tier B
JP-HR	Hokuriku	Japan	Tier B
JP-KN	Kansai	Japan	Tier B
JP-KY	Kyūshū	Japan	Tier B
JP-ON	Okinawa	Japan	Tier B
JP-TH	Tōhoku	Japan	Tier B
JP-TK	Tōkyō	Japan	Tier B
KE	Kenya	Kenya	Tier C
KG	Kyrgyzstan	Kyrgyzstan	Tier C
KH	Cambodia	Cambodia	Tier C
KM	Comoros	Comoros	Tier C
KP	North Korea	North Korea	Tier C
KR	South Korea	South Korea	Tier A
KW	Kuwait	Kuwait	Tier C
KY	Cayman Islands	Cayman Islands	Tier C
KZ	Kazakhstan	Kazakhstan	Tier C
LA	Laos	Laos	Tier C
LB	Lebanon	Lebanon	Tier C
LC	Saint Lucia	Saint Lucia	Tier C
LK	Sri Lanka	Sri Lanka	Tier B
LR	Liberia	Liberia	Tier C
LS	Lesotho	Lesotho	Tier C
LT	Lithuania	Lithuania	Tier A
LU	Luxembourg	Luxembourg	Tier A
LV	Latvia	Latvia	Tier A
LY	Libya	Libya	Tier C
MA	Morocco	Morocco	Tier C
MD	Moldova	Moldova	Tier A
MG	Madagascar	Madagascar	Tier C
MK	North Macedonia	North Macedonia	Tier B

ML	Mali	Mali	Tier C
MM	Myanmar	Myanmar	Tier C
MN	Mongolia	Mongolia	Tier C
MR	Mauritania	Mauritania	Tier C
MT	Malta	Malta	Tier C
MU	Mauritius	Mauritius	Tier C
MV	Maldives	Maldives	Tier C
MW	Malawi	Malawi	Tier C
MX	Mexico	Mexico	Tier A
MY-EM	Borneo	Malaysia	Tier C
MY-WM	Peninsula	Malaysia	Tier A
MZ	Mozambique	Mozambique	Tier C
NA	Namibia	Namibia	Tier C
NC	New Caledonia	New Caledonia	Tier C
NE	Niger	Niger	Tier C
NG	Nigeria	Nigeria	Tier A
NI	Nicaragua	Nicaragua	Tier A
NL	Netherlands	Netherlands	Tier A
NO-NO1	Southeast Norway	Norway	Tier A
NO-NO2	Southwest Norway	Norway	Tier A
NO-NO3	Middle Norway	Norway	Tier A
NO-NO4	North Norway	Norway	Tier A
NO-NO5	West Norway	Norway	Tier A
NP	Nepal	Nepal	Tier C
NZ	New Zealand	New Zealand	Tier A
OM	Oman	Oman	Tier C
PA	Panama	Panama	Tier A
PE	Peru	Peru	Tier A
PG	Papua New Guinea	Papua New Guinea	Tier C
PH-LU	Luzon	Philippines	Tier A
PH-MI	Mindanao	Philippines	Tier A
PH-VI	Visayas	Philippines	Tier A
PK	Pakistan	Pakistan	Tier C
PL	Poland	Poland	Tier A
PM	Saint Pierre and Miquelon	Saint Pierre and Miquelon	Tier C
PR	Puerto Rico	Puerto Rico	Tier C
PS	State of Palestine	State of Palestine	Tier C
PT	Portugal	Portugal	Tier A
PY	Paraguay	Paraguay	Tier C

QA	Qatar	Qatar	Tier C
RE	Réunion	Réunion	Tier A
RO	Romania	Romania	Tier A
RS	Serbia	Serbia	Tier A
RW	Rwanda	Rwanda	Tier C
SA	Saudi Arabia	Saudi Arabia	Tier C
SB	Solomon Islands	Solomon Islands	Tier C
SC	Seychelles	Seychelles	Tier C
SD	Sudan	Sudan	Tier C
SE-SE1	North Sweden	Sweden	Tier A
SE-SE2	North Central Sweden	Sweden	Tier A
SE-SE3	South Central Sweden	Sweden	Tier A
SE-SE4	South Sweden	Sweden	Tier A
SG	Singapore	Singapore	Tier A
SI	Slovenia	Slovenia	Tier A
SK	Slovakia	Slovakia	Tier A
SL	Sierra Leone	Sierra Leone	Tier C
SN	Senegal	Senegal	Tier C
SO	Somalia	Somalia	Tier C
SR	Suriname	Suriname	Tier C
SS	South Sudan	South Sudan	Tier C
SY	Syria	Syria	Tier C
SZ	Eswatini	Eswatini	Tier C
TD	Chad	Chad	Tier C
TG	Togo	Togo	Tier C
TH	Thailand	Thailand	Tier C
TJ	Tajikistan	Tajikistan	Tier C
TM	Turkmenistan	Turkmenistan	Tier C
TN	Tunisia	Tunisia	Tier C
TO	Tonga	Tonga	Tier C
TR	Turkey	Turkey	Tier A
TT	Trinidad and Tobago	Trinidad and Tobago	Tier C
TW	Taiwan	Taiwan	Tier A
TZ	Tanzania	Tanzania	Tier C
UG	Uganda	Uganda	Tier C
US-CAL-BANC	Balancing Authority of Northern California	USA	Tier A
US-CAL-CISO	CAISO	USA	Tier A
US-CAL-IID	Imperial Irrigation District	USA	Tier A
US-CAL-LDWP	Los Angeles Department of Water and Power	USA	Tier A

US-CAL-TIDC	Turlock Irrigation District	USA	Tier A
US-CAR-CPLE	Duke Energy Progress East	USA	Tier A
US-CAR-CPLW	Duke Energy Progress West	USA	Tier A
US-CAR-DUK	Duke Energy Carolinas	USA	Tier A
US-CAR-SC	South Carolina Public Service Authority	USA	Tier A
US-CAR-SCEG	South Carolina Electric & Gas Company	USA	Tier A
US-CAR-YAD	Alcoa Power Generating, Inc. Yadkin Division	USA	Tier A
US-CENT-SPA	Southwestern Power Administration	USA	Tier A
US-CENT-SWPP	Southwest Power Pool	USA	Tier A
US-FLA-FMPP	Florida Municipal Power Pool	USA	Tier A
US-FLA-FPC	Duke Energy Florida	USA	Tier A
US-FLA-FPL	Florida Power and Light Company	USA	Tier A
US-FLA-GVL	Gainesville Regional Utilities	USA	Tier A
US-FLA-JEA	Jacksonville Electric Authority	USA	Tier A
US-FLA-SEC	Seminole Electric Cooperative	USA	Tier A
US-FLA-TAL	City of Tallahassee	USA	Tier A
US-FLA-TEC	Tampa Electric Company	USA	Tier A
US-MIDA-PJM	PJM Interconnection	USA	Tier A
US-MIDW-AECI	Associated Electric Cooperative	USA	Tier A
US-MIDW-LGEE	Louisville Gas and Electric Company and Kentucky Utilities	USA	Tier A
US-MIDW-MISO	Midcontinent ISO	USA	Tier A
US-NE-ISNE	ISO New England	USA	Tier A
US-NW-AVA	Avista Corporation	USA	Tier A
US-NW-BPAT	Bonneville Power Administration	USA	Tier A
US-NW-CHPD	Chelan County	USA	Tier A
US-NW-DOPD	Douglas County	USA	Tier A
US-NW-GCPD	Grant County	USA	Tier A
US-NW-GRID	Gridforce Energy Management	USA	Tier A
US-NW-IPCO	Idaho Power Company	USA	Tier A
US-NW-NEVP	Nevada Power Company	USA	Tier A
US-NW-NWMT	Northwestern Energy	USA	Tier A
US-NW-PACE	Pacificorp East	USA	Tier A
US-NW-PACW	Pacificorp West	USA	Tier A
US-NW-PGE	Portland General Electric Company	USA	Tier A
US-NW-PSCO	Public Service Company of Colorado	USA	Tier A
US-NW-PSEI	Puget Sound Energy	USA	Tier A
US-NW-SCL	Seattle City Light	USA	Tier A
US-NW-TPWR	City of Tacoma	USA	Tier A

US-NW-WACM	Western Area Power Administration - Rocky Mountain Region	USA	Tier A
US-NW-WAUW	Western Area Power Administration - Upper Great Plains West	USA	Tier A
US-NY-NYIS	New York ISO	USA	Tier A
US-SE-SOCO	Southern Company Services	USA	Tier A
US-SW-AZPS	Arizona Public Service Company	USA	Tier A
US-SW-EPE	El Paso Electric Company	USA	Tier A
US-SW-PNM	Public Service Company of New Mexico	USA	Tier A
US-SW-SRP	Salt River Project	USA	Tier A
US-SW-TEPC	Tucson Electric Power Company	USA	Tier A
US-SW-WALC	Western Area Power Administration - Desert Southwest Region	USA	Tier A
US-TEN-TVA	Tennessee Valley Authority	USA	Tier A
US-TEX-ERCO	Electric Reliability Council of Texas	USA	Tier A
UY	Uruguay	Uruguay	Tier A
UZ	Uzbekistan	Uzbekistan	Tier C
VC	Saint Vincent and the Grenadines	Saint Vincent and the Grenadines	Tier C
VE	Venezuela	Venezuela	Tier C
VI	Virgin Islands	Virgin Islands	Tier C
VN	Viet Nam	Viet Nam	Tier C
VU	Vanuatu	Vanuatu	Tier C
WS	Samoa	Samoa	Tier C
YE	Yemen	Yemen	Tier C
YT	Mayotte	Mayotte	Tier C
ZA	South Africa	South Africa	Tier A
ZM	Zambia	Zambia	Tier C
ZW	Zimbabwe	Zimbabwe	Tier C

Appendix B - Documentation of estimation models

Time-Slicer Average estimation model

The Time-Slicer Average (TSA) method estimates short-time data gaps occurring in Tier A, usually ranging from hours to a couple of days. It can either be permanent delays or unexpected gaps.

This estimation method uses available data to fill in the gap. Each missing point in the gap is filled by the average of the available data points that belong to the same time but on different days in the given month. The estimation is then aligned to ensure the continuity of the estimation points with the neighboring of the gap observed. This is illustrated in Figure 7 below. This estimation method is also, in some cases, complemented by other estimates sourced from external or internal forecasts, in particular for highly weather-dependent production modes like solar and wind. These different models are associated with achieving more accurate estimates.

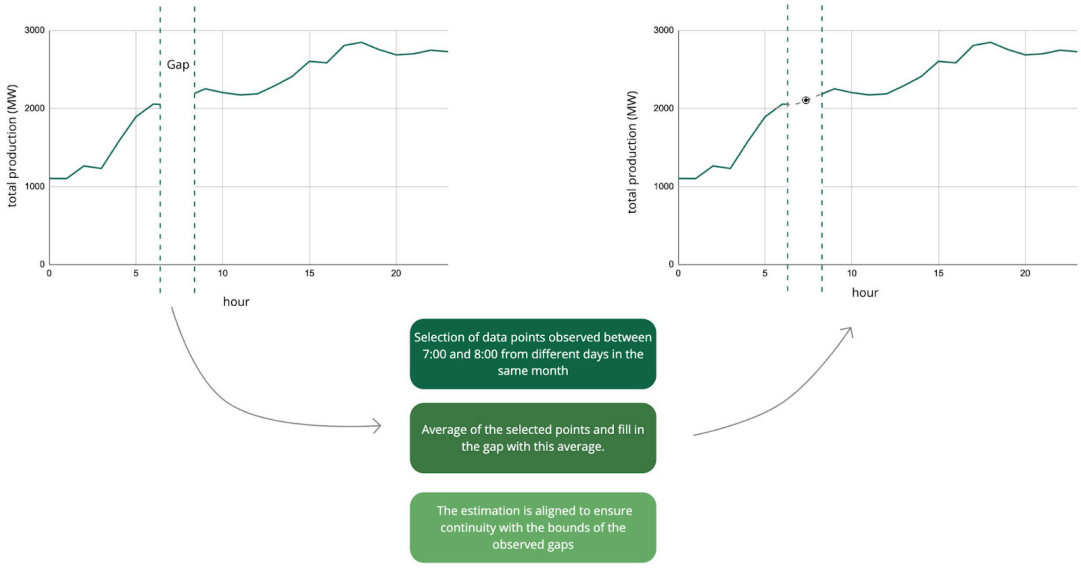

Figure 7: Illustration of the Time-Slicer Average (TSA) method used to estimate data gaps for Tier A zones.

Zone-specific estimation models

Zone-specific estimation models estimate hourly data in Tier B zones when only partly available. In some cases, only the total hourly production data is available in real time. In other cases, only some production modes can be available or reliable.

These estimation methods aim at leveraging all hourly (or daily) data available. When not available, variable renewable energy production (wind and solar) is estimated with models using weather

parameters such as wind speed, wind direction, and solar irradiation. These models are trained based on the historical data available. The rest of the production is estimated using dedicated estimation methods that are improved over time. The most basic estimation method used applies a static breakdown over the remaining gap between total production and variable renewables production based on the zone's yearly power mix. This is illustrated in Figure 8 below.

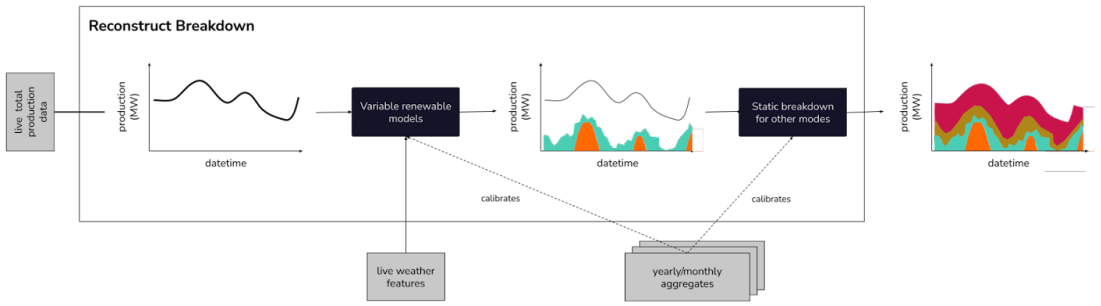

Figure 8: Illustration of the Reconstruct breakdown method used in zone-specific models for Tier A zones.

General Purpose Zone Development estimation model

The General Purpose Zone Development (GPZD) model estimates hourly data in Tier C zones when only monthly or yearly data is available. It estimates hourly production for all modes by leveraging the available data (yearly or monthly) and weather data. This estimation method also guarantees that yearly aggregates of hourly values match up with the publicly available yearly data.

As illustrated in Figure 9 below, it is broken down into two steps. The first step estimates monthly data from yearly data by capturing seasonal variations in electricity production. The second step estimates hourly data from monthly data by capturing daily and hourly variations in electricity production. The first step is skipped when monthly data is publicly available. Both steps use machine learning methods trained on zones with fully available hourly power mix data in combination with weather data.

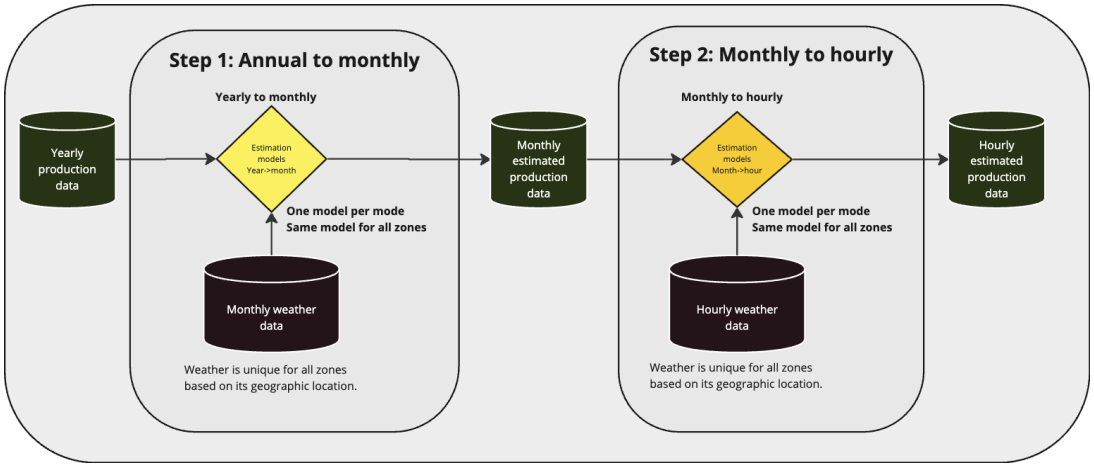

Figure 9: Illustration of the General Purpose Zone Development method used to estimate hourly data for Tier C zones.

Appendix C - Global emission factors

Table C1: Global emission factors used by Electricity Maps worldwide

Technology	Lifecycle emission factor (gCO2eq/kWh)	Direct emission factor (gCO2eq/kWh)	Sources
Biomass	230	0	IPCC 2014
Coal	820	760	IPCC 2014
Gas	490	370	IPCC 2014
Geothermal	38	0	IPCC 2014
Hydro	24	0	IPCC 2014
Nuclear	12	0	IPCC 2014
Oil	650	406	UK Parliamentary Office of Science and Technology, EIA 2020/BEIS 2021
Solar	45	0	IPCC 2014
Unknown	700	575	Assumes a mix of thermal sources
Wind	11	0	IPCC 2014

Appendix D - Data comparison with Ember and IEA datasets

Methodology for sourcing and comparing data

Data sourcing

Data used for the comparison of RE% and CFE% from the IEA is issued from the Monthly Electricity Statistics dataset, using the version of 14th November 2024. This dataset is updated monthly by the IEA and provides electricity production data for OECD member countries and "a selection of other economies". The renewable energy percentage for the IEA was calculated as 'Total Renewables (Hydro, Geo, Solar, Wind, Other)' divided by 'Electricity'. For the carbon-free energy percentage, the numerator used was the addition of 'Total Renewables (Hydro, Geo, Solar, Wind, Other)' and 'Nuclear'.

Data used for comparison from Ember is issued from the Yearly Electricity Data dataset, using the version from November 2024. This dataset is also updated monthly and provides the "electricity demand, generation, capacity, and CO2 data by country". Ember directly provides the renewable energy percentage (called 'Renewables') and the carbon-free energy percentage (called 'Clean').

Data used for comparison from Electricity Maps is the renewable energy percentage and the carbon-free energy percentage calculated according to the methodology described in this report. The numbers are calculated on the electricity production mix as the IEA and Ember do not provide any flow-traced numbers.

Values for all three datasets are for the year 2023.

Data comparison

The datasets are compared with two main metrics: the absolute difference and the difference. With $RE_{x,i}$ and $RE_{x,j}$, the renewable energy percentage for a zone x given by data sources i, j respectively, the two metrics are computed as follows:

$$Diff_{RE,x,i-j} = RE_{x,i} - RE_{x,j}, \quad AbsDiff_{RE,x,i-j} = abs(Diff_{RE,x,i-j}) = abs(RE_{x,i} - RE_{x,j})$$

The absolute difference (*AbsDiff*) quantifies the overall difference between two datasets, while the difference (*Diff*) more specifically quantifies if values from one dataset are consistently lower or greater than the others.

The two metrics are computed for all zones, and the median values are provided in the report.

Comparison results

Table D2.1: Comparison of the renewable energy percentage between Ember, the IEA, and Electricity Maps.

Country	Ember (2023)	IEA (2023)	Electricity Maps (2023)
Argentina	34%	40%	41%
Australia	35%	37%	38%
Austria	85%	85%	89%
Belgium	33%	35%	33%
Bolivia	29%		31%
Bosnia Herzegovina	40%		41%
Brazil	89%	90%	89%
Bulgaria	26%	26%	20%
Chile	61%	64%	61%
Colombia	66%	66%	80%
Costa Rica	96%	100%	94%
Croatia	69%	71%	69%
Cyprus	21%	21%	20%
Czech Republic	15%	16%	12%
Denmark	88%	89%	83%
Estonia	44%	42%	46%
Finland	52%	52%	52%
France	26%	28%	27%
Germany	52%	55%	60%
Greece	50%	50%	52%
Hungary	26%	27%	20%
Iceland		100%	100%
India	20%	22%	17%
Indonesia	19%		13%
Ireland	45%	45%	43%
Italy	44%	44%	43%
Latvia	76%	79%	74%
Lithuania	76%	81%	86%
Luxembourg	92%	94%	93%
Malaysia	19%		19%
Moldova	10%		7%
Montenegro	60%		60%
Netherlands	47%	48%	49%
New Zealand	87%	88%	88%

Nigeria	21%		24%
North Macedonia	34%	38%	23%
Norway	98%	99%	99%
Oman	1%		5%
Peru	59%		59%
Poland	27%	30%	27%
Portugal	73%	76%	76%
Qatar	%		4%
Romania	51%	54%	49%
Serbia	35%	38%	38%
Singapore	5%		4%
Slovakia	23%	25%	21%
Slovenia	39%	43%	39%
South Africa	13%		13%
South Korea	9%	9%	3%
Spain	51%	53%	55%
Sri Lanka	50%		49%
Sweden	69%	70%	70%
Switzerland	61%	66%	60%
Taiwan	9%		11%
Turkey	42%	43%	39%
United Arab Emirates	8%		6%
United Kingdom	47%	49%	41%
United States	23%	22%	21%
Uruguay	90%		91%

Table D2.2: Comparison of the carbon-free energy percentage between Ember, the IEA, and Electricity Maps.

Country		Ember (2023)	IEA (2023)	Electricity Maps (2023)
Argentina		40%	47%	47%
Australia		35%	37%	38%
Austria		85%	85%	89%
Belgium		74%	74%	73%
Bolivia		29%		31%
Bosnia Herzegovina		40%		41%
Brazil		91%	91%	91%
Bulgaria		66%	68%	61%
Chile		61%	64%	61%
Colombia		66%	66%	80%
Costa Rica		96%	100%	94%

Croatia		69%	71%	69%
Cyprus		21%	21%	20%
Czech Republic		55%	57%	53%
Denmark		88%	89%	83%
Estonia		44%	42%	46%
Finland		94%	94%	90%
France		92%	92%	94%
Germany		54%	56%	61%
Greece		50%	50%	52%
Hungary		70%	72%	68%
Iceland			100%	100%
India		22%	24%	20%
Indonesia		19%		13%
Ireland		45%	45%	43%
Italy		44%	44%	43%
Latvia		76%	79%	74%
Lithuania		76%	81%	86%
Luxembourg		92%	94%	93%
Malaysia		19%		19%
Moldova		10%		7%
Montenegro		60%		60%
Netherlands		51%	51%	52%
New Zealand		87%	88%	88%
Nigeria		21%		24%
North Macedonia		34%	38%	23%
Norway		98%	99%	99%
Oman		1%		5%
Peru		59%		59%
Poland		27%	30%	27%
Portugal		73%	76%	76%
Qatar		%		4%
Romania		71%	73%	69%
Serbia		35%	38%	38%
Singapore		5%		4%
Slovakia		85%	86%	84%
Slovenia		76%	79%	77%
South Africa		16%		17%
South Korea		38%	39%	34%
Spain		72%	73%	76%

Sri Lanka		50%		49%
Sweden		98%	98%	100%
Switzerland		95%	98%	98%
Taiwan		15%		17%
Turkey		42%	43%	39%
United Arab Emirates		28%		24%
United Kingdom		62%	62%	58%
United States		41%	41%	40%
Uruguay		90%		91%

Appendix E - Data comparison with the Eurostat dataset

Methodology for sourcing and comparing data

Data sourcing

Data used for comparison from Eurostat is issued in the Eurostat Energy Database, using the following datasets: 'Gross and net production of electricity and derived heat by type of plant and operator' (nrg_ind_peh) and 'Gross production of electricity and derived heat from combustible fuels by type of plant and operator' (nrg_ind_pehcf), using the version from January 9, 2025. The percentages are calculated with gross electricity production numbers expressed in gigawatt hours for all plant types, using only main-activity producers (and excluding auto-producers, who often don't deliver to the grid). The SIEC codes used for aggregation are *RA100, RA200, RA300, RA400, RA500, R5100, R5210P, R5220P, R5290, R5300, W6210* for Renewables; *N9000* for Nuclear and *TOTAL* for total electricity production.

Data comparison

The methodology used for data comparison is identical to the methodology used for comparison to the Ember and the IEA datasets and is described in Appendix B1.

Comparison results

Table E2.1: Comparison of the renewable energy percentage between Electricity Maps and Eurostat

Country	Eurostat (2022)	Electricity Maps (2022)
Austria	83%	80%
Belgium	21%	25%
Bosnia Herzegovina	33%	31%
Bulgaria	19%	14%
Croatia	65%	35%
Cyprus	12%	16%
Czech Republic	10%	11%
Denmark	10%	11%
Estonia	32%	36%
Finland	48%	47%
France	48%	47%

Germany	48%	51%
Greece	45%	44%
Hungary	16%	16%
Ireland	42%	39%
Italy	36%	34%
Latvia	36%	34%
Lithuania	86%	86%
Luxembourg	75%	70%
Moldova	75%	70%
Montenegro	53%	54%
Netherlands	35%	41%
North Macedonia	27%	22%
Norway	100%	99%
Poland	18%	20%
Portugal	62%	62%
Romania	48%	42%
Serbia	29%	31%
Slovakia	19%	20%
Slovenia	27%	30%
Spain	46%	45%
Sweden	67%	69%
Turkey	14%	6%

Table E2.2: Comparison of the carbon-free energy percentage between Electricity Maps and Eurostat

Country	Eurostat (2022)	Electricity Maps (2022)
Austria	83%	80%
Belgium	76%	72%
Bosnia Herzegovina	33%	31%
Bulgaria	52%	47%
Croatia	65%	35%
Cyprus	12%	16%
Czech Republic	50%	48%
Denmark	50%	48%
Estonia	32%	36%
Finland	89%	84%
France	89%	84%
Germany	54%	57%
Greece	45%	44%
Hungary	64%	64%

Ireland	42%	39%
Italy	36%	34%
Latvia	36%	34%
Lithuania	86%	86%
Luxembourg	75%	70%
Moldova	75%	70%
Montenegro	53%	54%
Netherlands	40%	44%
North Macedonia	27%	22%
Norway	100%	99%
Poland	18%	20%
Portugal	62%	62%
Romania	72%	62%
Serbia	29%	31%
Slovakia	86%	81%
Slovenia	72%	73%
Spain	68%	67%
Sweden	99%	100%
Turkey	14%	6%

Appendix F - Data updates

Table F1: Share of data points that are updated after selected periods per zone. These metrics are computed over all 2024 data for the 150 zones available commercially at that time.

Data source updates	Datapoints updated after 6 hours	Datapoints updated after 24 hours	Datapoints updated after 48 hours	Datapoints updated after 72 hours	Datapoints updated after 7 days	Datapoints updated after 30 days	Datapoints updated after 3 months
Mean	59%	43%	30%	28%	25%	22%	15%
Median	92%	48%	24%	21%	11%	8%	3%
75th percentile	100%	74%	52%	47%	44%	39%	25%
90th percentile	100%	90%	75%	74%	69%	58%	42%
AU-QLD	84%	73%	27%	21%	1%	0%	0%
AU-SA	81%	71%	16%	12%	2%	0%	0%
AU-TAS	80%	73%	23%	18%	2%	0%	0%
AU-VIC	77%	70%	14%	11%	2%	0%	0%
AU-WA	97%	40%	1%	0%	0%	0%	0%
BA	3%	1%	1%	0%	0%	0%	0%
BE	96%	83%	58%	27%	23%	19%	12%
BG	0%	0%	0%	0%	0%	0%	0%
BR-CS	0%	0%	0%	0%	0%	0%	0%
BR-N	0%	0%	0%	0%	0%	0%	0%
BR-NE	0%	0%	0%	0%	0%	0%	0%
BR-S	0%	0%	0%	0%	0%	0%	0%
CA-ON	9%	9%	9%	9%	7%	6%	0%
CA-QC	5%	1%	0%	0%	0%	0%	0%
CH	100%	100%	100%	100%	100%	98%	82%
CL-SEN	100%	90%	25%	25%	21%	20%	19%
CR	41%	35%	33%	33%	30%	26%	15%
CY	44%	20%	8%	8%	8%	8%	0%
CZ	0%	0%	0%	0%	0%	0%	0%
DE	90%	62%	31%	28%	27%	27%	17%
DK-BHM	0%	0%	0%	0%	0%	0%	0%
DK-DK1	22%	22%	21%	21%	21%	21%	18%
DK-DK2	20%	20%	19%	19%	19%	19%	18%
EE	61%	60%	60%	60%	60%	57%	43%
ES	1%	1%	0%	0%	0%	0%	0%
FI	4%	3%	2%	2%	2%	2%	1%
FR	71%	69%	45%	45%	44%	42%	29%
GB	98%	84%	81%	81%	80%	73%	56%

GB-NIR	11%	8%	8%	8%	6%	0%	0%
GR	59%	57%	57%	57%	56%	49%	30%
HK	0%	0%	0%	0%	0%	0%	0%
HR	7%	4%	4%	3%	3%	3%	3%
HU	100%	75%	33%	14%	12%	11%	6%
ID	0%	0%	0%	0%	0%	0%	0%
IE	10%	8%	8%	8%	6%	0%	0%
IL	0%	0%	0%	0%	0%	0%	0%
IN-EA	100%	90%	52%	27%	3%	0%	0%
IN-NE	100%	90%	52%	27%	3%	0%	0%
IN-NO	100%	90%	52%	27%	3%	0%	0%
IN-SO	100%	90%	52%	27%	3%	0%	0%
IN-WE	100%	90%	52%	27%	3%	0%	0%
IS	0%	0%	0%	0%	0%	0%	0%
IT-CNO	100%	49%	43%	43%	42%	37%	16%
IT-CSO	100%	50%	45%	45%	44%	39%	17%
IT-NO	100%	54%	44%	44%	44%	39%	17%
IT-SAR	100%	42%	39%	38%	37%	31%	13%
IT-SIC	100%	50%	45%	44%	43%	38%	16%
IT-SO	100%	51%	43%	42%	42%	37%	15%
JP-CB	0%	0%	0%	0%	0%	0%	0%
JP-CG	1%	0%	0%	0%	0%	0%	0%
JP-HKD	1%	0%	0%	0%	0%	0%	0%
JP-HR	1%	0%	0%	0%	0%	0%	0%
JP-KN	0%	0%	0%	0%	0%	0%	0%
JP-KY	0%	0%	0%	0%	0%	0%	0%
JP-ON	1%	0%	0%	0%	0%	0%	0%
JP-TH	1%	0%	0%	0%	0%	0%	0%
JP-TK	1%	0%	0%	0%	0%	0%	0%
KE	0%	0%	0%	0%	0%	0%	0%
KR	25%	25%	25%	25%	25%	22%	5%
LT	3%	2%	1%	0%	0%	0%	0%
LU	93%	46%	1%	0%	0%	0%	0%
LV	19%	19%	19%	19%	19%	19%	18%
MY-EM	0%	0%	0%	0%	0%	0%	0%
MY-WM	71%	67%	59%	58%	57%	51%	34%
NI	0%	0%	0%	0%	0%	0%	0%
NL	96%	94%	86%	86%	86%	80%	63%
NO-NO1	1%	0%	0%	0%	0%	0%	0%

NO-NO2	1%	1%	0%	0%	0%	0%	0%
NO-NO3	1%	0%	0%	0%	0%	0%	0%
NO-NO4	1%	0%	0%	0%	0%	0%	0%
NO-NO5	1%	0%	0%	0%	0%	0%	0%
NZ	0%	0%	0%	0%	0%	0%	0%
PA	0%	0%	0%	0%	0%	0%	0%
PE	100%	73%	52%	52%	52%	44%	24%
PH-LU	91%	12%	0%	0%	0%	0%	0%
PH-MI	91%	12%	0%	0%	0%	0%	0%
PH-VI	91%	12%	0%	0%	0%	0%	0%
PL	27%	20%	19%	19%	18%	13%	0%
PT	100%	97%	68%	31%	28%	27%	19%
QA	0%	0%	0%	0%	0%	0%	0%
RO	1%	1%	0%	0%	0%	0%	0%
RS	90%	32%	27%	26%	26%	25%	25%
SE-SE1	2%	1%	1%	1%	0%	0%	0%
SE-SE2	2%	1%	1%	1%	0%	0%	0%
SE-SE3	3%	1%	1%	1%	0%	0%	0%
SE-SE4	4%	3%	2%	2%	2%	0%	0%
SG	0%	0%	0%	0%	0%	0%	0%
SI	5%	3%	2%	2%	2%	1%	1%
SK	1%	1%	1%	1%	1%	0%	0%
TR	98%	82%	82%	82%	82%	78%	61%
TW	0%	0%	0%	0%	0%	0%	0%
US-CAL-BANC	100%	67%	51%	50%	45%	41%	27%
US-CAL-CISO	14%	10%	10%	10%	7%	3%	1%
US-CAL-IID	100%	57%	33%	32%	30%	30%	24%
US-CAL-LDWP	99%	74%	60%	59%	55%	53%	41%
US-CAL-TIDC	100%	51%	26%	25%	22%	20%	11%
US-CAR-CPLE	100%	98%	95%	88%	72%	56%	40%
US-CAR-CPLW	100%	96%	86%	84%	69%	67%	56%
US-CAR-DUK	100%	74%	52%	50%	48%	41%	36%
US-CAR-SC	100%	90%	75%	74%	70%	65%	53%
US-CAR-SCEG	100%	76%	46%	44%	41%	40%	27%
US-CAR-YAD	100%	42%	19%	17%	11%	9%	6%
US-CENT-SPA	99%	62%	41%	39%	36%	31%	22%
US-CENT-SWPP	1%	1%	0%	0%	0%	0%	0%
US-FLA-FMPP	100%	80%	59%	58%	53%	52%	35%
US-FLA-FPC	100%	86%	66%	65%	60%	58%	44%

US-FLA-FPL	100%	73%	42%	41%	39%	36%	23%
US-FLA-GVL	100%	73%	48%	47%	44%	42%	31%
US-FLA-JEA	100%	82%	59%	57%	52%	47%	35%
US-FLA-SEC	100%	73%	49%	48%	46%	41%	30%
US-FLA-TAL	100%	62%	31%	29%	26%	23%	15%
US-FLA-TEC	100%	92%	77%	76%	74%	73%	63%
US-MIDA-PJM	100%	100%	100%	100%	100%	100%	87%
US-MIDW-AECI	100%	61%	40%	38%	33%	29%	19%
US-MIDW-LGEE	100%	99%	94%	93%	93%	92%	69%
US-MIDW-MISO	100%	54%	17%	16%	12%	8%	4%
US-NE-ISNE	2%	2%	2%	2%	1%	1%	0%
US-NW-AVA	100%	62%	41%	39%	36%	35%	24%
US-NW-BPAT	100%	53%	29%	27%	24%	22%	15%
US-NW-CHPD	100%	52%	27%	26%	23%	18%	13%
US-NW-DOPD	98%	28%	6%	5%	2%	1%	0%
US-NW-GCPD	99%	32%	9%	8%	5%	3%	1%
US-NW-GRID	100%	59%	36%	35%	33%	30%	21%
US-NW-IPCO	100%	98%	97%	97%	97%	77%	42%
US-NW-NEVP	100%	85%	71%	70%	66%	61%	45%
US-NW-NWMT	100%	70%	50%	50%	47%	44%	33%
US-NW-PACE	100%	100%	100%	93%	72%	48%	20%
US-NW-PACW	100%	85%	73%	70%	64%	54%	34%
US-NW-PGE	100%	71%	51%	50%	46%	37%	24%
US-NW-PSCO	100%	85%	72%	71%	71%	68%	47%
US-NW-PSEI	100%	84%	69%	64%	55%	48%	36%
US-NW-SCL	100%	37%	9%	8%	5%	2%	0%
US-NW-TPWR	99%	32%	7%	6%	3%	2%	1%
US-NW-WACM	100%	65%	48%	46%	43%	38%	27%
US-NW-WAUW	100%	45%	16%	15%	12%	11%	8%
US-NY-NYIS	2%	1%	1%	1%	0%	0%	0%
US-SE-SOCO	100%	100%	99%	99%	99%	63%	31%
US-SW-AZPS	100%	76%	56%	55%	53%	51%	36%
US-SW-EPE	99%	45%	22%	21%	18%	18%	12%
US-SW-PNM	100%	77%	60%	59%	57%	52%	41%
US-SW-SRP	100%	71%	53%	53%	51%	49%	35%
US-SW-TEPC	100%	66%	48%	47%	45%	44%	32%
US-SW-WALC	100%	59%	39%	37%	35%	33%	17%
US-TEN-TVA	100%	89%	84%	83%	83%	79%	55%
US-TEX-ERCO	100%	100%	100%	100%	100%	95%	78%

UY	13%	11%	11%	11%	9%	7%	4%
ZA	100%	100%	99%	95%	46%	4%	0%

Table F2: Magnitude of updates to the renewable energy percentage after selected periods per zone. These metrics are computed over data from March 2024 to the end of the year for the 150 zones available commercially at that time.

Updates to RE%	Before 6 hours	Between 6 and 24 hours	Between 24 and 72 hours	Between 72 hours and 7 days	Between 7 days and 30 days	Between 7 days and 3 months	After 3 months
Mean	3.1	1.1	1.5	0.5	0.7	0.3	0.5
Median	2.0	0.3	0.3	0.2	0.3	0.1	0.1
75th percentile	4.4	1.6	1.5	0.6	0.8	0.4	0.7
90th percentile	6.8	3.4	3.7	1.2	1.4	0.8	1.8
AU-QLD	5.5	0.0	0.1	0.4	0.2	0.0	0.0
AU-SA	5.8	0.0	0.1	0.8	0.3	0.0	0.0
AU-TAS	2.7	0.0	0.0	0.2	0.1	0.1	0.0
AU-VIC	4.6	0.0	0.1	0.4	0.3	0.0	0.0
AU-WA	0.6	1.6	0.9	2.7	1.0	0.1	0.0
BA	6.3	0.5	0.3	0.3	0.6	0.4	0.4
BE	4.8	0.2	0.5	0.1	0.2	0.3	0.4
BG	3.1	0.1	0.1	0.0	0.1	0.0	0.0
BR-CS	0.3	0.0	0.0	0.1	0.1	0.0	0.0
BR-N	0.4	0.0	0.0	0.1	0.1	0.0	0.0
BR-NE	0.1	0.0	0.0	0.0	0.0	0.0	0.0
BR-S	0.3	0.0	0.0	0.0	0.0	0.0	0.0
CA-ON	2.1	0.0	0.0	0.1	0.1	0.0	0.0
CA-QC	0.8	0.2	0.1	0.0	0.0	0.0	0.0
CH	7.0	1.7	3.4	0.2	1.0	0.8	5.7
CL-SEN	1.2	4.1	0.2	0.7	0.1	0.1	0.0
CR	2.0	0.0	0.1	0.3	0.1	0.0	0.0
CY	2.6	0.8	0.3	0.7	0.1	0.0	0.0
CZ	5.9	0.1	0.0	0.0	0.0	0.1	0.0
DE	3.0	0.3	0.4	0.0	0.1	0.2	0.2
DK-BHM	11.3	0.1	0.0	0.4	0.2	0.0	0.0
DK-DK1	5.8	0.2	0.2	0.2	0.3	0.4	0.4
DK-DK2	8.2	0.1	0.1	0.1	0.1	0.1	0.1
EE	6.7	0.8	0.6	0.4	0.2	0.1	1.2
ES	2.5	0.1	0.0	0.1	0.0	0.0	0.0
FI	2.8	0.1	0.0	0.1	0.0	0.0	0.0
FR	1.6	0.1	0.1	0.0	0.1	0.1	0.1
GB	2.8	2.0	1.0	0.3	1.4	2.1	5.5

GB-NIR	2.8	0.7	0.5	0.4	0.6	0.6	2.0
GR	9.9	0.3	0.2	0.2	0.2	0.1	1.1
HK	0.0	0.0	0.0	0.0	0.0	0.1	0.8
HR	5.4	0.3	0.2	0.1	0.5	0.1	0.1
HU	5.0	0.5	0.2	0.0	0.1	0.1	0.0
ID	0.0	0.0	0.0	0.0	0.0	0.3	4.1
IE	2.8	0.6	1.1	0.4	0.7	0.4	0.1
IL	0.1	0.1	0.0	0.0	0.0	0.0	0.0
IN-EA	0.2	0.3	0.6	0.1	0.1	0.1	1.0
IN-NE	0.8	1.8	2.4	0.5	1.5	0.2	1.2
IN-NO	1.2	1.0	1.0	0.3	0.9	0.2	0.4
IN-SO	1.3	1.1	0.9	0.3	0.9	0.4	0.5
IN-WE	0.5	0.5	0.4	0.1	0.2	0.1	0.2
IS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IT-CNO	8.8	0.6	0.4	0.1	0.6	0.7	0.7
IT-CSO	9.9	0.8	0.3	0.3	1.4	0.4	0.5
IT-NO	5.0	0.5	0.5	0.1	0.5	0.3	0.7
IT-SAR	5.8	0.8	0.2	0.5	1.3	0.2	0.1
IT-SIC	9.4	0.7	0.2	1.1	1.3	0.3	0.1
IT-SO	6.8	0.5	0.3	1.0	1.9	0.2	0.1
JP-CB	3.5	0.0	0.0	0.9	0.3	0.1	0.0
JP-CG	3.6	0.1	0.1	1.2	0.3	0.1	0.0
JP-HKD	2.7	0.0	0.0	1.0	0.4	0.1	0.0
JP-HR	1.8	0.0	0.0	0.7	0.3	0.1	0.0
JP-KN	2.5	0.0	0.2	0.7	0.2	0.1	0.0
JP-KY	3.5	0.0	0.0	1.5	0.5	0.1	0.0
JP-ON	1.6	0.1	0.0	1.6	0.3	0.1	0.0
JP-TH	2.4	0.0	0.0	0.9	0.2	0.1	0.0
JP-TK	2.2	0.1	0.7	1.3	0.3	0.2	0.8
KE	0.0	0.0	0.0	0.0	0.2	0.3	0.5
KR	0.4	0.0	0.2	0.2	0.1	0.1	0.0
LT	15.7	0.5	0.5	0.4	0.9	0.2	0.1
LU	6.8	1.8	1.9	0.2	0.5	0.3	0.2
LV	10.8	0.7	0.3	0.2	0.3	0.1	0.3
MY-EM	0.0	0.0	0.0	0.0	0.0	0.1	0.0
MY-WM	0.8	0.1	0.5	0.3	0.2	0.1	0.0
NI	1.5	0.4	0.9	1.1	1.3	0.1	0.1
NL	6.9	0.5	0.5	0.2	1.2	2.2	3.2
NO-NO1	5.5	0.0	0.0	0.2	0.1	0.1	0.0

NO-NO2	1.2	0.2	0.3	0.3	0.6	0.7	0.2
NO-NO3	0.5	0.0	0.0	0.1	0.0	0.0	0.0
NO-NO4	1.3	0.0	0.0	0.1	0.0	0.0	0.0
NO-NO5	0.2	0.0	0.0	0.0	0.0	0.0	0.0
NZ	0.9	0.5	1.2	1.1	0.4	0.0	0.0
PA	0.8	1.9	1.7	1.6	1.5	0.1	0.0
PE	0.9	1.3	0.3	0.5	0.3	0.0	0.0
PH-LU	0.3	0.2	0.2	0.6	0.1	0.0	0.0
PH-MI	0.5	0.3	0.2	0.6	0.1	0.0	0.0
PH-VI	0.5	0.6	0.3	0.5	0.1	0.0	0.0
PL	4.9	0.3	0.1	0.0	0.1	0.9	0.0
PT	4.8	2.6	0.6	0.2	0.1	0.0	0.0
QA	0.1	0.8	11.9	6.3	18.4	9.3	2.7
RO	2.5	0.1	0.0	0.0	0.0	0.0	0.0
RS	11.3	3.6	0.6	0.2	0.3	0.1	0.7
SE-SE1	1.2	0.0	0.0	0.4	0.1	0.0	0.0
SE-SE2	0.5	0.0	0.0	0.1	0.0	0.0	0.0
SE-SE3	22.2	0.2	0.0	0.1	0.0	0.0	0.0
SE-SE4	28.7	0.3	0.1	0.1	0.2	0.1	0.0
SG	0.3	0.0	0.0	0.3	0.0	0.1	0.0
SI	8.8	0.2	0.1	0.1	1.1	0.1	0.1
SK	4.0	0.1	0.0	0.0	0.1	0.2	0.0
TR	4.9	0.5	0.1	0.1	2.9	0.0	0.7
TW	0.8	0.1	0.1	1.0	0.2	0.0	0.0
US-CAL-BANC	3.8	3.8	3.4	0.2	0.4	0.7	1.2
US-CAL-CISO	2.1	0.0	0.8	0.2	0.3	0.1	0.2
US-CAL-IID	2.5	2.7	0.9	0.6	1.4	0.2	2.7
US-CAL-LDWP	3.6	3.3	9.2	0.7	0.7	1.0	1.1
US-CAL-TIDC	2.9	2.3	2.9	0.5	0.6	0.4	0.9
US-CAR-CPLE	0.8	1.2	1.0	0.1	0.2	0.2	1.7
US-CAR-CPLW	2.2	2.2	3.1	0.3	0.9	0.2	1.9
US-CAR-DUK	1.5	1.7	0.7	0.2	0.4	0.4	1.8
US-CAR-SC	0.8	1.2	1.1	0.2	0.4	0.4	1.0
US-CAR-SCEG	1.7	2.3	1.0	0.2	0.3	0.2	0.4
US-CAR-YAD	0.0	0.0	4.0	1.7	3.0	0.4	0.2
US-CENT-SPA	0.1	0.1	7.6	1.5	3.7	0.1	0.1
US-CENT-SWPP	1.5	0.1	0.1	0.1	0.1	0.0	0.0
US-FLA-FMPP	0.6	0.7	0.5	0.1	0.4	0.2	0.5

US-FLA-FPC	1.2	1.4	0.8	0.1	0.3	0.1	0.6
US-FLA-FPL	0.4	0.8	0.3	0.1	0.1	0.0	0.1
US-FLA-GVL	0.0	0.0	0.4	0.1	0.0	0.1	0.1
US-FLA-JEA	0.2	0.1	1.7	0.1	0.1	0.1	0.1
US-FLA-SEC	0.0	0.0	0.1	0.0	0.0	0.0	0.2
US-FLA-TAL	0.6	0.7	0.3	0.1	0.2	0.1	0.1
US-FLA-TEC	1.5	1.9	1.2	0.2	0.8	0.4	2.8
US-MIDA-PJM	1.0	0.0	0.1	0.1	0.2	0.1	0.0
US-MIDW-AECI	2.4	2.9	2.4	0.4	0.5	0.6	0.6
US-MIDW-LGEE	0.4	0.7	1.7	0.1	0.2	0.2	0.3
US-MIDW-MISO	1.7	3.5	1.6	0.2	0.4	0.1	0.1
US-NE-ISNE	0.8	0.0	0.0	0.1	0.1	0.0	0.0
US-NW-AVA	3.5	3.9	3.3	0.2	0.5	0.4	0.8
US-NW-BPAT	1.8	2.3	3.0	0.1	0.3	0.5	0.5
US-NW-CHPD	0.0	0.0	0.4	0.0	0.1	0.1	0.0
US-NW-DOPD	0.0	0.0	0.4	0.0	0.1	0.0	0.0
US-NW-GCPD	0.0	0.0	3.0	0.2	0.3	0.2	0.2
US-NW-GRID	1.6	3.6	2.8	2.6	2.7	1.3	1.0
US-NW-IPCO	3.6	3.1	3.8	0.5	1.3	1.3	1.8
US-NW-NEVP	2.1	3.5	5.6	1.2	1.6	1.4	2.6
US-NW-NWMT	4.0	7.0	2.5	0.5	1.3	0.8	1.8
US-NW-PACE	3.5	3.8	1.7	0.5	1.0	0.4	0.4
US-NW-PACW	11.6	9.8	15.8	0.7	1.1	0.8	2.1
US-NW-PGE	1.9	2.0	14.7	0.5	1.5	1.4	0.4
US-NW-PSCO	5.9	9.0	2.5	1.8	4.4	1.6	2.9
US-NW-PSEI	5.2	5.1	23.2	1.2	1.5	1.0	0.8
US-NW-SCL	0.0	0.0	3.7	0.1	0.6	0.4	0.2
US-NW-TPWR	0.0	0.0	4.3	0.2	0.3	0.3	0.3
US-NW-WACM	3.3	4.2	2.5	1.0	1.1	0.6	1.3
US-NW-WAUW	1.6	0.8	4.3	0.5	1.3	0.2	0.4
US-NY-NYIS	0.7	0.0	0.0	0.0	0.0	0.0	0.0
US-SE-SOCO	0.6	0.6	0.4	0.1	0.6	0.3	0.3
US-SW-AZPS	2.6	2.9	5.6	0.5	1.3	0.4	0.6
US-SW-EPE	0.9	1.5	4.4	0.9	1.0	0.6	0.9
US-SW-PNM	6.0	6.8	5.3	1.5	2.9	1.1	1.9
US-SW-SRP	0.9	1.9	1.7	0.5	1.3	0.3	0.3
US-SW-TEPC	3.0	3.0	3.1	0.6	0.8	0.4	0.7
US-SW-WALC	4.0	5.8	10.2	1.4	2.2	1.8	1.2
US-TEN-TVA	1.4	2.2	1.8	0.6	1.2	0.3	0.1

US-TEX-ERCO	2.8	3.4	0.7	1.2	0.8	0.3	0.1
UY	0.6	0.0	0.0	0.0	0.1	0.0	0.0
ZA	0.2	0.1	0.5	0.1	0.1	0.0	0.0

Table F3: Magnitude of updates to the carbon-free energy percentage after selected periods per zone. These metrics are computed over data from March 2024 to the end of the year for the 150 zones available commercially at that time.

Updates to CFE%	Before 6 hours	Between 6 and 24 hours	Between 24 and 72 hours	Between 72 hours and 7 days	Between 7 days and 30 days	Between 7 days and 3 months	After 3 months
Mean	2.6	1.2	1.7	0.5	0.7	0.4	0.7
Median	1.9	0.3	0.3	0.2	0.3	0.1	0.1
75th percentile	3.5	1.6	2.0	0.6	0.9	0.4	0.7
90th percentile	5.9	3.6	4.4	1.1	1.5	0.9	1.8
AU-QLD	5.5	0.0	0.1	0.4	0.2	0.0	0.0
AU-SA	5.8	0.0	0.1	0.8	0.3	0.0	0.0
AU-TAS	2.7	0.0	0.0	0.2	0.1	0.1	0.0
AU-VIC	4.6	0.0	0.1	0.4	0.3	0.0	0.0
AU-WA	0.6	1.6	0.9	2.7	1.0	0.1	0.0
BA	7.9	0.5	0.3	0.3	0.5	0.4	0.4
BE	3.1	0.2	1.4	0.1	0.2	0.3	0.3
BG	2.0	0.1	0.1	0.0	0.1	0.0	0.0
BR-CS	0.2	0.0	0.0	0.1	0.0	0.0	0.0
BR-N	0.4	0.0	0.0	0.1	0.1	0.0	0.0
BR-NE	0.1	0.0	0.0	0.0	0.0	0.0	0.0
BR-S	0.3	0.0	0.0	0.0	0.0	0.0	0.0
CA-ON	2.3	0.0	0.0	0.1	0.1	0.0	0.0
CA-QC	0.2	0.1	0.0	0.0	0.0	0.0	0.0
CH	1.0	0.1	0.1	0.0	0.1	0.2	1.6
CL-SEN	1.2	4.1	0.2	0.7	0.1	0.1	0.0
CR	2.0	0.0	0.1	0.3	0.1	0.0	0.0
CY	2.6	0.8	0.3	0.7	0.1	0.0	0.0
CZ	3.3	0.0	0.0	0.0	0.0	0.1	0.0
DE	3.1	0.3	0.3	0.0	0.2	0.2	0.1
DK-BHM	0.3	0.0	0.0	0.0	0.0	0.0	0.0
DK-DK1	3.4	0.2	0.2	0.1	0.2	0.3	0.3
DK-DK2	7.6	0.1	0.1	0.1	0.1	0.0	0.0
EE	8.1	0.8	0.6	0.5	0.2	0.1	0.8
ES	2.0	0.1	0.1	0.0	0.0	0.0	0.0
FI	0.6	0.0	0.0	0.0	0.0	0.0	0.0
FR	0.3	0.0	0.0	0.0	0.0	0.0	0.0

GB	2.6	1.9	0.8	0.3	0.9	1.0	2.8
GB-NIR	2.8	0.8	0.5	0.4	0.5	0.3	1.1
GR	9.9	0.3	0.2	0.2	0.2	0.1	1.0
HK	0.0	0.0	0.0	0.0	0.0	1.7	21.2
HR	4.4	0.3	0.1	0.1	0.3	0.1	0.1
HU	3.3	0.2	0.1	0.0	0.2	0.1	0.0
ID	0.0	0.0	0.0	0.0	0.0	0.3	4.1
IE	2.8	0.6	1.1	0.4	0.9	0.5	0.0
IL	0.1	0.1	0.0	0.0	0.0	0.0	0.0
IN-EA	0.2	0.3	0.7	0.1	0.1	0.1	1.2
IN-NE	0.8	1.8	2.4	0.5	1.5	0.2	1.2
IN-NO	1.4	1.0	1.1	0.3	1.0	0.2	0.4
IN-SO	1.7	1.4	1.1	0.3	1.0	0.4	0.6
IN-WE	0.6	0.6	0.4	0.1	0.2	0.1	0.2
IS	0.0	0.0	0.0	0.0	0.0	0.0	0.0
IT-CNO	8.1	0.5	0.2	0.2	0.6	0.8	0.6
IT-CSO	10.2	0.8	0.3	0.4	1.4	0.4	0.4
IT-NO	11.0	0.4	0.1	0.1	0.5	0.2	0.2
IT-SAR	5.9	0.8	0.2	0.5	1.3	0.2	0.1
IT-SIC	9.5	0.7	0.2	1.1	1.3	0.3	0.1
IT-SO	6.8	0.4	0.2	1.0	1.9	0.2	0.1
JP-CB	3.6	0.0	0.0	0.8	0.3	0.1	0.0
JP-CG	3.7	0.1	0.1	1.1	0.4	0.1	0.0
JP-HKD	2.7	0.0	0.0	1.0	0.4	0.1	0.0
JP-HR	1.9	0.0	0.0	0.7	0.3	0.1	0.0
JP-KN	3.4	0.1	0.2	0.5	0.2	0.1	0.1
JP-KY	4.0	0.0	0.0	1.1	0.4	0.1	0.0
JP-ON	1.6	0.1	0.0	1.6	0.3	0.1	0.0
JP-TH	2.4	0.0	0.0	0.9	0.2	0.1	0.0
JP-TK	2.2	0.1	0.7	1.3	0.3	0.2	0.8
KE	0.0	0.0	0.0	0.0	0.2	0.3	0.5
KR	0.6	0.0	0.1	0.2	0.1	0.2	0.0
LT	10.2	0.5	0.5	0.4	0.8	0.5	0.3
LU	4.3	1.4	1.6	0.2	0.6	0.3	0.1
LV	10.6	0.8	0.3	0.2	0.2	0.1	0.2
MY-EM	0.0	0.0	0.0	0.0	0.0	0.1	0.0
MY-WM	0.8	0.1	0.5	0.3	0.2	0.1	0.0
NI	1.5	0.4	0.9	1.1	1.3	0.1	0.1
NL	6.8	0.5	0.5	0.2	1.2	2.4	3.2

NO-NO1	0.1	0.0	0.0	0.0	0.0	0.1	0.0
NO-NO2	0.4	0.1	0.2	0.2	0.3	0.4	0.1
NO-NO3	0.5	0.0	0.0	0.1	0.0	0.0	0.0
NO-NO4	1.4	0.0	0.0	0.1	0.0	0.0	0.0
NO-NO5	0.1	0.0	0.0	0.0	0.0	0.0	0.0
NZ	0.9	0.5	1.2	1.1	0.4	0.0	0.0
PA	0.8	1.9	1.7	1.6	1.5	0.1	0.0
PE	0.9	1.3	0.3	0.5	0.3	0.0	0.0
PH-LU	0.3	0.2	0.2	0.6	0.1	0.0	0.0
PH-MI	0.5	0.3	0.2	0.6	0.1	0.0	0.0
PH-VI	0.5	0.6	0.3	0.5	0.1	0.0	0.0
PL	5.4	0.3	0.1	0.1	0.1	0.9	0.0
PT	2.5	2.0	0.5	0.1	0.1	0.0	0.0
QA	0.1	0.8	11.9	6.3	18.4	9.3	2.7
RO	1.7	0.1	0.0	0.0	0.0	0.0	0.0
RS	12.6	3.9	0.7	0.2	0.3	0.1	0.7
SE-SE1	0.2	0.0	0.0	0.0	0.0	0.0	0.0
SE-SE2	0.1	0.0	0.0	0.0	0.0	0.0	0.0
SE-SE3	0.1	0.0	0.0	0.0	0.0	0.0	0.0
SE-SE4	1.3	0.1	0.1	0.0	0.2	0.1	0.0
SG	0.3	0.0	0.0	0.3	0.0	0.1	0.0
SI	4.0	0.1	0.1	0.0	0.4	0.0	0.0
SK	5.7	0.2	0.2	0.0	0.2	0.2	0.0
TR	4.9	0.5	0.1	0.1	2.9	0.0	0.7
TW	0.8	0.2	0.1	0.9	0.2	0.0	0.0
US-CAL-BANC	3.8	3.8	4.1	0.2	0.4	0.7	1.2
US-CAL-CISO	1.9	0.0	0.9	0.2	0.5	0.2	0.2
US-CAL-IID	2.5	2.7	1.3	0.6	1.5	0.2	2.7
US-CAL-LDWP	3.6	3.3	12.3	0.8	1.0	1.1	1.1
US-CAL-TIDC	2.9	2.3	3.3	0.5	0.6	0.4	0.9
US-CAR-CPLE	3.4	3.6	2.1	0.3	0.7	0.6	5.4
US-CAR-CPLW	2.2	2.2	7.2	0.7	1.0	0.3	3.1
US-CAR-DUK	3.1	3.2	2.0	0.4	1.2	0.3	5.8
US-CAR-SC	2.3	3.0	4.8	0.4	0.9	1.0	2.5
US-CAR-SCEG	3.5	4.5	2.1	0.2	0.4	0.3	0.5
US-CAR-YAD	0.0	0.0	1.9	0.9	1.5	0.2	0.4
US-CENT-SPA	0.1	0.1	6.9	1.3	3.0	0.1	0.1
US-CENT-SWPP	1.5	0.1	0.1	0.1	0.1	0.0	0.0

US-FLA-FMPP	1.2	1.5	1.4	0.2	1.0	0.6	0.8
US-FLA-FPC	1.2	1.4	2.0	0.2	0.5	0.2	0.9
US-FLA-FPL	1.2	2.1	1.3	0.2	0.2	0.1	0.1
US-FLA-GVL	0.0	0.0	1.7	0.2	0.1	0.2	0.1
US-FLA-JEA	0.2	0.1	6.0	0.3	0.2	0.4	0.2
US-FLA-SEC	0.0	0.0	0.1	0.0	0.0	0.0	0.2
US-FLA-TAL	0.6	0.7	2.3	0.3	0.2	0.1	0.1
US-FLA-TEC	1.5	1.9	1.4	0.2	0.8	0.5	3.0
US-MIDA-PJM	1.4	0.0	0.1	0.1	0.3	0.1	0.1
US-MIDW-AECI	2.5	2.9	2.5	0.3	0.4	0.6	0.6
US-MIDW-LGEE	0.4	0.7	3.8	0.2	0.4	0.4	0.8
US-MIDW-MISO	1.8	3.5	1.5	0.2	0.4	0.1	0.1
US-NE-ISNE	1.1	0.0	0.0	0.0	0.1	0.0	0.1
US-NW-AVA	3.5	3.9	4.0	0.2	0.5	0.4	0.8
US-NW-BPAT	1.3	1.5	4.2	0.1	0.3	0.5	0.6
US-NW-CHPD	0.0	0.0	0.3	0.0	0.1	0.1	0.0
US-NW-DOPD	0.0	0.0	0.3	0.0	0.1	0.0	0.0
US-NW-GCPD	0.0	0.0	2.6	0.1	0.3	0.2	0.2
US-NW-GRID	1.6	3.6	2.8	2.6	2.7	1.3	1.0
US-NW-IPCO	3.6	3.1	3.9	0.5	1.3	1.3	1.8
US-NW-NEVP	2.1	3.5	6.5	1.2	1.7	1.4	2.7
US-NW-NWMT	4.0	7.0	2.5	0.5	1.3	0.8	1.8
US-NW-PACE	3.5	3.8	1.8	0.5	1.1	0.4	0.4
US-NW-PACW	11.6	9.8	18.0	0.8	1.2	0.8	2.2
US-NW-PGE	1.9	2.0	17.6	0.5	1.6	1.6	0.5
US-NW-PSCO	5.9	8.9	2.5	1.8	4.4	1.6	2.9
US-NW-PSEI	5.2	5.1	27.5	1.3	1.5	1.1	0.9
US-NW-SCL	0.0	0.0	2.3	0.1	0.4	0.2	0.2
US-NW-TPWR	0.0	0.0	2.4	0.1	0.2	0.3	0.4
US-NW-WACM	3.3	4.2	2.5	1.0	1.1	0.6	1.2
US-NW-WAUW	1.5	0.8	4.4	0.5	1.3	0.2	0.4
US-NY-NYIS	1.1	0.0	0.0	0.0	0.1	0.0	0.0
US-SE-SOCO	0.9	1.0	0.7	0.2	0.6	0.3	0.3
US-SW-AZPS	2.6	2.9	13.1	1.1	3.5	0.8	0.9
US-SW-EPE	0.9	1.5	4.6	1.0	1.1	0.6	0.9
US-SW-PNM	6.0	6.8	5.0	1.5	3.0	1.1	1.9
US-SW-SRP	5.1	7.9	4.7	1.2	4.6	0.9	0.7
US-SW-TEPC	3.0	3.0	3.9	0.7	1.0	0.5	0.7
US-SW-WALC	4.0	5.8	6.5	1.1	2.8	2.0	1.1

US-TEN-TVA	2.1	3.1	2.6	1.0	2.1	0.6	0.2
US-TEX-ERCO	2.8	3.4	0.6	1.2	0.8	0.3	0.1
UY	0.6	0.0	0.0	0.0	0.1	0.0	0.0
ZA	0.2	0.1	0.5	0.1	0.1	0.0	0.0

Table F4: Magnitude of updates to lifecycle carbon intensity data after selected periods per zone. These metrics are computed over data from March 2024 to the end of the year for the 150 zones available commercially at that time. The metrics are computed in absolute difference and relative differences in parentheses.

Updates to carbon intensity	Before 6 hours	Between 6 and 24 hours	Between 24 and 72 hours	Between 72 hours and 7 days	Between 7 days and 30 days	Between 7 days and 3 months	After 3 months
AT	25 (23%)	2 (1%)	2 (2%)	0 (0%)	1 (1%)	1 (2%)	4 (5%)
AU-NSW	42 (8%)	0 (0%)	0 (0%)	3 (1%)	2 (0%)	0 (0%)	0 (0%)
AU-NT	0 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
AU-QLD	40 (7%)	0 (0%)	0 (0%)	3 (1%)	2 (0%)	0 (0%)	0 (0%)
AU-SA	30 (15%)	0 (0%)	0 (0%)	4 (3%)	2 (1%)	0 (0%)	0 (0%)
AU-TAS	20 (14%)	0 (0%)	0 (0%)	1 (1%)	1 (1%)	0 (0%)	0 (0%)
AU-VIC	35 (7%)	0 (0%)	0 (0%)	3 (1%)	2 (0%)	0 (0%)	0 (0%)
AU-WA	4 (1%)	9 (2%)	5 (1%)	16 (4%)	6 (2%)	1 (0%)	0 (0%)
BA	65 (11%)	4 (1%)	2 (0%)	2 (0%)	5 (1%)	4 (1%)	3 (1%)
BE	18 (13%)	1 (1%)	9 (7%)	0 (0%)	1 (1%)	2 (1%)	1 (1%)
BG	16 (5%)	1 (0%)	1 (0%)	0 (0%)	2 (1%)	2 (1%)	2 (1%)
BR-CS	1 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
BR-N	3 (2%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
BR-NE	1 (2%)	0 (1%)	0 (0%)	0 (1%)	0 (0%)	0 (0%)	0 (0%)
BR-S	2 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
CA-ON	11 (14%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
CA-QC	1 (3%)	0 (1%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
CH	8 (12%)	2 (3%)	3 (5%)	0 (0%)	1 (2%)	3 (4%)	24 (43%)
CL-SEN	7 (4%)	26 (12%)	1 (0%)	4 (2%)	1 (0%)	1 (0%)	0 (0%)
CR	12 (13%)	0 (0%)	1 (0%)	2 (1%)	0 (0%)	0 (0%)	0 (0%)
CY	23 (3%)	7 (1%)	2 (0%)	6 (1%)	2 (0%)	0 (0%)	0 (0%)
CZ	31 (7%)	1 (0%)	0 (0%)	0 (0%)	1 (0%)	2 (1%)	2 (1%)
DE	32 (9%)	4 (1%)	3 (1%)	1 (0%)	3 (1%)	4 (1%)	7 (2%)
DK-BHM	20 (26%)	1 (1%)	0 (0%)	1 (2%)	1 (1%)	0 (0%)	0 (0%)
DK-DK1	25 (18%)	1 (1%)	1 (1%)	1 (1%)	2 (1%)	2 (2%)	3 (3%)
DK-DK2	78 (36%)	1 (1%)	1 (1%)	1 (0%)	1 (1%)	1 (1%)	3 (2%)
EE	79 (19%)	9 (2%)	7 (1%)	5 (1%)	2 (0%)	1 (0%)	7 (2%)
ES	11 (8%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)
FI	5 (7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
FR	2 (7%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (2%)

GB	13 (7%)	10 (5%)	4 (2%)	1 (1%)	5 (3%)	6 (4%)	15 (9%)
GB-NIR	15 (5%)	4 (1%)	3 (1%)	2 (1%)	4 (1%)	4 (1%)	9 (3%)
GR	55 (17%)	2 (1%)	2 (0%)	1 (0%)	3 (1%)	2 (1%)	9 (3%)
HK	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	12 (2%)	132 (22%)
HR	35 (14%)	2 (1%)	1 (0%)	1 (0%)	2 (1%)	1 (0%)	1 (0%)
HU	26 (11%)	2 (1%)	1 (0%)	0 (0%)	2 (1%)	2 (1%)	1 (1%)
ID	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (0%)	9 (1%)
IE	19 (5%)	4 (1%)	7 (2%)	2 (1%)	7 (2%)	4 (1%)	1 (0%)
IL	1 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
IN-EA	1 (0%)	3 (0%)	6 (1%)	1 (0%)	1 (0%)	1 (0%)	10 (1%)
IN-NE	5 (1%)	11 (3%)	18 (4%)	3 (1%)	10 (2%)	2 (0%)	14 (3%)
IN-NO	11 (2%)	8 (1%)	8 (1%)	2 (0%)	7 (1%)	2 (0%)	3 (1%)
IN-SO	14 (2%)	11 (2%)	9 (2%)	3 (0%)	8 (1%)	3 (1%)	5 (1%)
IN-WE	4 (1%)	5 (1%)	4 (1%)	1 (0%)	1 (0%)	1 (0%)	2 (0%)
IS	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
IT-CNO	42 (16%)	3 (1%)	1 (1%)	1 (0%)	4 (1%)	11 (3%)	8 (3%)
IT-CSO	56 (20%)	5 (2%)	2 (1%)	2 (1%)	7 (2%)	4 (1%)	6 (2%)
IT-NO	62 (20%)	3 (1%)	1 (0%)	1 (0%)	3 (1%)	2 (1%)	5 (2%)
IT-SAR	51 (9%)	6 (1%)	2 (0%)	4 (1%)	10 (2%)	4 (1%)	3 (1%)
IT-SIC	52 (16%)	4 (2%)	1 (0%)	6 (2%)	8 (2%)	2 (1%)	2 (1%)
IT-SO	36 (13%)	2 (1%)	1 (1%)	5 (2%)	11 (3%)	2 (0%)	2 (1%)
JP-CB	22 (5%)	0 (0%)	0 (0%)	5 (1%)	2 (1%)	0 (0%)	0 (0%)
JP-CG	22 (5%)	0 (0%)	0 (0%)	7 (2%)	2 (1%)	1 (0%)	0 (0%)
JP-HKD	17 (4%)	0 (0%)	0 (0%)	6 (2%)	2 (1%)	0 (0%)	0 (0%)
JP-HR	11 (3%)	0 (0%)	0 (0%)	4 (1%)	2 (0%)	0 (0%)	0 (0%)
JP-KN	21 (6%)	0 (0%)	1 (0%)	3 (1%)	1 (1%)	0 (0%)	0 (0%)
JP-KY	25 (9%)	0 (0%)	0 (0%)	7 (3%)	2 (1%)	1 (0%)	0 (0%)
JP-ON	10 (2%)	0 (0%)	0 (0%)	9 (2%)	2 (0%)	1 (0%)	0 (0%)
JP-TH	14 (3%)	0 (0%)	0 (0%)	5 (1%)	1 (0%)	0 (0%)	0 (0%)
JP-TK	12 (2%)	1 (0%)	5 (1%)	8 (2%)	2 (0%)	1 (0%)	3 (1%)
KE	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (1%)	2 (2%)	3 (3%)
KR	3 (1%)	0 (0%)	2 (0%)	1 (0%)	1 (0%)	2 (0%)	0 (0%)
LT	82 (37%)	5 (2%)	4 (2%)	2 (1%)	5 (3%)	5 (3%)	4 (3%)
LU	36 (16%)	13 (6%)	12 (6%)	2 (1%)	6 (2%)	4 (2%)	5 (2%)
LV	58 (25%)	6 (2%)	2 (1%)	2 (1%)	2 (1%)	1 (1%)	2 (1%)
MY-EM	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	2 (1%)	0 (0%)
MY-WM	7 (1%)	0 (0%)	5 (1%)	3 (0%)	2 (0%)	1 (0%)	0 (0%)
NI	9 (3%)	2 (1%)	6 (2%)	6 (2%)	8 (3%)	0 (0%)	0 (0%)
NL	37 (14%)	3 (1%)	2 (1%)	1 (0%)	6 (3%)	9 (4%)	10 (4%)

NO-NO1	2 (5%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (1%)	0 (0%)
NO-NO2	3 (6%)	1 (1%)	1 (2%)	1 (2%)	2 (3%)	2 (4%)	1 (1%)
NO-NO3	3 (10%)	0 (0%)	0 (0%)	0 (2%)	0 (0%)	0 (0%)	0 (0%)
NO-NO4	7 (10%)	0 (0%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)	0 (0%)
NO-NO5	1 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
NZ	5 (5%)	3 (2%)	8 (4%)	8 (4%)	3 (2%)	0 (0%)	0 (0%)
PA	5 (3%)	12 (6%)	10 (6%)	9 (5%)	9 (5%)	0 (0%)	0 (0%)
PE	4 (2%)	6 (3%)	1 (1%)	3 (1%)	2 (1%)	0 (0%)	0 (0%)
PH-LU	2 (0%)	1 (0%)	1 (0%)	3 (0%)	1 (0%)	0 (0%)	0 (0%)
PH-MI	4 (1%)	2 (0%)	1 (0%)	4 (1%)	1 (0%)	0 (0%)	0 (0%)
PH-VI	3 (1%)	4 (1%)	3 (0%)	3 (1%)	1 (0%)	0 (0%)	0 (0%)
PL	60 (8%)	4 (0%)	1 (0%)	1 (0%)	3 (0%)	15 (2%)	8 (1%)
PT	12 (11%)	14 (10%)	3 (2%)	0 (0%)	1 (1%)	0 (0%)	2 (2%)
QA	0 (0%)	3 (1%)	53 (12%)	28 (6%)	82 (18%)	41 (9%)	12 (2%)
RO	14 (5%)	1 (0%)	0 (0%)	0 (0%)	1 (0%)	2 (1%)	2 (1%)
RS	100 (19%)	31 (6%)	5 (1%)	1 (0%)	2 (0%)	2 (0%)	5 (1%)
SE-SE1	2 (11%)	0 (0%)	0 (0%)	0 (2%)	0 (0%)	0 (0%)	0 (0%)
SE-SE2	1 (6%)	0 (0%)	0 (0%)	0 (1%)	0 (0%)	0 (0%)	0 (0%)
SE-SE3	3 (12%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
SE-SE4	35 (48%)	1 (1%)	1 (1%)	0 (0%)	3 (4%)	1 (1%)	1 (0%)
SG	1 (0%)	0 (0%)	0 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)
SI	40 (17%)	1 (0%)	1 (0%)	0 (0%)	4 (2%)	1 (1%)	2 (1%)
SK	65 (27%)	2 (1%)	2 (1%)	0 (0%)	3 (1%)	2 (1%)	2 (1%)
TR	34 (8%)	4 (1%)	1 (0%)	1 (0%)	17 (3%)	0 (0%)	4 (1%)
TW	5 (1%)	1 (0%)	0 (0%)	6 (1%)	1 (0%)	0 (0%)	0 (0%)
US-CAL-BANC	19 (5%)	19 (5%)	21 (7%)	1 (1%)	2 (1%)	4 (2%)	6 (2%)
US-CAL-CISO	10 (5%)	0 (0%)	7 (3%)	1 (1%)	3 (2%)	1 (1%)	1 (1%)
US-CAL-IID	17 (3%)	18 (3%)	9 (2%)	4 (1%)	10 (2%)	2 (0%)	19 (3%)
US-CAL-LDWP	31 (5%)	27 (4%)	88 (15%)	5 (1%)	7 (2%)	7 (2%)	7 (2%)
US-CAL-TIDC	17 (3%)	13 (3%)	21 (5%)	3 (1%)	4 (1%)	2 (1%)	5 (1%)
US-CAR-CPLE	33 (6%)	32 (7%)	16 (3%)	2 (1%)	5 (1%)	6 (1%)	43 (8%)
US-CAR-CPLW	14 (3%)	14 (3%)	36 (7%)	4 (1%)	5 (1%)	2 (0%)	22 (5%)
US-CAR-DUK	24 (5%)	24 (6%)	17 (4%)	4 (1%)	9 (2%)	3 (1%)	39 (9%)
US-CAR-SC	32 (3%)	39 (4%)	88 (10%)	8 (1%)	16 (2%)	17 (3%)	51 (8%)
US-CAR-SCEG	27 (4%)	32 (5%)	17 (3%)	1 (0%)	2 (1%)	2 (0%)	4 (1%)
US-CAR-YAD	0 (0%)	0 (0%)	12 (14%)	6 (5%)	10 (8%)	2 (1%)	3 (3%)
US-CENT-SPA	1 (0%)	0 (0%)	52 (19%)	9 (4%)	22 (6%)	1 (1%)	0 (0%)
US-CENT-SWPP	12 (3%)	1 (0%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
US-FLA-FMPP	15 (2%)	16 (2%)	17 (3%)	2 (0%)	8 (1%)	5 (1%)	7 (1%)

US-FLA-FPC	8 (1%)	9 (2%)	14 (3%)	1 (0%)	4 (1%)	1 (0%)	5 (1%)
US-FLA-FPL	6 (2%)	11 (3%)	10 (3%)	1 (0%)	2 (0%)	0 (0%)	1 (0%)
US-FLA-GVL	3 (0%)	2 (0%)	16 (3%)	2 (0%)	2 (0%)	1 (0%)	1 (0%)
US-FLA-JEA	10 (1%)	11 (1%)	80 (11%)	4 (1%)	3 (1%)	6 (1%)	3 (0%)
US-FLA-SEC	17 (2%)	17 (2%)	8 (1%)	1 (0%)	14 (2%)	1 (0%)	9 (1%)
US-FLA-TAL	3 (1%)	3 (1%)	5 (1%)	1 (0%)	1 (0%)	0 (0%)	1 (0%)
US-FLA-TEC	9 (2%)	11 (2%)	13 (3%)	2 (0%)	7 (1%)	3 (1%)	25 (5%)
US-MIDA-PJM	10 (3%)	0 (0%)	1 (0%)	1 (0%)	2 (1%)	1 (0%)	0 (0%)
US-MIDW-AECI	21 (3%)	26 (4%)	19 (3%)	3 (1%)	4 (1%)	6 (1%)	8 (1%)
US-MIDW-LGEE	13 (1%)	17 (2%)	45 (5%)	3 (0%)	8 (1%)	7 (1%)	15 (2%)
US-MIDW-MISO	13 (3%)	26 (5%)	11 (2%)	1 (0%)	3 (1%)	0 (0%)	1 (0%)
US-NE-ISNE	6 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
US-NW-AVA	19 (6%)	21 (6%)	19 (6%)	1 (1%)	3 (2%)	3 (2%)	5 (3%)
US-NW-BPAT	7 (5%)	8 (6%)	37 (28%)	1 (1%)	2 (2%)	3 (3%)	4 (3%)
US-NW-CHPD	0 (1%)	0 (1%)	2 (4%)	0 (0%)	1 (1%)	0 (0%)	0 (0%)
US-NW-DOPD	0 (0%)	0 (0%)	2 (2%)	0 (0%)	0 (1%)	0 (0%)	0 (0%)
US-NW-GCPD	0 (0%)	0 (0%)	15 (20%)	1 (2%)	2 (3%)	1 (2%)	1 (2%)
US-NW-GRID	13 (2%)	27 (5%)	20 (4%)	17 (4%)	20 (4%)	10 (2%)	5 (1%)
US-NW-IPCO	20 (7%)	18 (7%)	37 (11%)	4 (1%)	10 (3%)	10 (3%)	14 (3%)
US-NW-NEVP	22 (3%)	28 (5%)	34 (6%)	6 (1%)	10 (2%)	10 (2%)	14 (3%)
US-NW-NWMT	40 (7%)	70 (11%)	25 (4%)	5 (1%)	12 (2%)	8 (1%)	18 (3%)
US-NW-PACE	36 (6%)	39 (6%)	16 (2%)	5 (1%)	10 (2%)	4 (1%)	4 (1%)
US-NW-PACW	68 (17%)	61 (14%)	95 (25%)	5 (2%)	10 (3%)	6 (3%)	12 (6%)
US-NW-PGE	10 (3%)	11 (3%)	93 (23%)	3 (1%)	9 (4%)	9 (4%)	3 (2%)
US-NW-PSCO	45 (8%)	68 (12%)	20 (3%)	13 (2%)	37 (5%)	13 (2%)	19 (3%)
US-NW-PSEI	26 (7%)	26 (7%)	127 (35%)	6 (3%)	8 (5%)	6 (3%)	5 (3%)
US-NW-SCL	0 (0%)	0 (0%)	16 (15%)	0 (0%)	2 (2%)	1 (1%)	2 (2%)
US-NW-TPWR	0 (0%)	0 (0%)	16 (17%)	1 (1%)	1 (2%)	2 (2%)	3 (3%)
US-NW-WACM	35 (4%)	44 (6%)	33 (5%)	10 (2%)	11 (2%)	6 (1%)	15 (2%)
US-NW-WAUW	11 (5%)	6 (2%)	44 (14%)	4 (1%)	11 (3%)	2 (1%)	4 (1%)
US-NY-NYIS	6 (2%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0 (0%)
US-SE-SOCO	6 (1%)	7 (2%)	3 (1%)	1 (0%)	4 (1%)	2 (0%)	2 (0%)
US-SW-AZPS	25 (4%)	25 (4%)	113 (18%)	7 (2%)	26 (5%)	6 (1%)	7 (2%)
US-SW-EPE	6 (1%)	10 (2%)	30 (5%)	6 (1%)	8 (2%)	5 (1%)	6 (1%)
US-SW-PNM	58 (12%)	60 (14%)	42 (10%)	11 (3%)	24 (6%)	9 (2%)	14 (3%)
US-SW-SRP	34 (8%)	47 (11%)	36 (8%)	7 (2%)	32 (7%)	6 (1%)	4 (1%)
US-SW-TEPC	30 (4%)	27 (4%)	36 (5%)	5 (1%)	7 (1%)	4 (1%)	5 (1%)
US-SW-WALC	21 (6%)	43 (9%)	64 (17%)	13 (3%)	18 (4%)	21 (4%)	11 (3%)
US-TEN-TVA	14 (4%)	21 (5%)	20 (5%)	7 (2%)	14 (3%)	4 (1%)	1 (0%)

US-TEX-ERCO	17 (4%)	21 (5%)	4 (1%)	8 (2%)	5 (1%)	2 (0%)	1 (0%)
UY	8 (12%)	1 (2%)	0 (0%)	0 (1%)	1 (2%)	0 (0%)	0 (0%)
ZA	2 (0%)	0 (0%)	4 (1%)	1 (0%)	0 (0%)	0 (0%)	0 (0%)