Monthly and Quarterly Emission Factors

Database documentation

Note: The data package is updated on a quarterly basis. The updates in 1st, 2nd and 4th quarter correspond to the monthly and quarterly emission factors, while the update in 3rd quarter also comprises the yearly data.

International Energy Agency

INTERNATIONAL ENERGY AGENCY

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DESCRIPTION

This document contains a description of the monthly and quarterly emissions factors included in the 2025Q1 (first quarter) edition of the IEA Emission Factors Package. Within the package, the quarterly update of monthly and quarterly emission factors complements the yearly data published in the 2024 editions of the IEA Emission Factors database and the IEA Life Cycle Upstream Emission Factors databases. The data is included for:

- countries: 52 countries (see section *Geographical coverage*);
- years: 2015 to 2024.

The data is published in an excel format alongside the data published in the IEA *Emission Factors* and IEA *Life Cycle Upstream Emission Factors* databases. The factors are described below:

- Monthly CO_2 emission factors for electricity only generation (CHP electricity included) (in CO_2 per kWh, January 2015 to December 2024). (Sheet CO2KWH ELE - Monthly)

  Data cover 37 OECD countries and selected non-OECD countries.

- Quarterly CO_2 emission factors for electricity only generation (CHP electricity included) (in CO_2 per kWh, 1st quarter of 2015 to 4th quarter of 2024). (Sheet CO2KWH ELE - Quarterly)

  Data cover 37 OECD countries and selected non-OECD countries.

SCOPE AND OBJECTIVE

Electricity grids are sensitive to a variety of macro and micro events including wars, pandemics, extreme weather events, seasonality, and adoption of new climate and energy policy measures. Emissions data with high temporal granularity will enable monitoring and analysing the influence of periodical activities, seasonal patterns and disruptions on the grid and its impacts on climate. Access to timely and granular data can help to inform well-founded policy measures to influence both producer and consumer behaviours. The induced flexibility will allow reducing the climate impacts of electricity supply and consumption and is expected to be increasingly important as grids become progressively dominated by intermittent power generation.

This database provides for the first time data on carbon intensities of the grid at monthly and quarterly time scales, for a set of selected countries. It optimises the use of various IEA information on electricity: the IEA Monthly Electricity Statistics, compiling monthly data on electricity generation for over 50 countries; the IEA World Energy Balances, containing yearly energy balances for over 150 countries, including granular fuel/technology specific data for input and output to electricity generation plants; the IEA Electricity Information, containing detailed electricity supply and demand data including granular data based on facility types.

Additionally, the disclosure of GHG emissions by the private sector has increased significantly and will continue to do so as more disclosure requirements come into effect. Access to timely grid intensity factors for tracking the footprint corresponding to electricity consumption may better incentivise load management and procurement strategies that could support decarbonisation of grids.

DEFINITIONS

Flow categories

Name	Definition
CO_2 emissions per kWh of electricity only (gCO_2/kWh)	Corresponds to the monthly and quarterly CO_2 intensity of electricity generation expressed in gCO_2 per kWh. The indicator is computed by multiplying the yearly fuel-specific CO_2 intensities of electricity generation with respective monthly or quarterly generation data and dividing the result by the total respective electricity generation from all emitting and non-emitting sources for a given country. Output from both main activity and auto producers have been included in the computation. Please refer to the *Methodology* section for details.

METHODOLOGY

This section details the methodology corresponding to the development of monthly and quarterly grid emission factors based on monthly electricity data.

The IEA Monthly Electricity Statistics exhibits monthly data on electricity generation for over 50 countries. The IEA Electricity Information includes granular product-specific yearly data corresponding to both gross and net electricity output. By merging data from these two databases, it is possible to estimate gross monthly generation data per product scaled to match the yearly statistics.

On the other hand, the IEA World Energy Balances contains yearly energy balances for over 150 countries. The database includes granular fuel/technology specific input and output data to electricity generation plants. This enables estimating fuel-specific electricity generation CO_2 intensities at country-level. Merging the derived intensities with the monthly scaled generation data enables developing estimates of the CO_2 intensities associated with the electricity grids with monthly and quarterly resolutions.

The methodology includes three main steps as detailed below.

Step 1: Developing annual fuel-specific CO_2 intensities corresponding to electricity generation

The first step involves estimating annual electricity generation fuel-specific CO_2 intensities at country-level. These annual factors are the components which also allow developing the grid intensities published within the IEA Emission Factors database. The following formula is used to calculate these factors:

$$CO_2\ intensity_{i,y,w}\left(\frac{gCO_2}{kWh}\right) = \sum_j \frac{\left(Input_{\ plants} + Input_{CHP\ plants/Ele} + \ Own\ use_{\ plants/Ele}\ \right)_{\ j,y,w} \times\ EF_j}{Electricity\ output_{j,y,w}}$$

$CO_2\ intensity_{i,y,w}\left(\frac{gCO_2}{kWh}\right)$: *CO_2 intensity of electricity generation for fuel category i and country w in year y, expressed in gCO_2/kWh.*

Note: *The above corresponds to the direct intensity at the point of generation. As a result, the intensities corresponding to renewable sources (including biofuels) and nuclear are equal to zero.*

Note: *The fuel categories (i) are presented below. For additional details please refer to the IEA World Energy Balances documentation.*

a) *Coal: includes all primary and secondary coal, peat, peat products and oil shale.*

b) *Oil: includes all primary oil and secondary oil products.*

c) *Natural gas: represents natural gas and excludes natural gas liquids.*

d) *Non-renewables waste: includes industrial waste and non-renewable fraction of municipal waste.*

$Input_{plants\ j,y,w}$: *fuel input into the electricity plants for fuel j and country w in year y expressed in kWh*

$Input_{CHP\ plants/Ele\ j,y,w}$: *portion of the fuel input to CHP plants which is allocated to electricity generation for fuel j and country w in year y, expressed in expressed in kWh*

Note: *The IEA adopts the fixed-heat-efficiency approach to estimate the proportion of the input to the combined heat and power plants (CHP) which is allocated to electricity generation. For additional details, please refer to the documentation file corresponding to the IEA Emission Factors database.*

$Own\ use_{Plants/Ele\ j,y,w}$: *fuel input to the electricity plants and CHP plants (the portion allocated to electricity generation) which is used by the generation plant for its own operation for fuel j and country w in year y, expressed in expressed in kWh*

$Electricity\ output_{j,y,w}$: *electricity generation from fuel j and country w in year y, expressed in kWh*

EF_j: *default Tier 1 IPCC emission factor for fuel j, expressed in* gCO_{2eq}/kWh

Step 2: Scaling the monthly electricity generation data based on annual statistics

This step involves scaling the monthly electricity generation data per product to match the yearly electricity statistics.

Firstly, the yearly gross and net generation data for aggregated products are used to derive product-specific net to gross ratios. These ratios are applied to the granular gross yearly generation data to develop the product-specific annual net generation figures as per the following formula:

$$NetEle_{\ j,y,w} = \frac{NetEle_{\ i,y,w}}{GrossEle_{\ i,y,w}}\ x\ GrossEle_{j,y,w}$$

$NetEle_{\ j,y,w}$: *net electricity generation for fuel j and country w in year y*

$GrossEle_{\ i,y,w}$: *gross electricity generation for fuel category i and country w in year y*

$NetEle_{i,y,w}$: *net electricity generation for fuel category i and country w in year y*

$GrossEle_{j,y,w}$: *gross electricity generation for fuel j and country w in year y*

Note: *The product-specific annual net electricity generation data are available at an aggregated fuel level. Hence, the above computed gross to net ratios do not always match the granularity of gross generation included in the yearly statistics. Thus, it is assumed that the ratio is consistent among the sub-products of each aggregated fuel category.*

Following the above, the fuel-specific net monthly data are aggregated (accounting for fiscal year if applicable) to derive the raw annualized net generation data for the year y, as per the following:

$$AnnualizedNetEle_{j,y,w} = \sum_{m} NetEle_{j,m,w}$$

$AnnualizedNetEle_{j,y,w}$: *annualized net electricity generation for fuel j and country w in year y based on monthly data*

$NetEle_{j,m,w}$: *net monthly electricity generation for fuel j and country w in month m*

The product-specific scaling factors are computed by deriving the ratio between the above calculated annualized net electricity generation and the annual net electricity output as per the following formula:

$$SF_{j,y,w} = \frac{AnnualizedNetEle_{j,y,w}}{NetEle_{j,y,w}}$$

$SF_{j,y,w}$: *monthly to annual scaling factor for fuel j and country w in year y*

$NetEle_{j,y,w}$: *net electricity generation for fuel j and country w in year y*

$AnnualizedNetEle_{j,y,w}$: *annualized net electricity generation for fuel j and country w in year y based on monthly data*

Finally, the scaling factors are multiplied by the monthly generation data to compute the scaled net monthly generation data as per the following formula:

$$NetEleScaled_{j,m,w} = NetEle_{j,m,w} \; x \; SF_{j,y,w}$$

$NetEleScaled_{j,m,w}$: *scaled net monthly electricity generation for fuel j and country w in month m*

$NetEle_{j,m,w}$: *net monthly electricity generation for fuel j and country w in month m*

$SF_{j,y,w}$: *monthly to annual scaling factor for fuel j and country w in year y*

Note: *The yearly electricity data are available with a time lag of two years. This means that in the present year Y, the global coverage of the IEA Electricity Information database is up to year Y-2. Hence, the scaling factors corresponding to the most recent years (Y and Y-1) are assumed to be equal to the latest available year (Y-2).*

Note: *In some cases, monthly electricity generation data may be incomplete or significantly differ from the annual statistics. In such cases, scaling is not viable and monthly data is estimated based on available yearly data.*

Step 3: Developing monthly and quarterly grid emission factors

To develop monthly and quarterly grid emission factors, the scaled net monthly generation data derived in Step 2 are converted to monthly gross generation figures. Therefore, product-specific gross to net ratios are developed and multiplied by the scaled net monthly data as per the following formula:

$$GrossEle_{\,i,m,w} = \sum_{j} \left(\frac{GrossEle_{\,j,y,w}}{NetEle_{\,j,y,w}} \; x \; NetEleScaled_{\,j,m,w}\right)$$

$GrossEle_{\,i,m,w}$: *gross electricity generation for fuel category i and country w in month m*

$GrossEle_{\,j,y,w}$: *gross electricity generation for fuel j and country w in year y*

$NetEle_{\,j,y,w}$: *net electricity generation for fuel j and country w in year y*

$NetEleScaled_{\,j,m,w}$: *scaled net monthly electricity generation for fuel j and country w in month m*

Note: *The IEA monthly electricity statistics does not include gross generation. Therefore, the gross to net ratio applied in the above formula is derived based on annual data, assuming that the ratio is constant throughout the year.*

Following the above, monthly grid emission factors are computed as follows:

$$CO_2\ intensity_{m,w}\left(\frac{gCO_2}{kWh}\right) = \frac{\sum_i (CO_2\ intensity_{i,y,w} \times\ GrossEle_{\,i,m,w})}{\sum_i GrossEle_{\,i,m,w}}$$

$CO_2\ intensity_{m,w}\left(\frac{gCO_2}{kWh}\right)$: *$CO_2$ intensity of electricity generation for country w in month m, expressed in gCO_2/kWh.*

$CO_2\ intensity_{i,y,w}\left(\frac{gCO_2}{kWh}\right)$: *CO_2 intensity of electricity generation for fuel category i and country w in year y, expressed in gCO_2/kWh.*

$GrossEle_{i,m,w}$: *gross electricity generation for fuel category i and country w in month m, expressed in kWh*

Note: *As the yearly electricity data are available with a time lag of two years, for the present year Y, the global coverage of the IEA World Energy Balances database is up to year Y-2. Hence, the yearly fuel-specific emissions intensities corresponding to the most recent years (Y and Y-1) are assumed to be equal to those of the latest available year (Y-2). This approach assumes that there are no changes in the efficiency of the generation plants, the quality (calorific value) of the fuel inputs to plants and the fuel shares in the respective aggregated product categories comparing to year Y-2.*

Following the development of monthly emission factors, the quarterly emission factors are derived as per the following formula:

$$CO_2\ intensity_{Q,w}\left(\frac{gCO_2}{kWh}\right) = \frac{\sum_m (CO_2\ intensity_{m,w} \times GrossEle_{m,w})}{\sum_m GrossEle_{m,w}}$$

$CO_2\ intensity_{Q,w}\left(\frac{gCO_2}{kWh}\right)$: *$CO_2$ intensity of electricity generation for country w in quarter Q expressed in gCO_2/kWh.*

$CO_2\ intensity_{m,w}\left(\frac{gCO_2}{kWh}\right)$: *$CO_2$ intensity of electricity generation for country w in month m expressed in gCO_2/kWh.*

$GrossEle_{m,w}$: *total gross electricity generation for country w in month m*

GEOGRAPHICAL COVERAGE AND COUNTRY NOTES

Countries

This document is without prejudice to the status of or sovereignty over any territory, to the delimitation of international frontiers and boundaries and to the name of any territory, city or area. In this publication, 'country' refers to country or territory, as case may be. Data start in 2015 and ends in 2024 unless otherwise specified.

For details regarding the country-specific monthly electricity statistics which have been used as basis for developing this database, please refer to the IEA Monthly Electricity Statistics documentation.

Country/Region	Short name	Definition
Albania	ALBANIA	Data for Albania are available starting in 2018.
Argentina	ARGENTINA	
Australia	AUSTRALI	Excludes the overseas territories. Data are reported on a fiscal year basis. By convention data for the fiscal year that starts on 1 July Y-1 and ends on 30 June Y are labelled as year Y.
Austria	AUSTRIA	
Belgium	BELGIUM	
Bosnia and Herzegovina	BOSNIAHERZ	Data for Bosnia and Herzegovina are available starting in 2019.
Brazil	BRAZIL	
Bulgaria	BULGARIA	
Canada	CANADA	
Chile	CHILE	
People's Republic of China	CHINA	
Colombia	COLOMBIA	
Costa Rica	COSTARICA	Data for Costa Rica are available starting in 2021.

Country/Region	Short name	Definition
Croatia	CROATIA	
Cyprus	CYPRUS	Data for Cyprus are available starting in 2018. **Note by the Republic of Türkiye (Türkiye):** The information in the report with reference to "Cyprus" relates to the southern part of the Island. There is no single authority representing both Turkish and Greek Cypriot people on the Island. Türkiye recognises the Turkish Republic of Northern Cyprus (TRNC). Until a lasting and equitable solution is found within the context of the United Nations, Türkiye shall preserve its position concerning the "Cyprus" issue. **Note by all the European Union Member States of the OECD and the European Union:** The Republic of Cyprus is recognised by all members of the United Nations with the exception of Türkiye. The information in this report relates to the area under the effective control of the Government of the Republic of Cyprus. At its seventeenth session, the Conference of the Parties decided to amend Annex I to the Convention to include Cyprus (Decision 10/CP.17). The amendment entered into force on 9 January 2013.
Czech Republic	CZECH	
Denmark	DENMARK	Excludes Greenland and the Danish Faroes.
Estonia	ESTONIA	
Finland	FINLAND	
France	FRANCE	Includes Monaco and excludes the overseas collectivities: New Caledonia; French Polynesia; Saint Barthélemy; Saint Martin; Saint Pierre and Miquelon; and Wallis and Futuna. Energy data for the following overseas departments: Guadeloupe; French Guiana; Martinique; Mayotte; and Réunion are included.
Georgia	GEORGIA	Data for Georgia are available starting in 2018.
Germany	GERMANY	
Greece	GREECE	
Hungary		
Iceland	ICELAND	
India	INDIA	Data are reported on a fiscal year basis. By convention, data for the fiscal year that starts on 1 April Y and ends on 31 March Y+1 are labelled as year Y. This convention is different from the one used by Government of India, whereby fiscal year starts on 1 April Y and ends on 31 March Y+1 are labelled as year Y+1.
Ireland	IRELAND	
Italy	ITALY	Includes San Marino and the Holy See.

Country/Region	Short name	Definition
Japan	JAPAN	Includes Okinawa. Data are reported on a fiscal year basis. By convention data for the fiscal year that starts on 1 April Y and ends on 31 March Y+1 are labelled as year Y.
Korea	KOREA	
Latvia	LATVIA	
Lithuania	LITHUANIA	
Luxembourg	LUXEMBOU	
Malta	MALTA	Data for Malta are available starting in 2018.
Mexico	MEXICO	
Netherlands	NETHLAND	Excludes Suriname, Aruba and the other former the Netherlands Antilles (Bonaire, Curaçao, Saba, Saint Eustatius and Sint Maarten).
New Zealand	NZ	
Republic of North Macedonia	NORTHMACED	
Norway	NORWAY	.
Peru	PERU	Data for Peru are available starting in 2018.
Poland	POLAND	
Portugal	PORTUGAL	Includes the Azores and Madeira.
Romania	ROMANIA	
Serbia	SERBIA	
Slovak Republic	SLOVAKIA	
Slovenia	SLOVENIA	
Spain	SPAIN	Includes the Canary Islands.
Sweden	SWEDEN	
Switzerland	SWITLAND	Includes Liechtenstein for the oil data. Data for other fuels do not include Liechtenstein.
Republic of Türkiye	TURKEY	
United Kingdom	UK	
United States	USA	Includes the 50 states and the District of Columbia but generally excludes all territories. Starting with 2017 data, inputs to and outputs from electricity generation include Puerto Rico.

ABBREVIATIONS

CO_2	carbon dioxide
CDP	Carbon Disclosure Project
CSRD	Corporate Sustainability Reporting Directive
TSO	transmission system operator
GHG Protocol	Greenhouse Gas Protocol
T&D	transmission and distribution
CHP	combined heat and power
g	gramme
kWh	kilowatt hour
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
GHG	greenhouse gas
LCA	life cycle assessment

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