



Green
Transition
Office

GHG Emission Factors for Electricity Generation and Consumption in Ukraine

Analytical study
and description of the
methodological approach
to the calculation



The Green Transition Office is an independent advisory body to the Ministry of Economy of Ukraine, which supports implementation of reforms in the area of green transition, energy and climate policy. The work of the Green Transition Office is supported by the UK's International Development Agency and implemented by NGO DiXi Group.

The views expressed in the study are solely those of the NGO DiXi Group (Green Transition Office).



ABOUT THE STUDY

The study was prepared by the Green Transition Office as an advisory body to the Ministry of Economy of Ukraine in cooperation with the Recovery and Reform Support Team at the Ministry of Energy of Ukraine.

The study presents the methodological approach and results of calculating CO₂ emission factors for electricity production and consumption.

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- State Statistics Service of Ukraine
- National Energy and Utilities Regulatory Commission of Ukraine
- NPC Ukrenergo
- National Center for GHG Emission Inventory
- NASU Institute for Economics and Forecasting

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Executive Summary

What is this report about?

In response to growing business demands, the Green Transition Office has prepared a study on greenhouse gas emission factors for electricity generation and consumption in Ukraine

The report provides a publicly available dataset on greenhouse gas emission factors for electricity generation and consumption from the Integrated Power System of Ukraine. The dataset includes average emission factors for electricity supplied to the grid, average emission factors for electricity consumption, and marginal emission factors. The report also contains definitions and explanations of the types of factors and the specific use cases for each.

In addition, the study proposes a methodology for calculating emission factors for electricity generation and consumption that can be approved at the state level for regular data collection and annual updates of emission factor datasets.

Why do we need national emission factors for electricity?

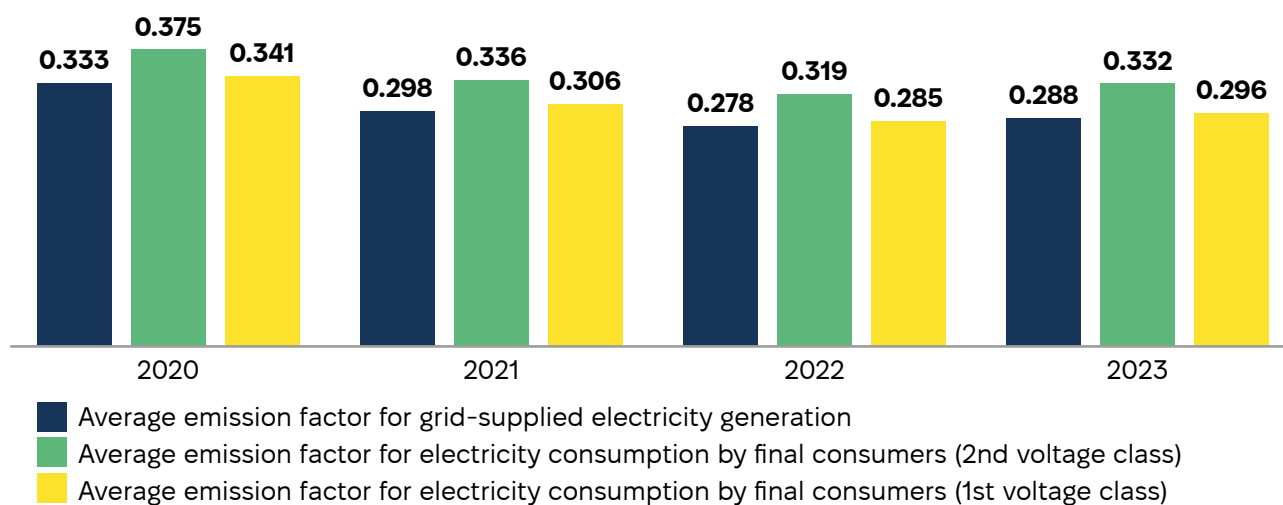
For Ukraine, there is no single publicly available up-to-date, reliable and accurate data on emission factors for electricity. Different organisations have published information on emission factors for the Ukrainian power system in different periods and for different purposes, but most of the data is outdated and inaccurate. The International Energy Agency's data is the most reliable, but it is not open, published with a delay, and does not cover all needs of all users of emission factors data. In addition, the IEA data are based on official state statistics, which are not fully collected and published during the martial law regime. Other data sources are less reliable and provide very different indicators, which leads to significant inconsistencies and diverse estimates.

The definition of a unified methodological approach to the calculation of national emission factors and relevant sources of information for data collection will allow for regular publication of national emission factors in the public domain for further use by all stakeholders.

National emission factors can be used by businesses and government agencies for various purposes, including determining the carbon footprint of products as part of the requirements of the Carbon Border Adjustment Mechanism, corporate greenhouse gas emissions accounting in accordance with the GHG Protocol, assessing emission reductions resulting from investment projects, evaluating the effectiveness of government policy in reducing greenhouse gas emissions, etc.

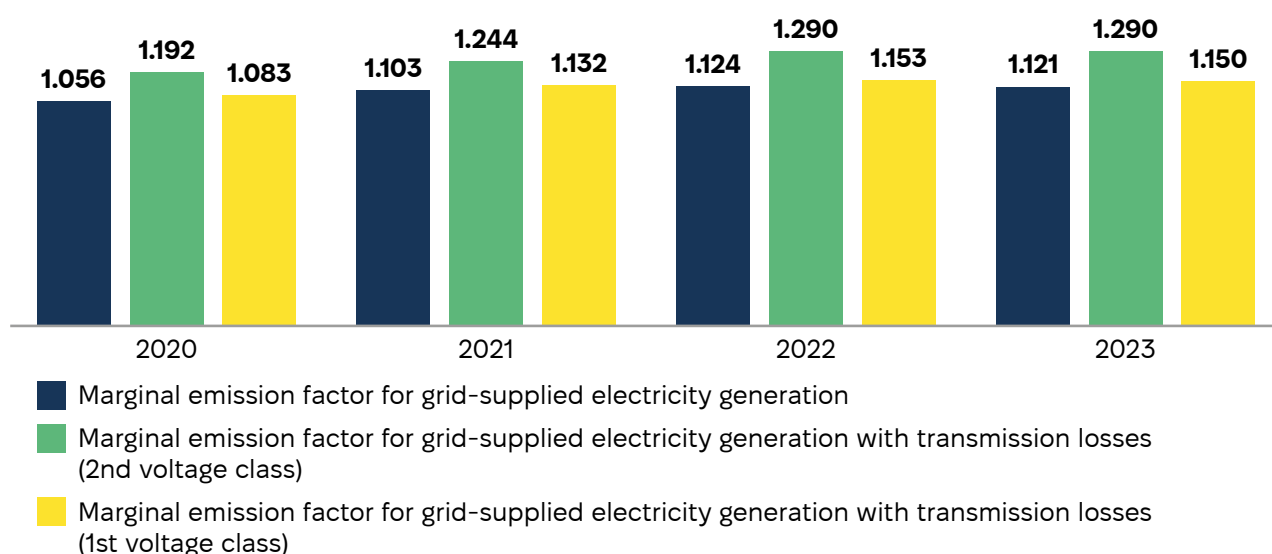
What are the findings of the study?

Average emission factors for electricity in Ukraine's power system (t CO₂/MWh):



Average emission factors for electricity can be used to determine the carbon footprint of products or for corporate greenhouse gas accounting.

Marginal emission factors for electricity in Ukraine's power system (t CO₂/MWh):



Marginal emission factors for electricity can be used to assess emission reductions resulting from energy-saving projects or the use of renewable energy sources.

For information on additional emission factors, please refer to Section 7.

A limitation of this study is the exclusion from the analysis of information on the activities of power plants of enterprises (autoproducers) due to the lack of reliable data on fuel consumption, total production and electricity supply to the grid in recent years. Although their share in the total electricity supply to the grid usually does not exceed 2%, the use of carbon-intensive fuels such as blast furnace gas may slightly affect the value of emission factors. In the future, it is recommended to include this category, preferably based on data for each individual installation, to ensure the completeness and accuracy of emission factor accounting for electricity generation and consumption.

How was the study conducted?

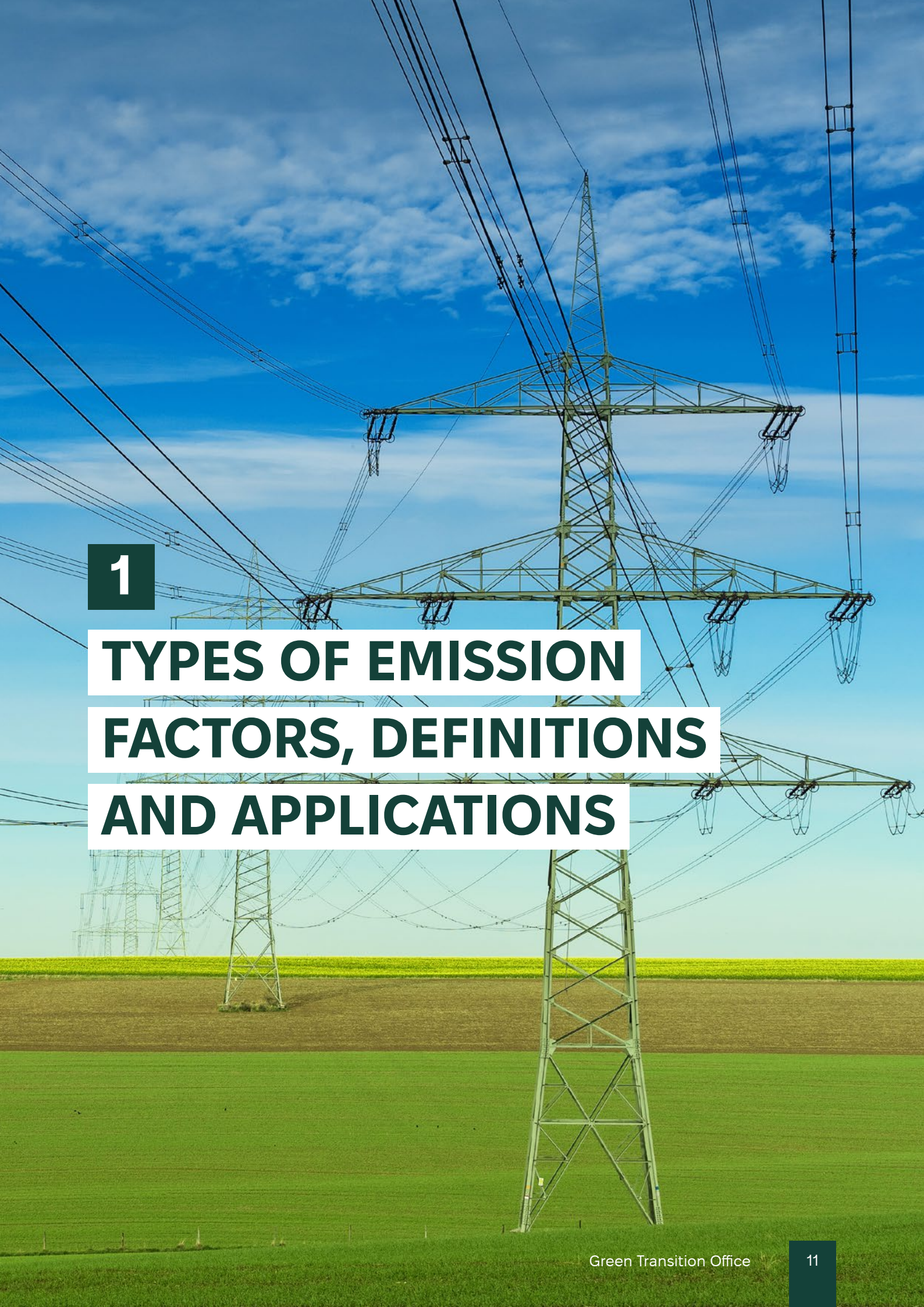
The study was prepared by the Green Transition Office as an advisory body to the Ministry of Economy of Ukraine in cooperation with the Recovery and Reform Support Team at the Ministry of Energy of Ukraine.

As part of the study preparation, a detailed analysis of available data sources and methodologies for calculating the emission factors was conducted, as well as working meetings and consultations with various stakeholders. In particular, discussions on problematic issues and available sources of information were held with experts from the State Statistics Service of Ukraine, the National Center for GHG Emission Inventory, NPC Ukrenergo, and the National Energy and Utilities Regulatory Commission.

What should be done next?

The study also contains a number of recommendations, including the adoption of an official methodology for calculating emission factors for electricity generation and consumption, further improvement of data quality, and the expansion of the scope of calculations, including by incorporating power plants of enterprises and detailed statistics on their activities.





1

TYPES OF EMISSION FACTORS, DEFINITIONS AND APPLICATIONS

1.1 Main Groups of Factors

Greenhouse gas emission factors associated with electricity generation or consumption can be divided into two main groups:

- Average emission factors, which demonstrate the amount of greenhouse gas emissions from electricity generation or consumption;
- Marginal emission factors, which demonstrate the impact on greenhouse gas emissions from additional production, increased consumption or reduced consumption of electricity.

Thus, the marginal factors reflect the emissions of those power plants that respond to changes in electricity demand and whose emissions are usually significantly higher than the average factor for the electricity grid.

Within each group there are different variants of the factors, which differ in terms of the inclusion of electricity losses, calculation methodology and other aspects.

1.2 Average Emission Factors

Average emission factors are used in determining the carbon footprint, for example, as part of corporate emissions reporting, assessing emissions from the production of certain types of products, including over the entire life cycle, etc.

The main types of average factors:

- The average emission factor for electricity generation and supply to the grid reflects the average specific emissions from all grid-connected power plants per unit of electricity generated and supplied to the grid;
- The average emission factor for electricity consumption by end-users reflects the average specific emissions from all grid-connected power plants per unit of electricity consumed (i.e., takes into account transmission and distribution losses).

It should be emphasised that the calculation of Scope 2 indirect emissions from electricity consumption in accordance with the GHG Protocol (Scope 2) uses average emission factors for electricity generation and supply to the grid (i.e. excluding transmission and distribution losses).

A residual mix emission factor can also be used to calculate corporate emissions using the market-based method, which takes into account contractual instruments for the use of electricity from renewable sources (such as guarantees of origin) in different countries.¹

1.3 Marginal Emission Factors

Marginal emission factors are used to determine the impact of projects, programmes or other initiatives on greenhouse gas emissions. Most commonly, such factors are used to estimate emission reductions resulting from renewable energy projects or from reduced electricity consumption due to energy efficiency measures. For such purposes, it is not objective to use average emission factors, as a reduction in demand for electricity or its additional supply from renewable energy sources will not affect a significant amount of baseload electricity generation.

¹ AIB, European Residual Mix, <https://www.aib-net.org/facts/european-residual-mix>

Marginal emission factors are intended to characterise the specific emissions from electricity generation by those power plants that would be replaced in the event of additional generation or reduced consumption. The projects or programmes being assessed may result in the replacement of existing power plants and/or avoidance of construction and operation of new power plants. The replaced generation of existing facilities is called the "operating margin" (OM), and the generation of potential new power plants is called the "build margin" (BM).²

Accordingly, the main types of marginal factors are as follows:

- Operating Margin (OM) reflects the emissions of existing power plants whose operation and electricity production will be affected by the project (due to reduced demand due to energy efficiency improvements or increased electricity supply due to renewable energy projects);
- Build Margin (BM) reflects the emissions of potential/future power plants whose construction and operation may be affected by a renewable energy project (based on an estimate of planned and expected new electricity generation capacity);
- Combined Margin (CM), which takes into account the operating margin and the build margin in certain proportions.

In the case of existing power plants, additional generation or demand reduction may affect the replacement/avoidance of power plants involved in balancing, usually with the exception of power plants that have low marginal operating costs (operating costs of producing an additional unit of electricity), such as hydropower plants.

Sometimes, the marginal factors are calculated based only on the performance of fossil fuel power plants, but in practice, the calculation needs to take into account the specifics of each grid in the relevant calendar year or shorter time periods. Depending on the demand for electricity, available generating capacity and economic factors, demand balancing can also be carried out using other types of power plants.

There are very different approaches to assessing marginal emission factors, which may use different temporal granularity and different estimation or modelling methodologies, including consideration of not only technical but also economic/market factors.³

It should be remembered that marginal emission factors can be developed for different purposes, so they may differ even for the same grid and are characterised by a higher level of uncertainty compared to average emission factors for the grid. The higher uncertainty is due to the fact that marginal emission factors do not represent the actual measured emission reductions due to certain measures but are used to determine the emission reductions compared to an imaginary baseline scenario in the absence of measures.

2 The Greenhouse Gas Protocol. Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects, <https://ghgprotocol.org/sites/default/files/2022-12/Guidelines%20for%20Grid-Connected%20Electricity%20Projects.pdf>

3 CEBI. Guide to sourcing marginal emissions factor data, <https://cebi.org/wp-content/uploads/2022/11/Guide-to-Sourcing-Marginal-Emissions-Factor-Data.pdf>



2

AVAILABLE DATA ON GRID EMISSION FACTORS FOR UKRAINE

2.1 Main Data Sources

The most detailed information on the sources and volumes of greenhouse gas emissions in Ukraine is provided in the annual national emission inventories submitted to the UNFCCC Secretariat as part of international commitments. The national inventories, however, do not contain separate data on total emissions for electricity generation only, nor on emission factors for electricity generation and consumption.

Currently, there are various sources of information on emission factors that differ in type (e.g., average emission factors and marginal emission factors), timeframe, availability, and methodological approaches. The available data sources include data from the International Energy Agency, recommendations of international financial institutions, documents of the Covenant of Mayors for Climate & Energy, national regulations on joint implementation projects under the Kyoto Protocol, etc. The use of different data sources leads to inconsistent estimates, errors and uncertainty among users, as even for the same type of factor, the differences can be quite significant.

2.2 Data on Average Emission Factors for Electricity

The available data is so different in terms of timeframes, types of factors and calculation methodologies that it is difficult to compare them.

The emission factor recommended by the Covenant of Mayors for Climate & Energy⁴ is 0.430 t CO₂/MWh for 2020 for Ukraine. At the same time, the default value for the purposes of reporting under the Carbon Border Adjustment Mechanism (CBAM) (valid until 31 December 2025), which is presented in the CBAM Transitional Registry and calculated on the basis of data from the International Energy Agency as average emissions from electricity generation in the national grid for the 5-year period 2016-2020, is more than 13% lower. Ember publishes data on emissions intensity per unit of electricity produced on average for the year and data for individual months⁵, but the methodology for calculating this data has a number of limitations and peculiarities.

At the same time, the available data are usually outdated and do not reflect the dynamics of changes in the structure of electricity generation using different sources, the development of renewable energy sources and the consequences of the destruction of energy infrastructure during the war.

There is also a scientific study on emission factors for electricity generation in Ukraine based on the life cycle method, taking into account emissions during the construction of power plants, extraction and transportation of fuel, generation and transmission of electricity, and waste management (spent nuclear fuel).⁶ However, the study does not provide an average emission factor, but only presents the results separately for different types of fuel (data for 2017):

- 1,240 t CO₂/MWh for coal;
- 0.699 t CO₂/MWh for natural gas;
- 0.117 t CO₂/MWh for nuclear power plants.

4 Joint Research Centre Data Catalogue, GHG Emission Factors for Electricity Consumption, <https://data.jrc.ec.europa.eu/dataset/919df040-0252-4e4e-ad82-c054896e1641>

5 Ember, <https://ember-climate.org/data/data-tools/data-explorer/>

6 O.V. Butrym, G.G. Panchenko, Carbon footprint of electricity production, Energy Technologies and Resource Saving, 2023, № 4, p. 19-30, <https://ouci.dntb.gov.ua/en/works/7AKobowl/>, <https://doi.org/10.33070/etars.4.2023.02>

Table 1. Available data on average emission factors for Ukraine (t CO₂/MWh)

Data source	2019	2020	2021	2022
Covenant of Mayors (JRC)	0.473	0.430	-	-
Ember	0.342	0.325	0.276	0.256
A study of emission factors in European countries ⁷	0.461	-	-	-

2.3 Data on Marginal Emission Factors for Electricity

Data on marginal emission factors for electricity in Ukraine are even more limited and the discrepancies between them are very high. Information on the data used in the calculations and details of the methodological approach are not always available. As a rule, the available data are very outdated, as such factors were developed and approved to account for emission reductions under joint implementation projects in accordance with the requirements of the Kyoto Protocol in 2008-2012.

In particular, the following documents on emission factors for electricity were developed for joint implementation projects:

- The study by Global Carbon B.V. was verified by TÜV SÜD Industrie Service GmbH in 2007 for the baseline emission factor for electricity based on data from 2003-2005; the calculation was based on the simple marginal emission factor method and only nuclear power plants were classified as low-cost/must-run.⁸
- The study by Lahmeyer International and Perspectives "Development of the electricity carbon emission factor for Ukraine"⁹ on emission factors for 2009-2020 was verified by TÜV SÜD Industrie Service GmbH¹⁰; the calculation was based on the simple adjusted marginal emission factor method, and low-cost/must-run power plants included nuclear power plants, renewable energy plants, and CHP plants operating in combined heat and power production mode.

7 Nicolae Scarlat, Matteo Prussi, Monica Padella, Quantification of the carbon intensity of electricity produced and used in Europe, Applied Energy, Volume 305, 2022, 117901, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2021.117901>, <https://www.sciencedirect.com/science/article/pii/S0306261921012149> (value for the emission factor for electricity production (net); the study also provides a value for the emission factor for electricity production (gross) - 434 t CO₂/MWh and for the emission factor for electricity consumption - 492 t CO₂/MWh).

8 Ukraine - Assessment of new calculation of CEF, <https://ji.unfccc.int/UserManagement/FileStorage/46JW2KL36KMOGEMIOPHDTQF6DVI514>

9 EBRD. Development of the electricity carbon emission factors for Ukraine, https://encon.sumdu.edu.ua/doc/methodics/Baseline_Study_Ukraine_Final_English.pdf

10 Assessment report. Assessment of the Grid Emission Factor Calculation Model for Ukraine, https://www.ebrd.com/downloads/sector/eecc/Validation_report_Ukraine_Final_15102010.pdf

- Specific carbon dioxide emission factors approved by the National Environmental Investment Agency of Ukraine based on the methodology for calculating specific carbon dioxide emissions from electricity generation at thermal power plants and electricity consumption¹¹; only includes emissions from thermal power plants.

All the studies relied on the UNFCCC's Clean Development Mechanism project guidance "Tool to calculate the emission factor for an electricity system", but used different data and assumptions.

Table 2. Available data on marginal emission factors for Ukraine for joint implementation projects

Source	Value, t CO ₂ /MWh	Period
Study by Global Carbon B.V. – a factor for projects that reduce energy consumption	0.896	Based on 2003-2005 data, it was intended to be used in 2006-2012
Study by Global Carbon B.V. – a factor for projects that produce electricity	0.807	
Study by Lahmeyer International and Perspectives	1.052	The figure is for 2009. The report also includes figures for 2010-2020 based on modelling.

Initial studies were based on data for a limited number of years and modelling results and were intended to be used for future periods without updating based on actual data.

Subsequently, the National Environmental Investment Agency approved a separate methodology on the basis of which the specific carbon dioxide emission indicators for 2008-2011 were calculated and approved by the orders.

Table 3. Specific carbon dioxide emission factors for electricity generated by thermal power plants for 2008-2011 (t CO₂/MWh)

Indicator	2008	2009	2010	2011
Specific carbon dioxide emissions from electricity generation by thermal power plants connected to the Integrated Power System of Ukraine	1.055	1.068	1.067	1.063
Specific indirect carbon dioxide emissions from electricity consumption by electricity consumers of the 1 st voltage class (Class 1) ¹²	1.082	1.096	1.093	1.090
Specific indirect carbon dioxide emissions from electricity consumption by electricity consumers of the 2 nd voltage class (Class 2)	1.219	1.237	1.225	1.227
Specific indirect carbon dioxide emissions associated with the consumption of electricity during its transmission through local power grids	1.082	1.096	1.093	1.090

11 Order of the National Environmental Investment Agency of Ukraine of 21.03.2011 No. 39 "On Approval of the Methodology for Calculating Specific Carbon Dioxide Emissions from Electricity Production at Thermal Power Plants and its Consumption" <https://zakon.rada.gov.ua/rada/show/v0039825-11#Text>

12 In accordance with the Procedure for Determining Consumer Classes, approved by Resolution of the National Energy and Utilities Regulatory Commission of Ukraine No. 1052 dated 13 August 1998

Later, in 2017, unofficial calculations of marginal emission factors for electricity production for 2012-2015 were published.¹³

Table 4. Marginal emission factors for 2012-2015 (t CO₂/MWh)

Indicator	2012	2013	2014	2015
Specific carbon dioxide emissions from electricity generation by thermal power plants	1.101	1.103	1.097	1.105
Specific indirect carbon dioxide emissions from electricity consumption by electricity consumers of the 2 nd voltage class (Class 2)	1.231	1.229	1.219	1.234

Subsequently, information on the marginal emission factors for Ukraine appeared only in some international databases. In particular, the IFI Dataset of Default Grid Factors, which is recommended for investment project evaluation, contains a number of factors that differ significantly in different versions.

Table 5. Available data on marginal emission factors for Ukraine from The IFI Dataset of Default Grid Factors (t CO₂/MWh)

Emission factor	Version 2.4	Version 3.2
Combined marginal emission factor for renewable energy projects with dispatchable generation	0.525	0.435
Combined marginal emission factor for renewable energy projects with intermittent generation	0.738	0.643
Combined marginal emission factor for energy efficiency projects	0.525	0.435
Combined marginal emission factor for projects that depend on grid electricity consumption	0.525	0.435
Operating marginal emission factor	0.866	0.768

2.4 Key Gaps and Shortcomings of the Available Data

Thus, there is no reliable, up-to-date and open data on average and marginal emission factors for electricity for the Ukrainian power grid.

The key gaps and shortcomings of the available data sources include the following:

- Lack of information on different emission factors from a single source to ensure consistency of data and calculation approaches;
- Lack of up-to-date information, as most emission factors are based on outdated data, while the structure of electricity generation changes from year to year; even the IEA average emission factors are published with a delay of almost two years;

13 Mykola Shlapak. Carbon Emission Factor for Ukrainian Electricity Grid, <https://www.slideshare.net/slideshow/carbon-emission-factor-for-ukrainian-electricity-grid-80745723/80745723>

- Significant data discrepancy – different data sources provide very different emission factor values even for the same or similar periods, which highlights the importance of reliable data and consistent methodological approaches to calculation; emission factors were developed in different periods, for different purposes and using different methodological approaches, so results may differ significantly;
- Lack of transparency – sometimes the results of the calculations themselves, as in the case of the IEA database, are available only on a commercial basis; in most cases, there is no information on the source data used for the calculation and no detailed description of the methodological approach.

At the same time, the need for such information is growing due to the need to estimate emissions from the manufacturing of products to comply with the requirements of the Carbon Border Adjustment Mechanism, corporate reporting, assessment of the climate impact of projects and programmes, and other needs.





3

ANALYSIS OF EXISTING APPROACHES AND KEY METHODOLOGICAL GUIDELINES

3.1 The International Energy Agency's Approach

The International Energy Agency annually prepares information on CO₂, CH₄ and N₂O emission factors for electricity production in different countries, including Ukraine¹⁴. In addition, the dataset contains information on the inclusion of transmission and distribution losses. The database is available only for a fee and contains data with a delay of two years in most cases (information on emission factors for 2022 was published in September 2024); more up-to-date data may be available only for OECD countries and some other countries based on preliminary reporting data.

The database of emission factors contains, in particular, information on the following indicators for the period since 1990:

- CO₂ emission factor for electricity and heat production for countries around the world (in kg CO₂ per kWh);
- CO₂ emission factor for electricity generation alone (including cogeneration units) for countries around the world (in kg CO₂ per kWh) – an average factor that takes into account the total emissions from fossil fuel consumption in electricity production, including power plants and cogeneration units, divided by the total electricity production by all power plants, i.e. including power plants that do not consume fossil fuels (also including power plants of enterprises (autoproducers));
- Emission factor characterising CO₂ emissions associated with electricity losses in the grid (in kg CO₂ per kWh) – a factor that takes into account losses during transportation from the power plant to the final consumer (usually in the range of 5%-15%);
- CH₄ and N₂O emission factors for electricity generation (in kg CO₂ eq. per kWh).

Thus, the dataset includes an indicator of the average emission factor for electricity generation (which can be used to calculate indirect emissions from electricity consumption in accordance with the GHG Protocol (Scope 2)), as well as a separate emission factor for electricity transmission and distribution losses, which can be used to separately calculate a part of other indirect emissions (Scope 3, Category 3) or to calculate the average factor for electricity consumption (the sum of emissions from generation and transmission and distribution losses).

Additionally, if data is available, an adjustment can be made to account for electricity imports and exports when calculating emissions from electricity consumption.

The IEA data contains information not only on CO₂ emissions, which are responsible for the lion's share of greenhouse gas emissions from fuel combustion, but also on emissions of other greenhouse gases: CH₄ and N₂O. At the same time, standard emission factors are used for CH₄ and N₂O in accordance with the IPCC Tier 1 methodology (Tier 1 from 2006 IPCC Guidelines), and global warming potential indicators are used to convert emissions to CO₂ equivalent in accordance with IPCC Sixth Assessment Report (27 for CH₄ and 273 for N₂O).¹⁵

14 For further information: <https://www.iea.org/data-and-statistics/data-product/emissions-factors-2024>

15 Until 2024, IPCC Assessment Report 4 indicators were used for alignment with country reporting under the UNFCCC in accordance with Decision 24/CP.19 from UNFCCC's Measurement, Reporting and Verification (MRV) framework, <https://unfccc.int/resource/docs/2013/cop19/eng/10a03.pdf>. Starting from 2024, the reporting under the UNFCCC will use IPCC Assessment Report 5 indicators in accordance with Decision 18/CMA.1 Modalities, procedures and guidelines for the transparency framework for action and support referred to in Article 13 of the Paris Agreement, <https://unfccc.int/resource/tet/0/00mpg.pdf>. At the same time, the IEA has chosen IPCC Assessment Report 6 indicators to align with the requirements of climate impact disclosure standards, including the European Sustainability Reporting (ESRS).

The CH₄ and N₂O emissions calculations include data on biomass consumption for electricity production, where CO₂ emissions are not taken into account in accordance with the IPCC guidelines, and emissions of other greenhouse gases are included in the calculation of the respective emission factors. Standard emission factors for CH₄ and N₂O have a high level of uncertainty.

The fuel consumption data used in the calculation are based on IEA World Energy Balances, which are sourced from IEA questionnaires.

Starting from 2023, the IEA also publishes a set of emission factors that take into account the extraction and transportation of energy resources used for electricity production (upstream emission factors).¹⁶ In particular, the database contains the following indicators:

- Total upstream emission factor for electricity generation in the national grid (in kg CO₂ eq. per kWh) – corresponds to all emissions during the life cycle of energy/fuel production technologies, but does not include direct emissions from fuel combustion during electricity generation; calculated on the basis of indicators for individual technologies as a weighted average.
- Upstream fuel-cycle emission factor for electricity generation in the national grid (in kg CO₂ eq. per kWh) – calculated on the basis of upstream emission factors for fossil fuels, uranium and biofuels as a weighted average, taking into account the shares of different technologies in electricity generation. This indicator is a component of the total upstream emission factor and also does not include direct emissions from fuel combustion, nor does it include upstream emissions associated with the production of energy equipment.
- An emission factor that characterises the emissions associated with electricity losses in the grid during transmission and distribution, taking into account the entire life cycle (in kg CO₂ eq. per kWh).

3.2 International Financial Institutions' Approach

International financial institutions have developed a common approach to determining the emission factor and publish a corresponding dataset for different countries.¹⁷

Since the priority of international financial institutions is the impact of the projects they finance on emissions, the methodological approach includes the calculation of marginal emission factors:

- Operating Margin;
- Build Margin;
- Combined Margin.

All three types of marginal emission factors take into account only domestic electricity generation data and do not take into account electricity trade between countries.

The calculation of default values of **Operating Margin** for different countries is based on the International Energy Agency's data on electricity production by fuel and CO₂ emissions from electricity production. The calculation uses a 3-year average to smooth out fluctuations, as well as a correction factor to account for the fuel consumption of TPPs for their own needs. The information can also be updated based on national data when such data become available.

16 IEA. Life Cycle Upstream Emissions Factors 2024, <https://www.iea.org/data-and-statistics/data-product/life-cycle-upstream-emissions-factors-2024-2>; Life cycle Upstream Emission Factors 2024. Database documentation, https://iea.blob.core.windows.net/assets/62c02614-3753-48f6-b5f8-2206ecf356f0/IEAupstreamlifecycleemissionfactors_2024.pdf

17 See Methodology GHG Accounting for Grid Connected Renewable Energy Projects developed by the IFI Technical Working Group (TWG) on GHG Accounting, <https://unfccc.int/climate-action/sectoral-engagement/ifis-harmonization-of-standards-for-ghg-accounting/ifi-twg-list-of-methodologies>

The Operating Margin takes into account generation from power plants that have the highest variable operating costs for electricity generation. These include natural gas and oil-fired power plants, as well as coal-fired power plants. Nuclear power plants, hydroelectric power plants, cogeneration plants and other power plants, including waste-to-energy and renewable energy plants, are assumed to provide baseload power (must-run) or to have low operating costs (low-cost), and are therefore only considered in the Operating Margin in certain cases.

Accordingly, for the purposes of calculating the Operating Margin, 50% of the most costly fossil fuel generation is taken into account. Only half of the generation is taken into account due to the fact that in many countries fossil fuels are also used to provide baseload power in the grid. Thus, the calculation of the Operating Margin includes primarily natural gas and oil-fired power plants, and additionally coal-fired power plants if the share of coal exceeds 50% of total fossil fuel generation. In cases where the share of non-fossil fuel generation exceeds 50%, the calculation also includes power plants from the "Other" category (hydroelectric, nuclear, wind, solar, biomass, geothermal, etc.).

The Build Margin is calculated based on the International Energy Agency's World Energy Model (WEM) projections, which allow estimating CO₂ emissions from new electricity generation capacity under different scenarios. To calculate the Build Margin, the average emissions for the next 8 years under the Stated Policy Scenario (STEPS) is used, according to the latest available version of the World Energy Outlook (WEO). For countries without detailed projections, a regression analysis is used to calculate the Build Margin, taking into account the regional projection, the 3-year average emissions and the level of GDP per capita.

The Combined Margin combines the Operating Margin and the Build Margin in ratios that depend on the type of project being assessed:

- for renewable energy projects:
 - > for variable generation (solar and wind power plants) – a Combined Margin calculated as 75% of the Operating Margin and 25% of the Build Margin;
 - > for non-intermittent generation (e.g. hydropower, geothermal, biomass) – a Combined Margin calculated as 33% of the Operating Margin and 67% of the Build Margin;
- for energy efficiency projects: a Combined Margin calculated as 33% of the Operating Margin and 67% of the Build Margin;
- for projects that depend on grid electricity consumption: a Combined Margin calculated as 33% of the Operating Margin and 67% of the Build Margin;
- more accurate emission factors based on additional studies should be used for projects that involve managing electricity demand by matching demand with available generation from a particular source.

The set of standard emission factors was expected to be updated every two years. Currently, the IFI Dataset (version 3.2), published in April 2022, is available.

3.3 Approach for Projects under the UN Framework Convention on Climate Change and the Paris Agreement

The UNFCCC's Clean Development Mechanism has developed specific guidance for calculating the emission factor for the electricity system¹⁸, which is likely to be used (after updating and adaptation) for projects under the Paris Agreement's market-based mechanisms. In 2024, public consultations were held to update this guidance.¹⁹ Comments received during the consultations concerned approaches to aligning the factors with the goals of the Paris Agreement, changing approaches to the selection of factors, consideration of energy storage technologies, estimating emissions from hydroelectric power reservoirs, using energy system modelling, and other aspects.²⁰ In addition, the guidance is also planned to be used for voluntary carbon market projects with minor changes.²¹

This guidance uses similar approaches and factors to the methodology of international financial institutions, but is more detailed in taking into account the specifics of different energy systems.

The guidance defines an approach to calculate CO₂ emissions linked to electricity displacement (due to reduced consumption or increased generation) by calculating a Combined Margin for the power system based on the Operating Margin and the Build Margin.

The guidance suggests different ways to calculate **the Operating Margin and the Build Margin**, which differ in terms of data requirements (e.g., fuel consumption and electricity generation data for each individual power plant or aggregated data, need for hourly fuel consumption and electricity generation data, hourly grid load data, etc.). In addition, the guidance provides a decision tree for deciding on the calculation method based on grid characteristics.

Table 6. Methods for calculating operating margins

Calculation method	Conditions of use and data requirements	Calculation procedure
Simple Operating Margin (Simple OM)	The share of low-cost/must-run (LCMR) electricity sources has been less than 50% for the last five years or the average capacity of low-cost/must-run electricity sources is less than the average lowest annual system load (LASL) for three years.	Weighted average (by generation volume) CO ₂ emissions in t CO ₂ /MWh for all power plants in the grid, excluding low-cost/must-run plants. It can be calculated on the basis of data for each individual power plant (Option A) or, if such data are not available and only nuclear and renewable power plants are included in the low-cost/must-run power plants, on the basis of the net output of all power plants in the grid, fuel types and data on total fuel consumption by power plants in the grid.

18 Methodological tool. Tool to calculate the emission factor for an electricity system. Version 07.0, <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf>

19 Article 6.4 SB, <https://unfccc.int/process-and-meetings/the-paris-agreement/paris-agreement-crediting-mechanism/calls-for-input/call-for-input-2024-acm0002-and-tool07>

20 Submission of the MDB Working Group on Article 6 of the Paris Agreement, https://unfccc.int/sites/default/files/resource/ACM0002_TOOL07_A6.4StakeholderInput_MDB%20WG_Clean.pdf

21 Verra. Consultation on Revision to CDM Tool to Calculate Electricity System Emission Factor, <https://verra.org/consultation-on-revision-to-cdm-tool-to-calculate-electricity-system-emission-factor/>

Calculation method	Conditions of use and data requirements	Calculation procedure
Simple Adjusted Operating Margin (Simple adjusted OM)	The share of low-cost/must-run (LCMR) electricity sources has been greater than 50% for the last five years and the average capacity of low-cost/must-run electricity sources is greater than the average lowest annual system load (LASL) for the last three years. Hourly grid load data is required, but in the absence of such data, the method can also be used when the lowest grid load is greater than 1/3 of the highest grid load.	This method is a variant of the Simple Operating Margin. The parameter λy is used for the adjustment, which is a factor that reflects the percentage of time when low-cost/must-run power plants operated in the marginal mode in each year. Thus, this method takes into account situations where low-cost/must-run power plants are used for balancing purposes and tends to reduce the marginal emission factor. The guidance suggests default values for λy depending on the share of low-cost/must-run power plants in electricity generation, as well as a separate calculation procedure.
Dispatch data analysis	Hourly data for each power plant on electricity generation and fuel consumption is required.	The method can only be used for ongoing monitoring and not for historical data analysis, as it is based on the analysis of dispatch data during the period of operation of the project power plant.
Average Operating Margin (Average OM)	Used when the lowest load in the grid is less than 1/3 of the highest load in the grid. Annual aggregated data for the grid on electricity generation, fuel types and consumption are required.	The Average Operating Margin is calculated as the average of the emissions for all power plants, using the same approach as for the Simple Operating Margin, but also including low-cost/must-run power plants.

The Build Margin is intended to estimate emissions from power plants whose construction and future operation may be affected by a renewable energy or energy efficiency project. For the sake of simplicity, the guidance suggests estimating this factor based on an analysis of the specific emissions of the newest existing power plants. It does not take into account power plants undergoing reconstruction or capacity expansion. The guidance proposes a detailed algorithm for selecting a list of power plants on the basis of which the Build Margin should be calculated. This sample of power plants should cover 20% of the total electricity generation and should include at least five of the newest power plants (even if their generation exceeds 20%). As a rule, the sample should be limited to power plants commissioned in the last 10 years, but if there was little new capacity, it can also include power plants built earlier. The Build Margin is calculated as the weighted average (by generation) CO₂ emissions in t CO₂/MWh for the power plants in the selected sample during the most recent year for which data are available.

The Combined Margin is calculated as a weighted average of the Operating Margin and the Build Margin or, in some cases, using a simplified approach with default values.

The ratios used to calculate the weighted average depend on the type of project being assessed:

- for variable generation (solar and wind power plants) – 75% of the Operating Margin and 25% of the Build Margin;
- For other projects, the values depend on the assessment period:
 - > 50% of the Operating Margin and 50% of the Build Margin for the first crediting period;
 - > 25% of the Operating Margin and 75% of the Build Margin for subsequent crediting periods.

For solar and wind power projects, the approach is similar to that of international financial institutions, but for other types of projects, the approach to calculating the Combined Margin is different.

For certain countries (least developed countries, small island states, countries with a small number of projects), the values of the Operating Margin are allowed to be used for the Combined Margin.

In cases where the share of renewable energy sources in the installed capacity of the power system is less than 20%, it is also allowed to use default values of the Build Margin:

- 0.326 t CO₂/MWh, if the power system uses natural gas for electricity generation; or
- 0.568 t CO₂/MWh if no natural gas is used.

If the share of renewable energy sources in the installed capacity of the power system exceeds 20%, it is allowed to use a value of the Build Margin of 0.

According to the guidance, if simplified approaches to calculating the Combined Margin are used, the Operating Margin should be calculated as the Average Operating Margin.

It is worth noting that the guidance was developed for Clean Development Mechanism projects, so they take into account the specifics of developing countries, which may not always be relevant for other countries.

Additional provisions of the guidance:

- When calculating the Operating Margin, the emission factor for imported electricity may be assumed to be zero or calculated separately for the electricity exporting grid;
- Electricity exports should not be deducted from production volumes when calculating emission factors;
- Low-cost/must-run power plants are power plants with low marginal costs or those that supply electricity to the grid regardless of daily or seasonal fluctuations in grid load; they may include hydro, geothermal, wind, low-cost biomass, nuclear and solar power plants; if a fossil fuel power plant supplies electricity regardless of daily or seasonal load fluctuations in the grid and this can be confirmed, it is also included in this category; in addition, electricity imports are included as one power plant in this category.

3.4 Specific Emissions Estimation Methodology for Joint Implementation Projects in Ukraine

Joint implementation projects were implemented in Ukraine during the first period of the Kyoto Protocol (2008-2012). For the purposes of the projects, a special methodology was developed to calculate specific carbon dioxide emissions from electricity generation at thermal power plants and from its consumption.²²

The methodology covered emissions only from the production of electricity at thermal power plants and its subsequent consumption and contained instructions on how to calculate specific carbon dioxide emissions, as well as on the sources of input data used in the calculations.

The calculation of specific carbon dioxide emissions from electricity production and consumption by thermal power plants was based on data on:

- the amount of electricity supplied by a thermal power plant;
- fuel consumption for electricity supply;
- lower calorific value of the fuel;
- heat loss due to chemical and mechanical incomplete combustion;
- technological losses of electricity in power grids.

Since the methodology was limited to thermal power plants, the calculation was based not on general statistical data, but on the performance of individual power plants, in particular:

- data on the amount of electricity supplied, fuel consumption and its lower heating value were taken from the annual report of the power plant according to the state statistical observation form No. 6-tp (annual) "Thermal Power Plant Operation Report", which was filled in in accordance with SOU-N MEPE 40.1.08.552:2005.
- data on heat loss due to chemical and mechanical incomplete combustion were taken from the annual report according to the form No. 3-tekh "Technical and Economic Indicators of Equipment Operation", calculated in accordance with HKD 34.09.103-96.

Additionally, the calculations used data on the technological consumption of electricity in the power grids, which were taken from the annual report according to Form 1-B TVE "Structure of the Electricity Balance and Technological Consumption of Electricity for Transmission through the Power Grids".

The calculation approach used in the methodology is consistent with the approach for calculating the Simple Operating Margin in accordance with the guidance for clean development projects in force at the time of preparation of the methodology ($EF_{grid, OMsimpley}$). According to the guidance, the Simple Operating Margin takes into account emissions from all power plants that supply electricity to the grid, except for those in the low-cost/must-run category.²³

22 Order of the National Environmental Investment Agency of Ukraine of 21.03.2011 No. 39 "On Approval of the Methodology for Calculating Specific Carbon Dioxide Emissions from Electricity Production at Thermal Power Plants and its Consumption", <https://zakon.rada.gov.ua/rada/show/v0039825-11#Text>

23 Tool to calculate the emission factor for an electricity system, https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v1.1.pdf/history_view

3.5 Requirements of the GHG Protocol and Scope 2 Guidance for Emissions Accounting

The GHG Protocol is a globally recognised international standard for accounting for corporate greenhouse gas emissions and defines the basic principles and rules for such accounting, including accounting for indirect emissions from electricity consumption.²⁴

The GHG Protocol for Scope 2 requires corporations to calculate emissions from the production of purchased electricity, as well as heat, steam or cooling. Such emissions are considered indirect, as the actual emissions do not occur within the companies' operational boundaries, but elsewhere, such as at power plants.

In Ukraine, corporate emissions accounting is only gaining popularity, but corporations operating in international markets and international corporations with assets in Ukraine already carry out such calculations and need a reliable source of information on the emission factor for electricity.

The Scope 2 Guidance defines two methods for calculating emissions from electricity consumption:

- location-based method, which reflects the average specific emissions for the electricity grid from which electricity is consumed;
- market-based method, which reflects emissions from electricity generation that a company consciously chooses to purchase, or may also reflect a lack of choice for the company.

Companies operating in markets where supplier-specific information is provided in the form of any contractual instruments should report Scope 2 emissions using both location-based and market-based methods (dual reporting).

Companies should indicate which method is used to calculate total emissions, set and track targets, and account for other indirect emissions if they are included in the calculation (Scope 3).

The location-based method uses an emission factor calculated on the basis of general statistics on emissions and electricity generation for a defined geographical area and a defined period of time (average emission factor for the grid). It should not take into account any adjustments due to the use of market-based contractual instruments.

The concept of average grid electricity emission factor can be interpreted differently, as such factors can be calculated for different purposes and may differ in terms of the inclusion of individual greenhouse gases, treatment of biomass and combined heat and power generation.

In particular, according to the GHG Protocol, any CH₄ or N₂O emissions from biogenic energy sources should be accounted for in Scope 2, while CO₂ emissions from biofuel combustion should be reported separately outside the defined emission scopes (as biogenic emissions). For the location-based method, average emission factors often cover only CO₂ emissions, considering biomass combustion as a zero-emission energy source. Such a deviation from the general requirements should be documented by companies in their reporting. If information on emissions from biomass (CH₄, N₂O and biogenic CO₂ emissions) from electricity production is available or included in the emission factors, they should be included in the reporting. The geographical coverage in the calculation of average emission factors should reflect or be close to the boundaries of electricity distribution in the grid. All data on electricity generation and emissions within the defined boundaries should be included, and any net physical imports or exports of electricity and the corresponding emissions should be included.

24 GHG Protocol. Scope 2 Guidance, <https://ghgprotocol.org/scope-2-guidance>

There are often limitations in the availability of average emission factor data – typically, it becomes available a year or two after the period of electricity generation and emissions. Companies should take this into account and use the most up-to-date data available.

It should be remembered that the average emission factor is different from the marginal emission factor for the grid, which reflect the emissions of only those power plants that participate in grid balancing. Marginal emission factors cannot be used for corporate accounting of Scope 2 emissions, but are appropriate for estimating emission reductions. Emission reductions or avoided emissions from renewable energy projects may be included in the corporate report separately for information purposes as recommended by GHG Protocol guidance.

The market-based method uses emission factors from contractual instruments, which may include any contracts between two parties for the purchase and sale of energy that specify certain attributes of the electricity produced, or separate contracts for the purchase of certain electricity attributes – unbundled attribute claims – that contain certain information about the electricity purchased but do not cover the actual purchase and sale of electricity. The availability of certain contractual instruments depends on the country and the relevant regulatory environment with respect to guarantees of origin for the electricity, renewable electricity certificates, direct power purchase agreements, etc. In addition, the market-based method requires information on supplier-specific emission factors or other standard emission factors that reflect electricity and emissions that cannot be tracked through market-based instruments (the so-called "residual mix").

The emission factor for the residual mix reflects emissions from electricity not covered by contractual instruments and is calculated using similar principles as the emission factor for the location-based method, minus the electricity for which contractual instruments are used.

Corporations should not attempt to calculate a supplier-specific emissions factor based on fuel share data on their own, due to possible different disclosure rules that may affect the accuracy of the calculated figure. The supplier-specific factor should take into account the emissions from the production of all purchased electricity, but not any possible purchase of carbon offsets.

Companies that do not use contractual instruments or do not have data on emission factors for contractual instruments (e.g., do not purchase any guarantees of origin, do not have direct power purchase agreements, and do not have information on the emission factor from the supplier) should use an emission factor for the residual mix for the market-based method. Depending on the region and the proportion of electricity whose origin is traceable, this factor may be close to the average grid factor, but may also differ significantly. Only in the absence of emission factor data for the residual mix can the average grid emission factor be used for the market-based method, as in the case of the location-based method. Corporations should not attempt to calculate the residual mix on their own.

The GHG Protocol Scope 2 emissions accounting guidance sets out quality criteria for contractual instruments (Scope 2 Quality Criteria) that companies must meet. If the available contractual instruments do not meet the criteria, other sources of emissions data should be used for the market-based method.

Scope 2 includes only indirect emissions from electricity generation, so other emissions related to fuel extraction or production, grid losses during transmission or distribution are not included in Scope 2, but can be included in other indirect emissions in Scope 3 (Category 3 – fuel and energy-related emissions not included in Scope 1 or 2). Accordingly, only emission factors for electricity generation (emissions from electricity generation) should be used to calculate Scope 2 emissions. In cases where available emission factors are calculated for end-users of electricity, i.e. include losses, they should be divided into emissions from production and emissions associated with electricity losses during transmission and distribution.

In general, corporations are encouraged to use the most relevant, reliable and accurate emission factors available for both the location-based and market-based methods.

3.6 Residual Mix Emission Factor

The residual mix emission factor reflects the greenhouse gas emissions for electricity generation that remain after the exclusion of electricity generation for which contractual instruments, including guarantees of origin, have been used. In European countries, the calculation of this factor is closely linked to the functioning of the system of guarantees of origin of electricity from renewable sources. In other words, this factor reflects the emissions per MWh of electricity produced, taking into account only the residual amount of electricity – the amount that is not covered by guarantees of origin. Accordingly, the residual mix emission factor is usually higher than the average emission factor for the grid.

The residual mix emission factor may be used to calculate corporate Scope 2 GHG emissions using the market-based method in accordance with the provisions of the GHG Protocol.

The purpose of this accounting system is to avoid double counting of the benefits of electricity produced from renewable sources. After all, if companies or other consumers report electricity consumption from renewable sources on the basis of guarantees of origin and claim zero emissions, while other companies or consumers report indirect emissions from electricity consumption on the basis of the average emission factor for the grid, double counting occurs, as all electricity from renewable sources is taken into account when calculating the average emission factor.

For the majority of European countries (34 countries), the calculation of residual mix emission factors and the publication of relevant information is carried out by the Association of Issuing Bodies (AIB), an association of issuing bodies of guarantees of origin. Since it is possible to trade electricity between countries and transfer guarantees of origin to other countries, the residual mix emission factor calculation should be done centrally and take into account such transactions.

The residual electricity is calculated in accordance with a special methodology that considers electricity imports and exports by different countries, as well as international transactions with guarantees of origin.²⁵ The residual electricity volume includes all electricity whose origin cannot be traced through contractual instruments, so in addition to electricity generated from fossil fuels, it may include electricity generated by nuclear power plants. In addition, the residual volume may include cancelled guarantees of origin for electricity produced from renewable sources, as such guarantees can no longer be used by consumers.

Direct emissions from electricity generation are based on national data (if available) or calculated based on electricity generation sources and Ecoinvent emission factors database (used for most countries). The emission factors are country-specific and based on the main fuel technologies/sources, so they may not reflect actual fuel characteristics, changes in electricity generation efficiency, different approaches to emission allocation in case of cogeneration, and some other factors.

The results of the calculation of residual emission factors for European countries are published annually.²⁶ If the entire volume of electricity produced can be traced through contractual instruments, the residual volume of electricity will be zero and therefore no residual mix emission factor is calculated (in Austria and Switzerland, the entire volume of electricity consumed can be traced through guarantees of origin and information on the corresponding emission factors can be obtained from the electricity supplier). Residual mix emission factors for electricity can also be calculated on a country-by-country basis.

25 Issuance Based Residual Mix Calculation Methodology. Antti Kuronen, Marko Lehtovaara, Stefan Jakobsson, 31.03.2020, Version 1.2, <https://www.aib-net.org/facts/european-residual-mix>

26 European Residual Mixes. Results of the calculation of Residual Mixes for the calendar year 2023, https://www.aib-net.org/sites/default/files/assets/facts/residual-mix/2023/AIB_2023_Residual_Mix_FINALResults09072024.pdf

The Association of Issuing Bodies also publishes the values of estimated average emission factors for electricity production (production mix emission factor), but due to differences in methodological approaches, these values may differ from other sources of information, in particular, official national data on average emission factors. Since most countries use emission factors from the Ecoinvent database to calculate greenhouse gas emissions, the results of the calculations will not take into account all national specifics and national approaches to calculating emissions from electricity generation.

Residual mix emission factors also exist for a variety of other systems.²⁷

3.7 Environmental Value of Electricity

In 2024, Ukraine introduced a mechanism for guaranteeing the origin of electricity produced from renewable energy sources²⁸ and is currently working to create conditions for its full functioning. The procedure for issuing, circulating and redeeming guarantees of origin for electricity produced from renewable energy sources, in particular, determines the functioning of the register of guarantees of origin, registration of facilities, issuance, circulation and redemption of guarantees of origin. The information contained in the register of guarantees of origin is used to disclose information to electricity consumers about the sources of energy in the overall structure of the balance of electricity purchased by electricity suppliers and/or produced at their own generating facilities. The NEURC is the holder and administrator of the register of guarantees of origin as the authorised body for issuing, circulating and redeeming guarantees of origin in Ukraine. The guarantee of origin is generated automatically using the functionality of the register of guarantees of origin solely on the basis of certified commercial metering data entered by the commercial metering administrator. The guarantee of origin is issued for the amount of electricity from renewable energy sources supplied to the transmission and/or distribution system and/or to the grid of other owners, in particular through a direct line, or produced and used for own consumption of electricity. Guarantees of origin are not issued for electricity generated by pumped storage power plants. Issued guarantees of origin can be transferred (by moving between accounts in the register within 12 months from the date of electricity generation), redeemed (once with no further circulation) or cancelled (if no redemption occurs within 18 months). Guarantees of origin can potentially be transferred outside of Ukraine based on relevant international agreements.

Guarantees of origin may be redeemed to confirm the production of electricity from renewable energy sources; confirm the production of goods using electricity generated from renewable energy sources; or disclose information to the consumers of electricity about the sources of energy in the overall structure of the electricity balance purchased by electricity suppliers and/or produced at their own generating facilities.²⁹

The CMU Resolution No. 227 also approved the Procedure for Determining the Environmental Value of Electricity Generated from Renewable Energy Sources. According to the Procedure, the environmental value is measured in kilograms of CO₂ equivalent per 1 MWh of electricity and determines the average amount of greenhouse gases that would be emitted by electricity producers using thermal power plants in the process of electricity generation from fossil fuels if electricity generated from renewable energy sources were substituted. Information on environmental value is contained in the guarantee of origin, and the guarantee of origin certifies the rights of its holder to the environmental value and positive effect of

27 See, e.g., Residual Mix methodology for IREC issuing countries, https://www.trackingstandard.org/wp-content/uploads/NORSUS-Residual-Mix-Methodology_OR15.23.pdf

28 Resolution of the Cabinet of Ministers of Ukraine of 27 February 2024 No. 227 "On the Introduction of Guarantees of Origin of Electricity Generated from Renewable Energy Sources", <https://zakon.rada.gov.ua/laws/show/227-2024-%D0%BF#Text>

29 In accordance with the Procedure for Disclosure of Information to Electricity Consumers on Energy Sources in the General Structure of the Electricity Balance Purchased by the Electricity Supplier and/or Generated at its Own Power Plants, approved by NEURC Resolution No. 2626 of 27 December 2023

electricity generation from renewable energy sources. The administrator of the register of guarantees of origin shall annually enter into the register of guarantees of origin and publish on its official website the indicator of the environmental value of electricity for the following year by 31 December. The calculation of the environmental value is carried out by the Ministry of Energy on the basis of public information on annual greenhouse gas emissions from the energy sector as defined in the national inventory (category 1.A(a)s1 of the common reporting format of the national inventory) and the volume of electricity production from fossil fuels according to the actual balance of electricity of the Integrated Power System (IPS) of Ukraine for a period of five years and ending two years before the year in which the guarantee of origin is issued.

For 2024, the indicator of the environmental value of electricity generated from renewable energy sources was approved in the amount of 1232.84 kilograms of CO₂ equivalent per 1 MWh of electricity.³⁰

3.8 The European Environment Agency's Approach

The European Environment Agency publishes information on specific greenhouse gas emissions from electricity generation in Europe.³¹ Specific CO₂ emissions are calculated as the ratio of CO₂ emissions from electricity generation to gross electricity generation.

The calculations are based on the greenhouse gas emissions data reported to the UNFCCC and energy balance data on total electricity production by both public power plants (main activity producers, statistical codes GEP_MAPE and GEP_MAPCHP) and enterprise power plants (autoproducers, statistical codes GEP_APE and GEP_APCHP). The results are published in g CO₂ eq. per kWh. Greenhouse gas emissions data are based on national emission inventories prepared in accordance with the requirements of the UNFCCC and the EU Greenhouse Gas Monitoring Mechanism.

Data from GHG emission inventories for electricity production (EEA category 1A1a) do not differentiate between emissions from the production of heat and electricity in cases of cogeneration, so the method of alternative heat generation is used for such a division (the default value of heat production efficiency of 90% is allowed). In addition, national inventory data in this category do not include data on emissions from autoproducers, so such emissions are estimated separately by multiplying the ratio of fuel use by autoproducers to fuel use by main activity producers by the calculated emissions from electricity generation by main activity producers. In other words, the emissions from electricity generation by enterprise power plants are roughly estimated assuming a similar carbon intensity as that of main activity producers. For nuclear power plants and power plants based on renewable energy sources (including the share of biomass in municipal solid waste and other types of biomass), a zero emission factor is used, as the methodology does not include life-cycle emissions.

Data on electricity generation and fuel consumption are based on energy balance data.³²

30 Order of the Ministry of Energy of Ukraine "On Approval of the Environmental Value of Electricity Generated from Renewable Energy Sources for 2024", https://mev.gov.ua/sites/default/files/field/file/nakaz-325-vid-030924_dod.pdf

31 Greenhouse gas emission intensity of electricity generation in Europe, <https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1>

32 See Complete energy balances (nrg_bal_c), https://www.eea.europa.eu/data-and-maps/data/external/complete-energy-balances-nrg_bal_c ta Simplified energy balances,

3.9 Life Cycle Assessment

In some cases, a life-cycle approach is used to estimate emissions from electricity consumption, which includes emissions from the extraction, production and transportation of the fuel used to generate electricity. Furthermore, some studies take into account emissions associated with the production and future dismantling and disposal of power plant equipment, spreading them over the entire amount of electricity that can be generated over the whole lifetime of the equipment. In addition, this approach can also take into account emissions associated with electricity losses during transmission and distribution (life-cycle emission factor for electricity consumed). Studies of life-cycle emission factors for electricity may differ in the number of life-cycle stages covered and the detail of the calculations.

In the context of electricity use in transport, this method is also known as the Well-To-Wheel approach and is used for comparison with similar calculations for other fuels. However, emissions from equipment manufacturing and dismantling are usually not taken into account due to the expected insignificant contribution to the overall values.

For example, a study of life-cycle emission factors for European countries took into account the following emission sources:³³

- Emissions from upstream processes of fuel supply to power plants: extraction or cultivation (cultivation and harvesting in the case of biomass) of fuel, fuel processing, and transport to the places of electricity production;
- Emissions from power plant construction: extraction of minerals for construction, production of materials and equipment, transportation from production sites to construction sites, and energy consumption during construction;
- Emissions from electricity generation: emissions from fuel combustion for electricity generation (for biomass, only CH₄ and N₂O emissions are taken into account, and for waste, the origin of carbon in materials is taken into account), other emissions related to the maintenance and repair of power plants;
- Emissions from downstream processes: waste disposal, decommissioning of power plants and land reclamation.

At the EU level, the study found that the average life-cycle emission factor for electricity generation was 296 g CO₂ eq./kWh, which included:

- 251 g CO₂ eq./kWh from fuel combustion (85%);
- 36 g CO₂ eq./kWh from upstream fuel consumption processes (12%);
- 9 g CO₂ eq./kWh from power plant construction and decommissioning (3%).

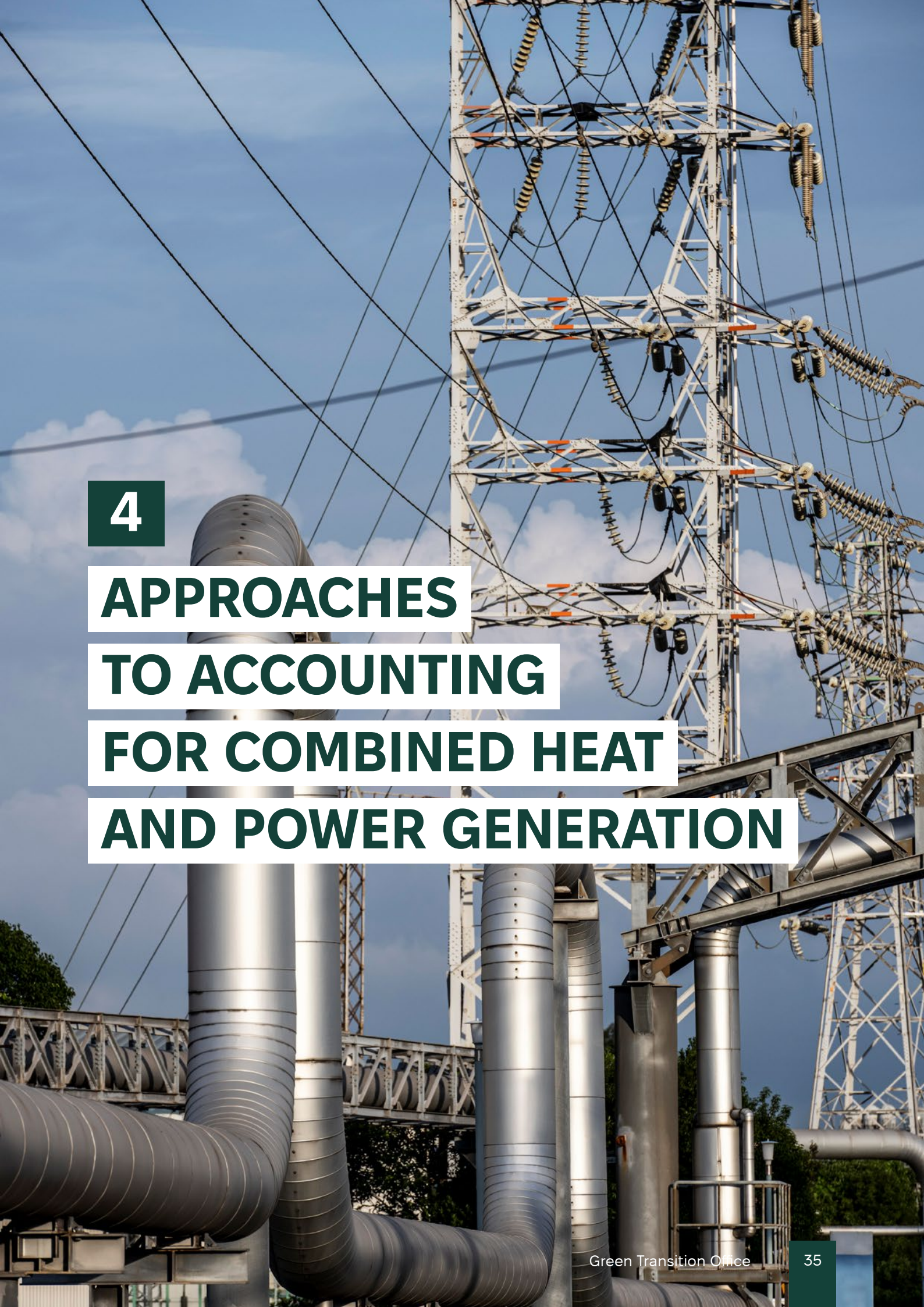
It is important to note that the magnitude of emissions from upstream fuel supply processes depends on the fuel types and methods of extraction, so applying uniform standardised factors for the main fuels reduces the accuracy of the calculations. Generally, the largest emissions are associated with the extraction and supply of coal and natural gas, but upstream emissions for biofuels can also be high and exceed those of fossil fuels. As a result, in some EU countries that use large volumes of fossil fuels and biomass, upstream emissions from fuel supply processes were significantly higher than average, reaching 122 g CO₂ eq./kWh.

33 Nicolae Scarlat, Matteo Prussi, Monica Padella, Quantification of the carbon intensity of electricity produced and used in Europe, *Applied Energy*, Volume 305, 2022, 117901, ISSN 0306-2619, <https://doi.org/10.1016/j.apenergy.2021.117901>, <https://www.sciencedirect.com/science/article/pii/S0306261921012149>

For fossil fuels, the main source of emissions is direct emissions from fuel combustion, but other sources of emissions during the life cycle can also be quite significant and amount to about 60 to 100 g CO₂ eq./ kWh.

Emissions from power plant construction also include emissions applicable for renewable energy plants (SPPs, WPPs, etc.), the value of which per kWh is, however, highly uncertain and depends on assumptions about the lifetime and utilisation rates of the installed capacity. The value of such emissions typically ranges from 10 to 40 g CO₂ eq./kWh.





4

APPROACHES TO ACCOUNTING FOR COMBINED HEAT AND POWER GENERATION

4.1 The Need to Disaggregate Fuel Consumption and Emissions

Combined heat and power (CHP), also referred to as 'cogeneration', is the simultaneous production of heat (hot water and/or steam) and electricity in a single integrated process.

Combined heat and power generation can significantly improve fuel efficiency. At the same time, for the purposes of estimating emissions per unit of electricity and heat produced, it is necessary to allocate fuel consumption separately for the production of the two energy sources using certain assumptions and formulas.

There are very different approaches to this allocation, differing in complexity, data requirements and applications. The primary methods include:

- efficiency method,
- alternative heat generation method,
- alternative electricity generation method,
- energy-based method,
- 1/3 : 2/3 method.

There are many other methods for allocating fuel consumption and emissions for combined heat and power plants that have been developed for different needs.^{34, 35} However, there is also no consensus on the most optimal allocation method, or at least an algorithm for transparently selecting the most appropriate method for a particular need.³⁶

The difference between the methods can be quite significant – up to 30-50% or more, depending on the methods being compared.

It is also worth noting that the methods are described in different cases for different accounting purposes (e.g., for accounting at the level of an individual installation or consumer, rather than at the level of the national grid), and therefore cannot always be directly used for the purposes of calculating the national average greenhouse gas emission factor for electricity generation and consumption.

4.2 Efficiency Method

There are several approaches to allocate fuel consumption for the production of heat and electricity in cogeneration plants using efficiency indicators, as well as efficiency indicators for alternative methods of separate heat and electricity production.

34 CO2 emission allocation in CHP systems and recommendations, BSR LTDH project, https://www.lowtemp.eu/wp-content/uploads/2021/06/PPT_CO2Allocation.pdf

35 Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant. Guide to calculation worksheets (September 2006) v1.0 A. WRI/WBCSD GHG Protocol Initiative calculation tool, https://ghgprotocol.org/sites/default/files/2023-03/CHP_guidance_v1.0.pdf

36 Allocation of carbon dioxide emissions to the by-products of combined heat and power plants: A methodological guidance, <https://www.sciencedirect.com/science/article/pii/S2667095X23000259>

Standard efficiencies for alternative methods of separate heat and power production for different types of fuel and taking into account the period of construction of facilities are given in Annex IX of the Regulation.

For example, for individual electricity generation, the efficiency factors include the following:

- 52.5% for natural gas-fired power plants built before 2012;
- 44.2% for coal-fired power plants, including anthracite and bituminous coal;
- 33% for dry biomass power plants, including pellets and briquettes, built before 2012;
- 25% for power plants using other types of biomass and solid waste built before 2012;
- 42% for biogas-fired power plants, including biogas from anaerobic digestion and solid waste landfills.

For individual heat production, the efficiency factors include the following:

- 90% for natural gas-fired hot water boilers installed before 2016;
- 70% for biogas-fired hot water boilers, including biogas from anaerobic digestion and solid waste landfills, installed before 2016;
- 88% for coal-fired hot water boilers, including anthracite and bituminous coal, installed before 2016;
- 86% for dry biomass-fired boilers, including pellets and briquettes, installed before 2016;
- 80% for hot water boilers fuelled by other types of biomass and solid waste installed before 2016.

The Annex of the Regulation contains other default values for different types of boilers, power plants, as well as different fuels and periods of plant construction.

Accordingly, the emission factors for heat and electricity in their combined production are determined by multiplying the determined share by the total emissions and dividing the result by the volume of heat or electricity production, respectively.

There is also a slightly different way to calculate the allocation based on the efficiency method. This mathematical expression of the method is, in particular, recommended for use by the GHG Protocol guidance documents.³⁹

In this calculation, the shares are determined based on the proportion of fuel required for separate heat and power generation at two separate plants, taking into account their efficiency.⁴⁰

39 Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant. Guide to calculation worksheets (September 2006) v1.0 A. WRI/WBCSD GHG Protocol Initiative calculation tool, https://ghgprotocol.org/sites/default/files/2023-03/CHP_guidance_v1.0.pdf

40 The formulas provided in the GHG Protocol guidance have been adapted to use the same approaches and notation throughout the study.

$$F_{CHP, heat} = \frac{H / \eta_{ref, heat}}{H / \eta_{ref, heat} + P / \eta_{ref, el}}$$

Share attributable to heat production

$$F_{CHP, el} = 1 - F_{CHP, heat}$$

Share attributable to electricity production

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- H is the volume of heat (steam) production;
- P is the volume of electricity production;
- $\eta_{ref, heat}$ is the assumed efficiency of heat production – the efficiency of heat production by an alternative method (boiler);
- $\eta_{ref, el}$ is the assumed efficiency of electricity production – the efficiency of electricity production by an alternative method (power plant) without combined heat and power generation.

The efficiencies are used to determine the amount of fuel, and therefore emissions, required for the individual heat and power generation. It is recommended to use efficiencies specific to the energy production conditions, but default values can also be used in the absence of such indicators.

It is worth noting that there may be other efficiency-based allocation methods, including those based on the efficiency of cogeneration alone.⁴¹

4.3 Alternative Heat Generation Method

The alternative heat generation method (known in the UK as the Boiler Displacement Method and in the International Energy Agency as fixed-heat-efficiency approach) assumes that the heat produced by the cogeneration unit replaces the heat generated by a boiler with a specific efficiency (81% in the UK, while the International Energy Agency recommends 90%). The fuel or fuel mixture is assumed to be the same for both the boiler and the cogeneration unit. Mathematically, this method can be represented as follows:⁴²

$$F_{CHP, heat} = \frac{H / \eta_{ref, heat}}{FC}$$

Share attributable to heat production

$$H_{fuel} = 1 - F_{CHP, heat}$$

Share attributable to electricity production

$$H_{fuel} = FC - \frac{H}{\eta_{ref, heat}}$$

Fuel consumption for heat production

41 Allocation of carbon dioxide emissions to the by-products of combined heat and power plants: A methodological guidance, <https://www.sciencedirect.com/science/article/pii/S2667095X23000259>

42 The mathematical formulation may differ depending on the parameters used. For example, the International Energy Agency methodology document provides formulas for determining fuel consumption for electricity production, but not the share of fuel consumption for electricity production. See https://iea.blob.core.windows.net/assets/bf862218-7fd8-4637-aca6-5a347b6ca4f1/IEA_Methodology_Emission_Factors_2023.pdf

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- FC is total fuel consumption (in energy units);
- H is the volume of heat (steam) production;
- $\eta_{ref, heat}$ is the assumed efficiency of heat production – the efficiency of heat production by an alternative method (boiler);
- H_{fuel} is the volume of fuel consumption for heat production.

This method is used by the International Energy Agency and the European Environment Agency.⁴³

4.4 Alternative Electricity Generation Method

The alternative electricity generation method (known in the UK as the Power Station Displacement Method) assumes that the electricity produced by a cogeneration plant replaces the electricity produced by other power plants (without combined heat and electricity production) at a defined efficiency (47.6% in the UK, corresponding to the efficiency of a gas power plant)

$$F_{CHP, el} = \frac{P / \eta_{ref, el}}{FC}$$

Share attributable to electricity production

$$F_{CHP, heat} = 1 - F_{CHP, el}$$

Share attributable to heat production

$$H_{fuel} = FC - \frac{P}{\eta_{el, ref}}$$

Fuel consumption for heat production

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- FC is total fuel consumption (in energy units);
- P is the volume of electricity production;
- $\eta_{ref, el}$ is the assumed efficiency of electricity production – the efficiency of electricity production by an alternative method (power plant) without combined heat and power generation.

43 EEA, <https://www.eea.europa.eu/en/analysis/indicators/greenhouse-gas-emission-intensity-of-1>

4.5 Energy-Based Method

The energy-based method allocates emissions based on the energy value of each individual energy product. This method is suggested by the GHG Protocol guidance as an alternative.⁴⁴

The energy value of electricity corresponds to the amount of electricity produced by the installation. The energy value of steam or hot water corresponds to the energy content of the steam or hot water minus the energy returned to the system as condensate (i.e. useful heat). The amount of useful heat energy can be calculated as the product of the amount of steam in tonnes divided by the difference in enthalpies of the steam and condensate produced (enthalpy values are given in special tables for the respective temperature and pressure). This method is particularly suitable for cases where steam is used for process needs.

The shares for emission allocation are determined according to the share of the energy value of a particular product produced to the total energy value of heat and electricity. This method is relatively simple and transparent and is therefore often used, but it does not take into account the difference between the energy value of heat and electricity (in other words, it does not take into account the qualitative characteristics of different types of energy).

$$F_{CHP, heat} = \frac{H}{H+P} \qquad F_{CHP, el} = 1 - F_{CHP, heat}$$

Share attributable to heat production

Share attributable to electricity production

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- H is the volume of heat (steam) production;
- P is the volume of electricity production.

4.6 The 1/3 : 2/3 Method

In the **UK**, for facilities participating in the UK Climate Change Agreements scheme, the so-called **1/3 : 2/3 (DUKES) method** is used, the basic assumption being that twice as much fuel is required to produce a unit of electricity as to produce a unit of heat.⁴⁵ This approach is based on data on the efficiency of electricity production, which can vary between 25% and 50%, while the efficiency of heat production by boilers varies between 50% and 90%.

The following formulas are used to calculate fuel consumption for individual types of energy⁴⁶

44 Allocation of GHG Emissions from a Combined Heat and Power (CHP) Plant. Guide to calculation worksheets (September 2006) v1.0 A. WRI/WBCSD GHG Protocol Initiative calculation tool, https://ghgprotocol.org/sites/default/files/2023-03/CHP_guidance_v1.0.pdf

45 Department for Energy Security and Net Zero, 2023 Government Greenhouse Gas Conversion Factors for Company Reporting Methodology Paper for Conversion Factors Final Report, <https://assets.publishing.service.gov.uk/media/647f50dd103ca60013039a8a/2023-ghg-cf-methodology-paper.pdf>

46 The notation of values has been changed compared to the source to ensure consistency with other parts of the document.

$$F_{CHP, el} = \frac{2P}{2P+H}$$

Share attributable to electricity production

$$F_{CHP, heat} = \frac{H}{2P+H}$$

Share attributable to heat production

$$P_{fuel} = \frac{2FC}{2P+H} \times P$$

Fuel consumption for electricity production

$$H_{fuel} = \frac{FC}{2P+H} \times H$$

Fuel consumption for heat production

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- FC is total fuel consumption (in energy units);
- P is the volume of electricity production;
- H is the volume of heat (steam) production;
- P_{fuel} is the volume of fuel consumption for electricity production;
- H_{fuel} is the volume of fuel consumption for heat production.

4.7 Individual Plant Data Approach

Although the methods described above were developed for different purposes, they can all be adapted to use aggregated data at the national level and assumptions about typical efficiency of heat and power generation in the country. A fundamentally different approach would be to use detailed data from each individual plant and calculate the fuel consumption separately for heat and electricity production at the plant level.

This approach allows taking into account the individual characteristics of specific cogeneration units (efficiency indicators, fuel characteristics, technical condition, percentage of electricity consumption for own needs, load modes, etc.) and external factors (temperature of the cooling medium, weather characteristics of the heating period in a particular year – outdoor air temperature and the corresponding heat load according to the individual temperature schedule of a particular heating network) that directly affect the performance of the unit.

At the same time, this approach requires a much larger amount of data, due to the large number of plants, based on statistical reporting forms or other sources of information. For example, the statistical reporting forms 4a-NKREKP, 3-TEKH-TES, 6-tp provide data on specific consumption of standard fuel (separately for thermal and electrical energy, calculated in accordance with approved sectoral methodologies) for a particular installation. This data can be directly used to calculate the carbon intensity of the thermal and electrical energy produced by the plant. The use of this method is possible and appropriate in the case of a relatively small number of combined heat and power plants or the availability of an efficient digitised system for collecting and analysing data at the plant level.

For example, the methodology used for joint implementation projects under the Kyoto Protocol mechanisms,⁴⁷ was limited to thermal power plants and used statistical reporting data to calculate the actual fuel consumption in physical terms for electricity only output by a power plant. The calculation formula is based on the total actual consumption of a fuel type for both electricity and heat output in physical terms and data on the consumption of fuel in tonnes of coal equivalent separately for electricity generation only in accordance with statistical reporting forms (Form N 6-TP "Thermal Power Plant Operation Report"):

$$B_{\text{нпе}, m, y, i} = B_{\text{нп}, m, y, i} \times \frac{B_{\text{ype}, m, y}}{B_{\text{yn}, m, y}}$$

Where:

- $B_{\text{нпе}, m, y, i}$ is the actual consumption of the i -th fuel type in physical terms for the electricity supplied by power plant m in the year y (tonnes or thousand m^3);
- $B_{\text{нп}, m, y, i}$ is the actual consumption of the i -th fuel type in physical terms for the supply of electricity and heat by power plant m in the year y (tonnes or thousand m^3);
- $B_{\text{ype}, m, y}$ is the actual consumption of fuel in tonnes of coal equivalent for electricity supplied by power plant m in the year y (tonnes of coal equivalent);
- $B_{\text{yn}, m, y}$ is the actual consumption of fuel in tonnes of coal equivalent for the supply of electricity and heat by power plant m in the year y (tonnes of coal equivalent).

4.8 Summary and Method Selection

In the case of combined heat and power generation, the results of allocating fuel consumption, and thus greenhouse gas emissions, separately to electricity generation for the purposes of calculating emission factors depend on the method chosen and the assumptions made.

There are also differences in the data requirements for the different methods. Most methods require data on heat and electricity production, while some additionally require data or assumptions on the efficiency of heat and electricity production by alternative methods or the amount of fuel used by the cogeneration plant for direct use in the calculations or for calculating the efficiency of heat and electricity production by the cogeneration plant.

47 Methodology for calculation of specific carbon dioxide emissions for electricity production at thermal power plants and its consumption, approved by the Order of the National Environmental Investment Agency of Ukraine No. 39 of 21.03.2011, <https://zakon.rada.gov.ua/rada/show/v0039825-11#Text>

Table 7. Data requirements for different methods of allocating fuel consumption and emissions from combined heat and power

Method	Recommendations for use	Data requirements				
		Fuel consumption	Heat production	Electricity production	Assumptions about the efficiency of heat production by an alternative method	Assumptions about the efficiency of electricity production by an alternative method
Efficiency method	CBAM Regulation, GHG Protocol Guidance	+	+	+	+	+
Alternative heat generation method	IEA, Department for Energy Security and Net Zero (UK)	+	+		+	
Alternative electricity generation method	Department for Energy Security and Net Zero (UK)	+		+		+
The energy method	KOBIZE (Poland)		+	+		
1/3 : 2/3 method	Department for Energy Security and Net Zero (UK) - primary method		+	+		

The results of calculations of the share of electricity generation in total fuel consumption and greenhouse gas emissions can vary significantly, depending on the method and assumptions used. Calculations based on the limited statistical data available for 2020-2023 show results in the range of 24% to 67% (Table 8). The lowest figures are typical for the energy method, and the largest share is for the alternative electricity generation method with relatively low efficiency.

The higher the production volumes and the share of cogeneration in total electricity production, the greater the impact of the choice of method and assumptions on the results of calculating emission factors for electricity production and consumption. A smaller share attributed to electricity production will reduce the factors and vice versa.

Proper consideration of combined heat and power production in the calculation of emission factors is also important in the context of possible future changes in the power system and the use of highly efficient cogeneration to improve the reliability of power supply and the efficiency of energy use.

Table 8. Results of calculations based on different methods and assumptions

Allocation method	2020	2021	2022	2023
Share attributable to electricity production				
Efficiency method (CBAM Regulation) - calculated efficiency based on fuel production and consumption	51%	40%	39%	44%
Efficiency method (CBAM Regulation) - standard efficiency	48%	48%	48%	48%
Efficiency method (GHG Protocol) - reference efficiency values from the CBAM Regulation	51%	40%	39%	44%
Efficiency method (GHG Protocol) - reference efficiency values based on assumptions about national values	61%	50%	48%	54%
Alternative heat generation method (IEA approach - heat production efficiency of 90%)	57%	50%	52%	56%
Alternative heat generation method (heat production efficiency of 81%)	52%	45%	46%	51%
Alternative electricity generation method (electricity generation efficiency of 30%)	67%	50%	45%	52%
Alternative electricity generation method (electricity generation efficiency of 44.2%)	45%	34%	30%	35%
Energy method	34%	25%	24%	28%
1/3 : 2/3 method	51%	40%	38%	44%
Share attributable to heat production				
Efficiency method (CBAM Regulation) - calculated efficiency based on fuel production and consumption	49%	60%	61%	56%
Efficiency method (CBAM Regulation) - standard efficiency	52%	52%	52%	52%
Efficiency method (GHG Protocol) - reference efficiency values from the CBAM Regulation	49%	60%	61%	56%
Efficiency method (GHG Protocol) - reference efficiency values based on assumptions about national values	39%	50%	52%	46%
Alternative heat generation method (IEA approach - heat production efficiency of 90%)	43%	50%	48%	44%
Alternative heat generation method (heat production efficiency of 81%)	48%	55%	54%	49%
Alternative electricity generation method (electricity generation efficiency of 30%)	33%	50%	55%	48%
Alternative electricity generation method (electricity generation efficiency of 44.2%)	55%	66%	70%	65%
Energy method	66%	75%	76%	72%
1/3 : 2/3 method	49%	60%	62%	56%

For the purposes of calculating national emission factors, it is proposed to use the **alternative heat generation method**. The use of this method requires data on total fuel consumption and heat production and only assumptions about the efficiency of heat production by alternative methods. In addition, the use of this method will ensure alignment with the International Energy Agency's approach and better comparability of data. Alternatively, if data availability is confirmed, an individual plant data approach could be used to estimate emissions more accurately.





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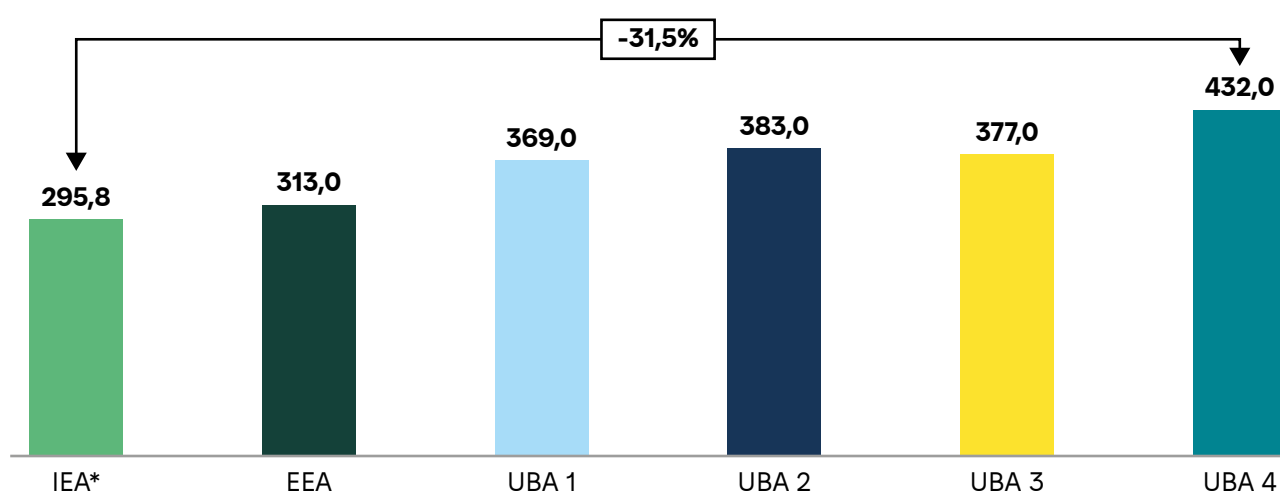
DESCRIPTION OF THE METHODOLOGICAL APPROACH

5.1 The Importance of a Consistent Methodological Approach

Effective climate policy planning at the level of the state or individual companies requires a clear understanding of the sources and volumes of greenhouse gas emissions, as well as consistent approaches to emissions accounting.

As electricity generation and consumption is a significant source of emissions, having a consistent methodological approach and a single source of information on different types of emission factors is important for a proper assessment of the climate impacts and benefits of different measures and policies.

The consistency of the methodological approach includes aspects related to the method of calculating emission factors and all intermediate steps, the scope of coverage of emission sources and electricity generation, as well as the quality of data on fuel consumption, emission factors for fuels, and electricity output to the grid.



The study used preliminary data from the IEA for the grid average emission factor for Germany based on the Electricity Market Report published in December 2020. The actual value of the average grid emission factor reported by IEA in the Emissions Factors database for Germany is 310.1 g CO₂/kWh.

Figure 1. Discrepancies in the average emission factor for electricity in Germany according to different sources / calculation approaches (g CO₂ eq. per kWh).

Source: Emission factor study for Germany⁴⁸

Studies show that, depending on the source of information and the calculation approach, emission factors for electricity can vary significantly. For example, the average emission factor for Germany in 2020 according to the International Energy Agency was 295.8 g CO₂/kWh (IEA in the figure). The German Environmental Agency (Umweltbundesamt or UBA) provides calculations based on different approaches, in particular, in terms of taking into account international electricity trade, defining the calculation boundaries (only direct emissions from combustion or life cycle emissions) and taking into account different greenhouse gases (all major greenhouse gases or only CO₂). As a result, the value of the emission factor ranges between 369 and 432 g CO₂ eq./kWh. Even the lowest value, which takes into account only direct CO₂ emissions from fuel combustion and excludes electricity trade, differs significantly from the IEA and the European

48 Malte Schäfer, Felipe Cerdas, Christoph Herrmann. Towards standardized grid emission factors: methodological insights and best practices, Energy Environ. Sci., 2024, 17, 2776–2786, <https://pubs.rsc.org/en/content/articlehtml/2024/ee/d3ee04394k>

Environment Agency. Overall, the difference between the highest and lowest values is 31.5%.⁴⁹

To agree on a methodological approach, it is important to consider the following aspects:

- Determining the boundaries for estimating emissions from electricity production – considering only direct emissions from fuel combustion or also indirect emissions associated with fuel extraction and transportation or construction of power plants;
- Determination of greenhouse gases to be taken into account in the calculation of emission factors: consideration of CO₂ emissions only or also other greenhouse gases based on global warming potentials (GWP);
- Selection of a method for allocating emissions from combined heat and power generation;
- Determining the approach to accounting or not accounting for power plants of enterprises that generate electricity for their own needs but can also supply electricity to the grid; the impact of this choice on the emission factor is particularly large when only electricity production or only emissions are taken into account in the calculation, but not both;
- Determining the approach to accounting for power plants' own electricity consumption, i.e. using either total electricity production or electricity supply (net electricity production) in the calculation of emission factors;
- Deciding whether to include inter-state electricity trade (imports and exports) in the calculation; when considering trade, it is necessary to take into account net imports by country and major interconnectors, as well as to have information on emission factors for the grids from which electricity is imported;
- Other factors that may affect the calculation include the consideration of losses from different electricity storage technologies, including PSPPs, and the granularity of the data used in the calculation (annual, daily or hourly data).

The inclusion of transmission and distribution losses also affects the results, but in line with emission factor practices, it is recommended to calculate emission factors with and without losses (or an emission factor without losses and a separate factor for transmission losses).

The choice of options for each of these aspects can lead to differences in the calculated emission factors ranging from a few percent to ten percent or more. Accordingly, the combination of different options can lead to differences in emission factors of 10-20% or more.

5.2 Methodological Approach to Calculating Average Emission Factors

This section describes the chosen methodological approach for calculating the following factors:

- **Average factor for electricity supplied to the grid**, which reflects the average specific emissions of all power plants of the Integrated Power System of Ukraine per unit of electricity supplied;
- **Average factor for electricity consumption** by end-users, which reflects average specific emissions per unit of electricity consumed and takes into account emissions from electricity generation and losses during transmission and distribution.

49 Malte Schäfer, Felipe Cerdas, Christoph Herrmann. Towards standardized grid emission factors: methodological insights and best practices, Energy Environ. Sci., 2024, 17, 2776-2786, <https://pubs.rsc.org/en/content/articlehtml/2024/ee/d3ee04394k>

The methodological approach to calculating average emission factors is based on the following assumptions:

- Only direct emissions from fuel combustion are taken into account, while indirect emissions associated with fuel extraction and transportation or power plant construction are not;
- Only CO₂ emissions are taken into account (inclusion of other greenhouse gases, including those from biomass use, is recommended for future consideration);
- Alternative heat generation method is used to allocate emissions from combined heat and power production separately into heat and electricity;
- The calculation does not take into account emissions and electricity generation supplied to the grid by power plants of enterprises (autoproducers);
- The calculation is based on the volume of electricity supplied to the grid (net generation);
- The calculation does not take into account electricity imports and exports.

5.2.1 Average Emission Factor for Electricity Supplied to the Grid

The average emission factor for electricity supplied to the grid, or specific emission factor for electricity supplied, is calculated as the ratio of all emissions from the use of fuel for electricity generation to total electricity supply and is measured in kg CO₂ equivalent per kWh (t CO₂ equivalent per MWh) of electricity supplied to the grid. The total electricity supply takes into account the supply from all power plants connected to the grid (both fossil fuel-fired thermal power plants and other power plants, including nuclear power plants and renewable energy plants).⁵⁰

$$EF_{average, grid, CO_2} = \frac{E}{P}$$

Where:

- $EF_{average, grid, CO_2}$ is the average emission factor for electricity supplied to the grid in kg CO₂ eq. per kWh (tonnes CO₂ eq. per MWh);
- E is the total amount of greenhouse gas emissions from electricity generation by power plants of the IPS of Ukraine in tonnes of CO₂ equivalent;
- P is the total electricity output by power plants of the IPS of Ukraine in thousand kWh (MWh).

The use of fuel for electricity production and the corresponding greenhouse gas emissions from its combustion should take into account both electricity only plants and combined heat and power plants. In this case, for combined heat and power production, fuel consumption and emissions should be disaggregated and emissions for electricity production should be allocated.

50 IEA, Emissions Factors 2023. Database documentation, https://iea.blob.core.windows.net/assets/bf862218-7fd8-4637-aca6-5a347b6ca4f1/IEA_Methodology_Emission_Factors_2023.pdf

Taking into account the need to calculate the total amount of greenhouse gas emissions from electricity generation by power plants of the IPS of Ukraine, the formula can be written as follows:

$$EF_{average, grid, CO_2} = \frac{44}{12} \times \sum FC_{i,j} \times Q_{i,j} \times EF_{i,j} \times k_{i,j} \div P$$

Where:

- $EF_{average, grid, CO_2}$ is the average emission factor for electricity supply to the grid, t CO₂ per thousand kWh (t CO₂ per MWh);
- FC is the actual consumption of the *i-th* type of fuel in physical terms for electricity generation in tonnes or thousands of cubic metres, depending on the type of fuel; in the case of electricity generation only, it corresponds to the total fuel consumption, and in the case of combined electricity and heat generation, it is calculated using the alternative heat generation method described below;
- Q is the net calorific value of the *i-th* type of fuel used for electricity generation, in TJ per tonne or TJ per thousand m³, depending on the type of fuel; if necessary, conversion to the appropriate energy units (e.g. from kcal per kg to TJ per tonne is performed);
- EF is the carbon emission factor for the combustion of the *i-th* type of fuel used for electricity generation, in tonnes of carbon (C) per TJ;
- k is the carbon oxidation factor for the *i-th* type of fuel used for electricity generation when it is burned at a power plant, in relative units;
- P is the amount of electricity supplied by all power plants to the grid, in thousand kWh.
- 44/12 is the conversion factor for converting carbon mass to carbon dioxide mass based on the molar mass ratio;
- *i* is the index of the kind and/or grade/type of fuel used at power plants for electricity generation;
- *j* is the index of an individual power plant or a group of power plants (for example, for TPPs or CHPs, the calculation can be performed for each power plant separately, taking into account the actual fuel consumption, net calorific value and other characteristics, or power plants can be combined into groups and the calculation can be based on general statistics for this type of power plants).

The calculation is made for each calendar year based on actual data. For the calculation, it is important to take into account information on the structure of electricity generation and the classifications used to collect statistical information.

The average emission factor for electricity generation can be used to account for indirect Scope 2 emissions (from consumption of electricity purchased from the grid).

Fuel consumption for electricity generation

In Ukraine, fossil fuels are used to generate electricity at thermal power plants, CHPs and power plants of enterprises (autoproducers).

To account for the combined heat and power generation, given the availability and accessibility of statistical data at the time of this study, it is proposed to use the method of alternative heat generation.

$$F_{CHP, heat} = \frac{H / \eta_{ref, heat}}{FC}$$

Share attributable to heat production

$$F_{CHP, el} = 1 - F_{CHP, heat}$$

Share attributable to electricity production

Where:

- $F_{CHP, heat}$ is a factor for determining the share of heat energy;
- $F_{CHP, el}$ is a factor for determining the share of electricity;
- H is the volume of heat supply;
- $\eta_{ref, heat}$ is the assumed efficiency of heat production – the efficiency of heat production by an alternative method (boiler);
- FC is the total fuel consumption (in energy units).

Data on fuel consumption for electricity generation may be based on data from individual power plants (based on the indicators of statistical reporting forms 3-TEKH TES "Power Plant's Report on Technical and Economic Indicators of Equipment Operation", 4-a-NKREKP "Production of Electricity and Heat (Monthly)") or groups of power plants (for example, all public TPPs based on available statistical information).

Net calorific value of fuel

For consistency with the national emissions accounting system, the data on the net calorific value of fuel are based on the data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine.⁵¹

The net calorific value for natural gas and coal combusted at TPPs is based on national data. According to the national emission accounting methodology, the approach developed by the Institute of Coal Energy Technologies of the National Academy of Sciences of Ukraine was chosen to estimate emissions from TPPs, which uses national values of the net calorific value, as well as the carbon oxidation factor and the carbon emission factor for fuel combustion for all Ukrainian TPPs. For other fuels, default values of the net calorific value or national statistics are used. Detailed information is provided in Table A2.4 of the national inventory report.

Among Ukraine's large thermal power plants, half were designed to burn bituminous and long-flame coal (Zuivska, Vuhlehirska, Zaporizka, Kurakhivska, Ladyzhynska, Dobrotvirska, Burshtynska TPPs), and half were designed to burn anthracite (Trypilska, Zmiivska, Prydniprovsk, Starobeshivska, Slovianska, Luhanska, Kryvorizka TPPs). Starting in 2014, due to an acute shortage of anthracite coal supplies, some of the power units at Trypilska, Zmiivska, Prydniprovsk and Kryvorizka TPPs were reconstructed to switch from anthracite to bituminous coal, and the share of anthracite coal use dropped significantly.

Consideration of fuel characteristics is important, as they can vary significantly between TPPs and over time and affect the calculation results.

For the purposes of calculating emission factors, data on the net calorific value of fuels can be based on data from individual power plants (e.g., based on the Form 3-TEKH TES "Power Plant's Report on Technical and Economic Indicators of Equipment Operation" or data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine) or groups of power plants (e.g., weighted average or default values).

In the absence of data for recent years, the value of the nearest year for which data is available may be used.

51 Ukraine. 2023 National Inventory Report (NIR), <https://unfccc.int/documents/628276>

Carbon emission factors

The value of carbon emission factors depends on the carbon content of the fuel. The emission factors are based on national data in accordance with the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine.⁵² In particular, the national methodology takes into account the characteristics of coal combusted at TPPs, including the share of volatile components.

Detailed information on the methods of estimating the carbon content of fuels for the purposes of national emission accounting is provided in Annex A2.6.1 of the inventory (for natural gas) and Annex A2.6.2 (for coal combusted in TPPs). For other fuels, standard carbon content indicators are used.

For the purposes of calculating emission factors for electricity, carbon emission factors may be based on data from individual power plants (e.g., calculated on the basis of 3-TEKH TES "Power Plant's Report on Technical and Economic Indicators of Equipment Operation" or 4-a-NKREKP "Production of Electricity and Heat (Monthly)" forms or data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine of Ukraine) or groups of power plants (e.g., weighted average or default values).

In the absence of data for recent years, the value of the nearest year for which data is available may be used.

A default value⁵³ can also be used in accordance with the table below.

Table 9. Carbon emission factors (default values)

Type of fuel	Carbon emission factor, t C/TJ
Coal:	
anthracite	26.8
lean	26.8
bituminous and long-flame	25.8
brown	27.6
Fuel oil	21.1
Natural gas	15.3

Carbon oxidation factor

The carbon oxidation factors are based on national data according to the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine.⁵⁴ For all fuels, except for coal combusted at TPPs, the carbon oxidation factor is assumed to be 1.

For coal combusted at TPPs (category 1.A.1.ai of the national inventory, see Annex A.2.6.2 of the inventory), the oxidation factor is based on the inventory data.

52 Ukraine. 2023 National Inventory Report (NIR), <https://unfccc.int/documents/628276>

53 Order of the National Environmental Investment Agency of Ukraine of 21.03.2011 No. 39 "On Approval of the Methodology for Calculating Specific Carbon Dioxide Emissions from Electricity Production at Thermal Power Plants and its Consumption", <https://zakon.rada.gov.ua/rada/show/v0039825-11#Text>

54 Ukraine. 2023 National Inventory Report (NIR), <https://unfccc.int/documents/628276>

For the purposes of calculating emission factors for electricity, data on carbon oxidation factors can be based on data from individual power plants (e.g., calculated on the basis of indicators from the Form 3-TEKH TES "Power Plant's Report on Technical and Economic Indicators of Equipment Operation" or data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine) or groups of power plants (e.g., weighted average or default values).

In the absence of data for recent years, the value of the nearest year for which data is available may be used.

A default value of 0.98 can also be used.⁵⁵

In the absence of information on the coal grade used at the power plant, the value corresponding to the design coal grade should be assumed.

Data on fuel characteristics

To calculate emission factors for electricity, it is important to use national data on fuel characteristics, in particular, coal used in thermal power plants, as the difference with default values can be significant.

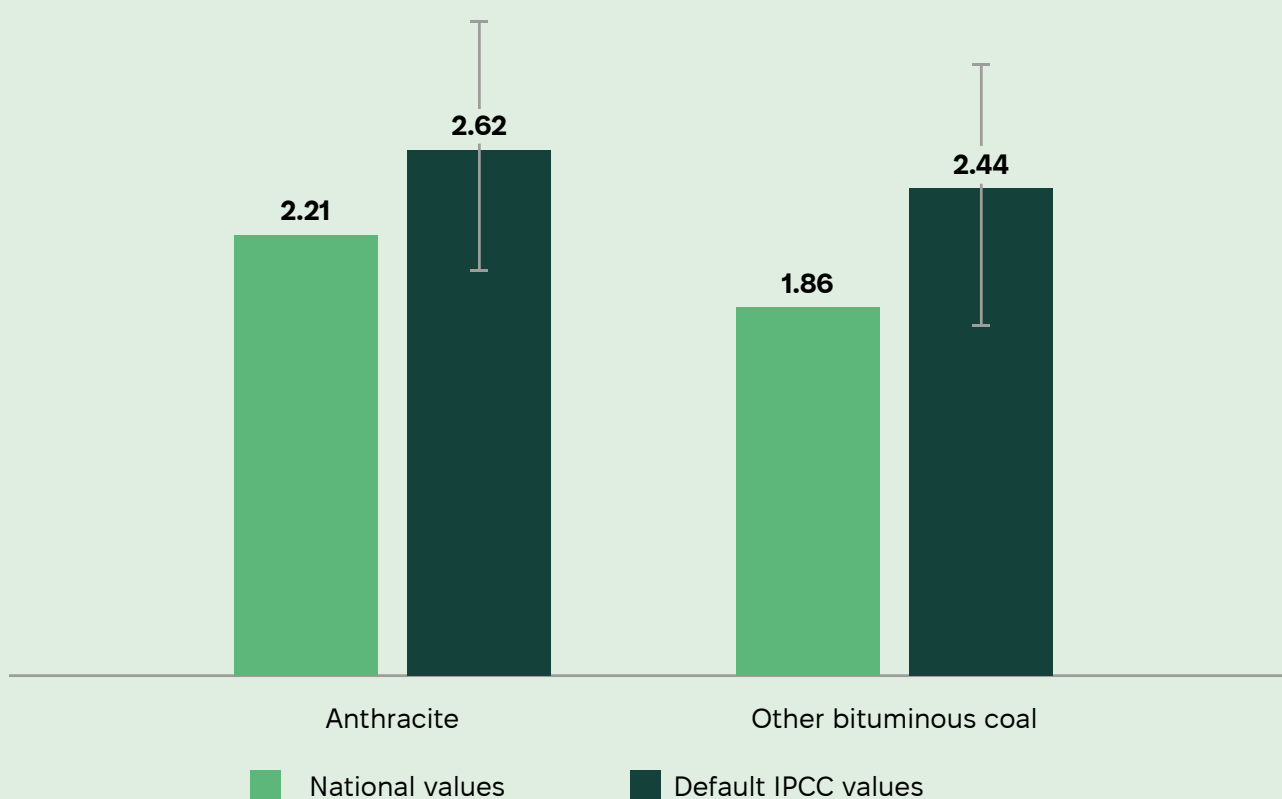


Figure 2. Discrepancies between standard and national CO₂ emission indicators per tonne of coal burned at power plants

The IPCC in its Guidelines for National Greenhouse Gas Inventories⁵⁶ provides default values for the characteristics of different fuels, including the net calorific value, carbon emission factor and carbon oxidation factors.

⁵⁵ Order of the National Environmental Investment Agency of Ukraine of 21.03.2011 No. 39 "On Approval of the Methodology for Calculating Specific Carbon Dioxide Emissions from Electricity Production at Thermal Power Plants and its Consumption", <https://zakon.rada.gov.ua/rada/show/v0039825-11#Text>

⁵⁶ 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. Chapter 1: Introduction, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

Comparison of the calculated emissions per tonne of coal combusted with the relevant national data for 2021 shows a significant difference. The IPCC default values have a significant level of uncertainty and the difference between the values based on possible minimum and maximum values is significant. The calculated national figures are close to the minimum values according to the IPCC Guidelines.

The data also shows the importance of using non-aggregated data by coal type used, as emissions per tonne of anthracite coal and bituminous coal differ significantly. Bituminous coal has a higher volatile content and lower carbon content compared to anthracite.

Electricity supply volume

Data on the volume of electricity supplied to the grid may be based on data from individual power plants or groups of power plants, depending on the available statistical data.

Electricity supplied by pumped storage power plants (PSPPs) is not taken into account in the calculation of emission factors, as PSPPs first use electricity to pump water into the upper reservoir and then generate electricity by discharging the accumulated volume of water into the lower reservoir, effectively performing the function of energy accumulation, storage and return. At the same time, due to the alternate energy conversion, a significant portion of electricity is lost (the overall efficiency of PSPPs in real conditions, taking into account losses in the power grid, is estimated at 65%). Depending on the state of electricity production in the power system, PSPPs can be either an urgent consumer of electricity (consumes electricity during periods of low demand) or an urgent generator (generates electricity to cover peak loads), increasing the balance of the power system. Their mode of operation differs significantly from that of hydroelectric power plants (HPPs), and they are not classified as renewable energy sources (since energy from non-renewable sources can be used for pumping). Electricity consumption occurs during periods of low demand, when electricity is produced by power plants that provide baseload generation and whose electricity output is already accounted for in other categories. In the case of taking into account the electricity supplied by PSPPs, electricity losses that occurred during the operation of PSPPs in pumping and generating modes – the difference between the total electricity consumption of PSPPs and its supply – should be deducted from the total electricity supply to the grid to avoid double counting (such data are not available for analysis for the purposes of this study).

Power plants of enterprises

A number of enterprises in various industries have their own power generating units.

In various statistical forms, such power plants are classified as "unit-plants" («блок-станції») or "TPPs of enterprises" and "CHPs and cogeneration plants of enterprises". In particular, the statistical forms collected by NPC Ukrenergo use the term "unit-plant". A unit-plant was defined as a power plant owned by an energy consumer, operating in the IPS of Ukraine and subordinated to its centralised dispatch control, whose electricity is used to cover its own consumption, and whose surplus electricity is sold to the energy supplier.⁵⁷

As a rule, such power plants are installed at those enterprises that generate by-products and waste that can be used as secondary energy resources (e.g. blast furnace gases, coke oven gases, ferroalloy gases, synthesis gases, biomass waste, etc.). The main task of such power plants is the beneficial utilisation of secondary energy resources to generate electricity (and, if necessary, heat) to cover the enterprises' own energy needs. Own power plants of enterprises can also be constructed due to limitations of the power grid in a particular region (for example, the inability to cover the load due to insufficient capacity

⁵⁷ On Approval of the Procedure for Preparing Annual and Monthly Forecast Balances of Electricity of the Integrated Power System of Ukraine (the document is no longer in force), <https://zakon.rada.gov.ua/laws/show/z1224-16#Text>

of the existing power transmission system). Excess electricity generated by an enterprise's power plant can be supplied to the public grid, and as a rule, this supply is only a small proportion of the total production.

Power plants of enterprises (autoproducers) can use a variety of fuels, including various secondary energy resources, by-products and waste. However, an analysis of the limited historical data available over the past decade shows that the lion's share of the power plants of enterprises used natural gas or industrial gases, with blast furnace and coke oven gases accounting for about two-thirds of electricity generation by the power plants of enterprises.⁵⁸

Other fuels may include fuel oils and other heavy oil products, as well as other solid fuels.

The consumption volumes and shares of different fuels by the power plants of enterprises may also vary significantly from year to year, depending on the production volumes of the enterprises, availability of energy resources, economic and other factors. As a result, the shares of natural gas, coke oven gas and blast furnace gas may vary significantly from year to year. The shares of other fuels are insignificant.

Moreover, data on fuel consumption by the power plants of enterprises may vary from source to source.

A high share of blast furnace gas can have a significant impact on emissions from electricity generation at power plants of enterprises. Blast furnace gas can have different characteristics and default values have a high level of uncertainty, but in general, the emission factor for this fuel is more than twice that of coal. Blast furnace gas is produced during the smelting of iron in blast furnaces at steel mills and has a high carbon content. The default value is 70.8 kg of C per GJ or 260 kg of CO₂ per GJ.⁵⁹ The emission factor takes into account the CO₂ that was originally in the blast furnace gas and that which is produced during its combustion. For comparison, the corresponding standard figure for anthracite is 26.8 kg C per GJ, for natural gas – 15.3 kg C per GJ, and for coke oven gas – 12.1 kg C per GJ. When producing electricity from blast furnace gas, specific emissions can reach about 3 t CO₂/MWh.

In view of this, the average specific emissions from electricity generation by the enterprises' power plants can be quite significant and, according to preliminary estimates based on the limited historical data available, in some years reached 1.23-1.45 tonnes of CO₂ per MWh.

At the same time, there is no information on fuel consumption by enterprises' power plants in recent years, and the structure of electricity production in this category has undergone significant changes. Due to the destruction of metallurgical enterprises during the war, the use of blast furnace gas has significantly decreased. At the same time, the share of natural gas is likely to have increased.

Nevertheless, the supply of electricity to the grid by such autoproducers accounts for only a small share of the total electricity supply, averaging approximately 1.6% over 2011-2020.

Due to data limitations for the purposes of the study, the enterprises' power plants were not taken into account for the calculation of emission factors. As noted above, the impact of this exclusion is not significant if both grid electricity supply from enterprises' power plants and fuel consumption are excluded. As shown in the above data, the share of enterprises' power plants in the total grid electricity supply is insignificant, so their operation does not significantly affect the calculated emission factors. Nevertheless, accounting for enterprises' power plants for future periods is important to ensure the completeness and accuracy of accounting for emission factors for electricity production and consumption.

In order to properly account for the power plants of enterprises in the calculation of emission factors for electricity, reliable data for each individual plant are needed, including data on total electricity

58 See, e.g., the Bulletins of the State Statistics Service of Ukraine "Results of Fuel, Heat and Electricity Use" for 2011-2015. https://www.ukrstat.gov.ua/druk/publicat/Arhiv_u/5a/Arch_zept_bl.htm

59 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2: Energy. Chapter 1: Introduction, https://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

production, electricity supply to the grid, total fuel consumption, fuel types and their characteristics, and data on heat production in the case of combined heat and power generation (to separate fuel consumption between electricity and heat). The fuel consumption information should be disaggregated to allow accounting for different fuel characteristics and carbon emission factors. For example, it is not sufficient to have industrial gases as a fuel type, as the emission factor for blast furnace gas is many times higher than for coke oven gas. Similarly, information on other solid fuels is insufficient if the category can include both fossil fuels and biomass.

Data on total electricity production and total fuel consumption are collected from government statistics for the purposes of the IEA questionnaires⁶⁰, but such up-to-date data are not currently available for analysis.

Volume of heat supply

To calculate emission factors, it is important to have information on the volume of heat supplied by combined heat and power plants. The data is used to calculate the share of fuel and, accordingly, greenhouse gas emissions attributable to electricity generation.

Data on heat production

The difficulty in collecting reliable and complete data on heat production is related to the large number and diversity of heat production sources, as well as the different forms of regulation and subordination of such enterprises.

Data on heat production by CHP plants are collected by at least two institutions: the NEURC and the State Statistics Service.

The NEURC uses the form "4a-NKREKP-Electricity and Heat Generation", which, among other parameters, contains data on the useful energy supply, including the useful supply of electricity and/or heat (from collectors of heat generation sources to heat transmission systems, including for the needs of other activities of the licensee, as well as for further sale of heat to consumers) in accordance with the data of commercial metering points of electricity supplied and/or data of heat production metering units. Detailed information on the volumes of useful heat supply is provided in Annex 1 to the forms.⁶¹

The State Statistics Service uses the form 4-mtp (annual) "Report on the Consumption and Stocks of Fuel"⁶², which, among other parameters, contains indicators on the volume of heat supply for the reporting year by categories of installations, including:

- thermal power plants (TPP),
- enterprises' thermal power plants (TPP),
- combined heat and power plants (CHP),
- enterprises' combined heat and power plants (CHP).

60 Electricity and heat annual questionnaire. https://iea.blob.core.windows.net/assets/080c855b-6fe1-4f61-bed4-3aa3ecb1272d/Electricity_Heat_Questionnaire_Instructions.pdf

61 INSTRUCTIONS for completing the reporting form No. 4a-NKREKP-Electricity and Heat Generation (monthly) "Report on Fuel/Electricity Consumption and Status of Settlements", <https://www.nerc.gov.ua/derzhavnij-kontrol/formi-zvitnosti-nkrekp>

62 On Approval of State Statistical Observation Forms No. 4-mtp (monthly) "Report on Fuel Consumption and Stocks" and No. 4-mtp (annual) "Report on Fuel Consumption and Stocks", <https://zakon.rada.gov.ua/rada/show/v0109832-22#Text>

At the same time, public aggregated data from the State Statistics Service are provided for groups of TPPs and CHPs in general without dividing them into main power plants and enterprises' power plants. Analysis of historical data shows that the share of CHPs of enterprises in heat production can be quite significant and fluctuate significantly from year to year (approximately 40%-70%).



Figure 3. Data on heat production by CHPs in 2020, thousand Gcal

As shown by the 2020 data, the difference in CHP heat production based on the State Statistics Service and the NEURC is significant. This may be due to different data coverage (e.g., different approaches to the inclusion of enterprises' CHP plants, different coverage due to the inclusion of only licensees in the NEURC data, etc.), different completeness of data presentation (e.g., due to the submission of data in different periods and the possibility of their clarification, the use of different sources of primary data, inclusion of heat production by individual boilers installed at the same facility, etc.), or different approaches to data analysis and aggregation. Data collection on heat production is also complicated by the imperfect system of heat production and supply metering at CHPs (e.g., the absence of heat supply metering devices).

It is important to improve the system of accounting for heat energy production using various statistical forms, including in terms of harmonising definitions, categories and classifications.

In addition, for the purposes of calculating emission factors for electricity, it is important to reconcile data on heat production and supply, electricity production and supply, and fuel consumption, which are often collected using separate statistical forms.

A detailed analysis of data on heat generation by CHP plants is possible when processing various statistical forms of individual power plants.

5.2.2 Average Emission Factor for Electricity Consumption

The calculation of the average emission factor for electricity consumption by end-users (specific emissions per unit of electricity consumed by the end-user) is based on the value of the average factor for electricity supply and takes into account electricity losses during transmission and distribution.

$$EF_{average, consumption, CO_2} = \frac{EF_{average, grid, CO_2}}{(1 - L)}$$

Where:

- $EF_{average, consumption, CO_2}$ is the average emission factor for electricity consumption, t CO₂ per thousand kWh (t CO₂ per MWh);
- $EF_{average, grid, CO_2}$ is the average emission factor for electricity generation, t CO₂ per thousand kWh (t CO₂ per MWh);
- L is the indicator of electricity losses in the power system, % or relative units.

The calculations are based on the average technological consumption of electricity in the transmission system and in the grids of energy supply companies in Ukraine as a whole.

In the absence of actual data on the technological consumption of electricity in power grids, a conservative value of 12.5% can be used for consumers of the second voltage class, which takes into account the technological consumption of electricity in power grids with a voltage of 154-0.38 kV (approximately 10%) and technological consumption in the transmission system with a voltage of 800-220 kV (approximately 2.5%), and 2.5% for consumers of the first voltage class, which takes into account only the technological consumption in transmission system with a voltage of 800-220 kV.

It should be emphasised that this factor takes into account emissions from both electricity generation and transmission and distribution losses. For the purposes of corporate emissions accounting in accordance with the GHG Protocol in terms of Scope 2 indirect emissions, it is necessary to use the average emission factor for electricity supplied to the grid.

5.2.3 Average Emission Factor for Electricity Losses

The average emission factor for electricity losses is calculated as the difference between the average emission factor for electricity consumption and the average emission factor for electricity supplied to the grid.

$$EF_{average, losses, CO_2} = EF_{average, consumption, CO_2} - EF_{average, grid, CO_2}$$

Where:

- $EF_{average, losses, CO_2}$ is the average emission factor for electricity losses, t CO₂ per thousand kWh (t CO₂ per MWh);
- $EF_{average, consumption, CO_2}$ is the average emission factor for electricity consumption, t CO₂ per thousand kWh (t CO₂ per MWh);
- $EF_{average, grid, CO_2}$ is the average emission factor for electricity supplied to the grid, t CO₂ per thousand kWh (t CO₂ per MWh).

An alternative way of mathematically expressing the calculation is to calculate it based on the average emission factor for the electricity supplied to the grid and the loss rate.

$$EF_{average, losses, CO_2} = EF_{average, grid, CO_2} \times \frac{L}{1 - L}$$

Where:

- $EF_{average, losses, CO_2}$ is the average emission factor for electricity losses, t CO₂ per thousand kWh (t CO₂ per MWh);
- $EF_{average, grid, CO_2}$ is the average emission factor for electricity supplied to the grid, t CO₂ per thousand kWh (t CO₂ per MWh);
- L is the indicator of electricity losses in the power system, % or relative units.

5.3 Approach to the Calculation of Marginal Emission Factors

The marginal emission factor is intended to estimate the reduction or increase in emissions due to changes in electricity demand. Given the large share of nuclear power plants in Ukraine's baseload generation, the marginal emission factors for electricity are significantly higher than the average emission factors for the Ukrainian power grid.

The approach to calculating the marginal emission factor is based on the provisions of the methodological guidance for Clean Development Mechanism projects of the United Nations Framework Convention on Climate Change.⁶³ The guidance was developed to estimate the CO₂ emission factor for electricity that is replaced in the grid, either through renewable energy projects or through reduced electricity consumption due to energy efficiency improvements.

5.3.1 Approach to the Calculation of the Operating Margin

In the absence of hourly data from each power plant on electricity output, fuel type and fuel consumption, the method is chosen based on the general characteristics of the grid.

Previous studies (see section 2.2) have used either a simple operating margin or a simple adjusted operating margin.

To calculate the margin, it is important to identify low-cost/must-run sources of electricity generation that have low marginal costs of generation (i.e., the cost of producing an additional unit of electricity) or that operate regardless of the daily or seasonal load in the grid. According to the guidance, these include nuclear, hydro, wind, solar, geothermal, and biomass power plants with low operating costs. If a fossil fuel plant operates independently of the daily or seasonal load of the grid and if this can be demonstrated on the basis of publicly available data, it should also be considered as low-cost/must-run source. In addition, electricity imports should be treated as one low-cost/must-run power plant.

Previous studies (see section 2.2) used different approaches to identifying low-cost/must-run power plants, in particular, in terms of including hydropower plants and CHP plants.⁶⁴

For the purposes of calculating the marginal emission factor, low-cost/must-run power plants include nuclear power plants, renewable energy power plants, and CHP plants.

For the purposes of the study, the group of CHP plants is included in the category of low-cost/must-run power plants, as such power plants in Ukraine ensure the operation of district heating systems and electricity production is largely determined by the heat load of these CHP plants. A similar approach was used in previous studies (see Section 2.2).

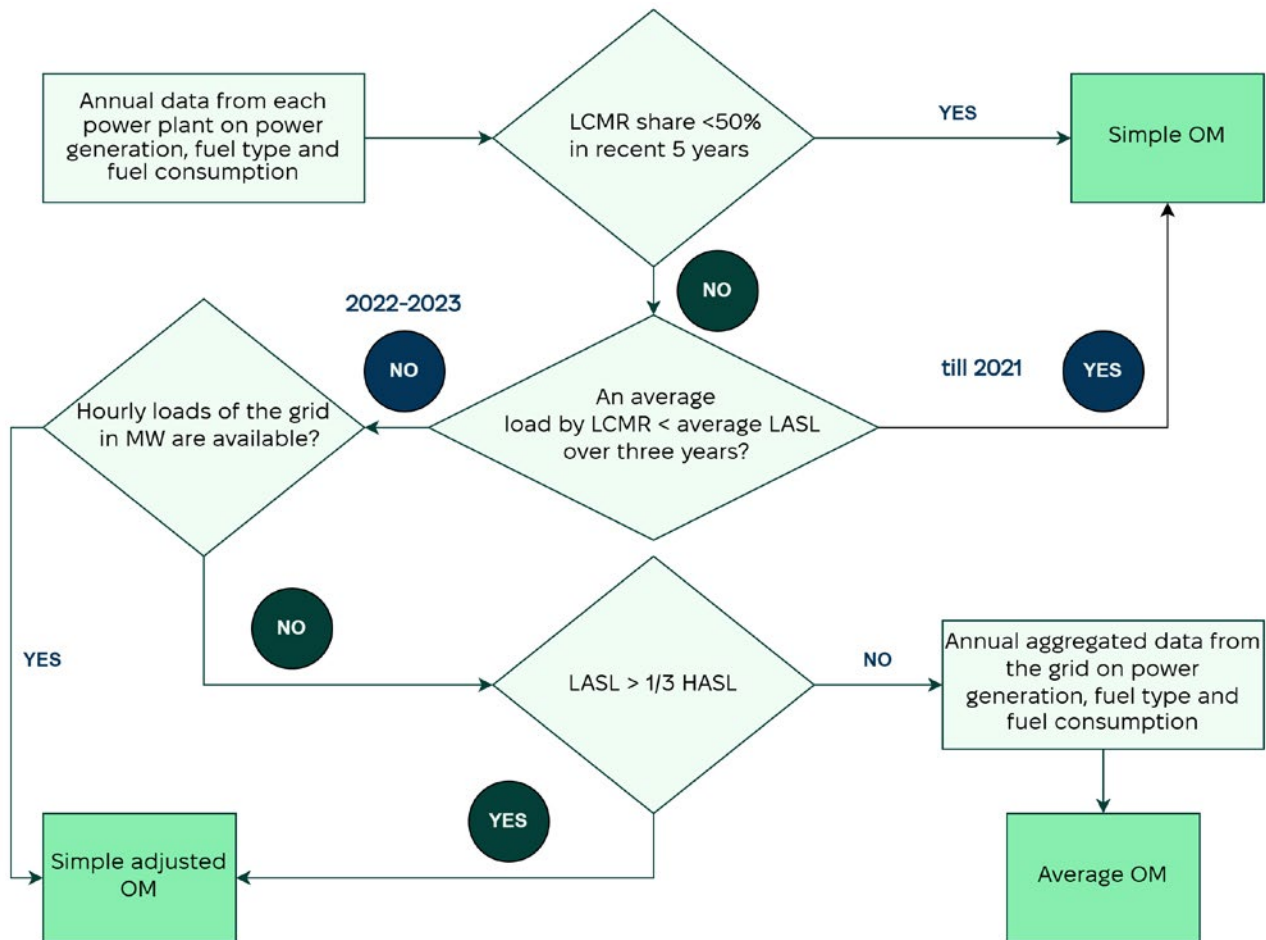
In practice, CHP plants in Ukraine differ in terms of installed heat and power capacity, steam parameters, composition and characteristics of boiler and turbine equipment, the nature of reconstructions and modernisations, fuel balances (natural gas, coal, peat, biomass, etc.), operating modes, temperature schedules of heating networks and other factors. CHP plants can also participate in balancing the power system, and their operating modes can vary significantly and change throughout the year. Proper consideration of such features is possible when analysing the data of each individual power plant and determining whether it belongs to operating margin or baseline generation.

According to the guidelines, electricity net imports should be treated as one power plant in the group of low-cost/must-run power plants, but Ukraine has traditionally been an electricity exporter, and the net

63 Methodological tool. Tool to calculate the emission factor for an electricity system, Version 07.0, <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf>

64 EBRD. Development of the electricity carbon emission factors for Ukraine, https://encon.sumdu.edu.ua/doc/methodics/Baseline_Study_Ukraine_Final_English.pdf

electricity imports observed in 2023, which were caused by damage to the grid as a result of hostilities, were insignificant in terms of their impact on the indicators used to select the method for calculating the operating margin.



Explanation:

- LCMR – Low-cost/must-run sources of electricity generation
- LASL – Lowest annual system load during a calendar year in MW
- HASL – Highest annual system load during a calendar year in MW
- OM – Operating margin emission factor

Figure 4. Algorithm for selecting a method for calculating the operating margin emission factor

A simple operating margin may be used if either of the following two requirements is met (see also Figure 4):

- low-cost/must-run sources of electricity generation account for less than 50% of grid electricity generation (on average for a 5-year period including the calculation year); or
- the average load in MW provided in the grid by low-cost/must-run generation sources (calculated as the production volume divided by 8760 hours) over the last three years (on average for the 3-year period including the calculation year) is less than the average of the minimum recorded values of hourly load in the power system during the same three years in MW.

In the Ukrainian integrated power system, due to the high share of NPPs, the share of low-cost/must-run power plants has always exceeded 50% in recent decades, so the first condition is not met for the Ukrainian power system.

The second condition was met for most years, but the situation has changed over the past few years. Back in 2021, the average load provided by low-cost/must-run generation sources in the grid was close to, but slightly higher than the minimum load in the grid. In 2022-2023, the difference became much larger, as the minimum load decreased significantly due to hostilities and damage to the grid, while the load of low-cost/must-run sources of electricity production decreased less significantly. As a result, the second condition for using a simple operating margin is not met for 2022-2023. At the same time, hourly grid loads are not available for the analysis, and the minimum grid loads exceed one third of the maximum hourly loads.

However, this situation is associated with the destruction of the energy infrastructure, including the transmission system and generation system, as a result of hostilities and forced temporary power outages. As a result, the minimum load in the power system during the year is associated with the periods of outages and does not reflect the normal operation of the power system. In other words, forced power outages do not characterise the possibility of displacing the power plants that are currently included in the group of low-cost/must-run electricity sources.

In view of this, and taking into account the need for data for each individual power plant to use a simple adjusted operating margin, **the simple operating margin method** was chosen to calculate the marginal emission factor.

The simple operating margin is calculated as a generation-weighted average CO₂ emissions per unit of electricity output (t CO₂ per MWh) for all power plants in the grid, except for those included in the low-cost/must-run group. Thus, based on the above analysis, this factor will reflect the weighted average emissions from TPP electricity generation, and therefore will differ slightly from the average factor for fossil fuel power plants (including TPPs and CHPs).

The guidance proposes two main calculation methods, one requiring data on electricity output and emission factors for each power plant/installation (Option A), and the other allowing the use of aggregate data on electricity output of all power plants and aggregate data on fuel consumption for electricity generation (Option B). However, the second option can only be used if all of the following requirements are met:

- lack of information for Option A;
- inclusion in the group of low-cost/must-run only nuclear power plants and power plants using renewable energy sources and availability of information on electricity output from these sources;
- exclusion of power plants not connected to the grid from the calculation of the emission factor.

These options are similar and differ only in the level of data granularity, but the use of more aggregated data may lead to an increased level of uncertainty in the results.

In accordance with the proposed methodological approach, the operating margin is calculated using the following formula (aligned with the methodological approach to calculating average emission factors):

$$EF_{OM, grid, CO_2} = \frac{44}{12} \times \frac{\sum FC_{i,m} \times Q_{i,m} \times EF_{i,m} \times k_{i,m}}{P_{OM}}$$

- $EF_{OM, grid, CO_2}$ is the operating margin for electricity generation, t CO₂ per thousand kWh (t CO₂ per MWh);
- FC is the actual consumption of the i -th fuel type in physical terms for electricity generation by power plants that are not included in the low low-cost/must-run group, in tonnes or thousands of cubic metres, depending on the fuel type; in the case of electricity generation only, it corresponds to the total fuel consumption, and in the case of combined electricity and heat generation, it is calculated using the alternative heat generation method;
- Q is the net calorific value of the i -th type of fuel used for electricity generation, in TJ per tonne or TJ per thousand m³, depending on the type of fuel; if necessary, conversion to the appropriate energy units (e.g. from kcal per kg to TJ per tonne) is performed;
- EF is the carbon emission factor for the combustion of the i -th type of fuel used for electricity generation, in tonnes of carbon (C) per TJ;
- k is the carbon oxidation factor for the i -th type of fuel used for electricity generation when it is burned at a power plant, in relative units;
- P_{OM} is the volume of electricity supplied to the grid by power plants that are not included in the low-cost/must-run group, in thousand kWh (MWh).
- $44/12$ is the conversion factor for converting carbon mass to carbon dioxide mass based on the molar mass ratio;
- i is the index of the type and/or grade of fuel used at power plants for electricity generation;
- m is the index of an individual power plant or a group of power plants that are not included in the low-cost/must-run group.

Given the available data, data for certain groups of power plants were used for the purposes of the study. The level of disaggregation used for the purposes of the study is actually midway between Options A and B proposed by the guidance. In the future, when using data for individual power plants, the approach will be consistent with the guidance's Option A (A.1).

The analysis for selecting the marginal emission factor calculation method shall be repeated each year based on the relevant performance of the country's power system. If individual power plant data is available (on electricity output, fuel types and consumption, and fuel consumption), it should be used for both the simple operating margin method and, if necessary, the simple adjusted operating margin method.

5.3.2 Approach to the Calculation of the Build Margin

According to the GHG Protocol recommendations, the Build Margin may not be taken into account for power grids where there is no need for new capacity, as well as for projects aimed at reducing electricity consumption. The role of the Build Margin is also less important for projects with unstable generation volumes, such as SPPs and WPPs. To summarise, the importance of the Build Margin depends on the extent to which the project meets the need for new capacity when it exists, and thus may influence the refusal to build additional power plants. In the case of excess capacity in the grid, generation projects will not affect any new capacity, but will only affect the operational reserve of the grid. Similarly, small projects

with a capacity of up to 1 MW can be assumed to have no impact on the decision to build new capacity.⁶⁵

Since the early 1990s, Ukraine's power system has experienced a surplus of installed power capacity that has persisted for a long period of time. However, due to the obsolescence and significant physical deterioration of most power plants' equipment, low manoeuvrability, operation on fuels not envisaged at the design stage, and the rather rapid development of renewable energy sources, the need for manoeuvring capacities has been growing in recent years. Before the Russian invasion, the report on the assessment of the adequacy of generating capacities in 2020 cited the need for at least 1 GW of highly manoeuvrable capacities with a quick start and at least 0.5 GW of energy storage systems.⁶⁶ The damage and destruction of power plants during the war has significantly changed the situation, but detailed data on updated assessments of the adequacy of generating capacities are currently confidential.⁶⁷

The Clean Development Mechanism project guidance⁶⁸ estimates the Build Margin based on data from power plants built in recent years. At the same time, capacity growth due to the reconstruction of power plants is not taken into account in the calculation of the BM emission factor. According to the guidance, only a sample of newly built power plants should be considered: the 5 newest or those responsible for 20% of electricity generation, whichever is higher (priority is given to power plants with a lifespan of less than 10 years, but in the absence of such, power plants built more than 10 years ago are also included).

In the Ukrainian context, over the past two decades, mainly renewable energy power plants have been built, including solar and wind power plants, small hydropower plants, as well as biomass and biogas power plants. New capacities of power plants and cogeneration units of enterprises were also added, but their share in the total electricity supply to the grid is insignificant. In addition, projects were implemented to reconstruct and modernise the power equipment of thermal power plants and large hydropower plants, including increasing their actual capacity, but such capacity additions are not taken into account when calculating the Build Margin. New hydropower units at PSPPs were also built and put into operation (Dnistrovska PSPP in 2009–2021, Tashlytska PSPP in 2007), but as noted above, PSPPs perform the function of electricity storage and are not taken into account in the calculation of emission factors for electricity. To achieve a 20% share of electricity generation from newly built power plants, it would be necessary to take into account at least the nuclear power units of Khmelnytska NPP (Unit 2) and Rivnenska NPP (Unit 4) added to the grid in 2004.

The Build Margin for Ukraine calculated on the basis of this sample will be close to zero, as the share of power plants of enterprises that can use fossil fuels will be very low.

At the same time, the inclusion of power plants built over such a long period of time, especially considering large-scale nuclear power plant projects, does not reflect the current conditions of the power system development and the capacity that can be expected to be built in the near future.

The need to replace the destroyed facilities and to provide manoeuvring generation explains the announced plans to build distributed natural gas-fired generation, but their total capacity and possible supply to the grid are highly uncertain. Ukraine will also continue to develop distributed generation using renewable energy sources and will partly rebuild destroyed power plants.

65 The Greenhouse Gas Protocol. Guidelines for Quantifying GHG Reductions from Grid-Connected Electricity Projects, <https://ghgprotocol.org/sites/default/files/2022-12/Guidelines%20for%20Grid-Connected%20Electricity%20Projects.pdf>

66 NEURC Approves the Report on the Assessment of Generation Conformity in 2020, <https://ua.energy/zagalni-novyny/nkrekp-zatverdyla-zvit-z-otsinky-vidpovidnosti-generatsiyi-u-2020-rotsi/>

67 NEURC Approves the Report on the Assessment of Conformity (Sufficiency) of Generating Capacities to Cover the Forecasted Electricity Demand and Ensure the Necessary Reserve in 2023, <https://www.nerc.gov.ua/news/nkrekp-zatverdila-zvit-z-ocinki-vidpovidnosti-generuyuchih-potuzhnostej-dlya-pokritya-prognozovanogo-popitu-na-elektrichnu-energiyu-ta-zabezpechennya-neobhidnogo-rezervu-u-2023-roci>

68 Methodological tool. Tool to calculate the emission factor for an electricity system. Version 07.0, <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v7.0.pdf>

These factors will determine the new capacities that will be added to the grid in the coming years and may be affected by the projects for which greenhouse gas emission reductions are calculated.

The CDM project guidance also suggests the use of default values for the Build Margin depending on the characteristics of the grid:

- for power systems with a share of renewable energy sources in the installed capacity of more than 20% – 0 tonnes of CO₂ per MWh; in Ukraine, the share of all types of RES in the installed capacity of the power system exceeds 20%.
- for power systems with a share of renewable energy sources in the installed capacity of less than 20% – based on best practices for technologies using natural gas or petroleum products traditionally used in the project region for new capacity construction (e.g. 0.326 t CO₂ per MWh for combined cycle gas turbines (CCGT)).

For the purposes of the current study, the Build Margin is assumed to be zero.

5.3.3 Combined Margin

The general approach to calculating the weighted average Combined Margin can be represented by the following formula:

$$EF_{CM, grid, CO_2} = EF_{OM, grid, CO_2} \times W_{OM} + EF_{BM, grid, CO_2} \times W_{BM}$$

Where:

- $EF_{CM, grid, CO_2}$ is the Combined Margin for electricity generation, t CO₂ per thousand kWh (t CO₂ per MWh);
- $EF_{OM, grid, CO_2}$ is the Operating Margin for electricity generation, t CO₂ per thousand kWh (t CO₂ per MWh);
- w_{OM} is the weighting factor for the Operating Margin (relative units);
- $EF_{BM, grid, CO_2}$ is the Build Margin for electricity generation, t CO₂ per thousand kWh (t CO₂ per MWh);
- W_{BM} is the weighting factor for the Build Margin (relative units).
- The Clean Development Mechanism project guidance suggests the following standard weighting factors:
 - for wind and solar power plant projects: $w_{OM} = 0.75$ and $W_{BM} = 0.25$;
 - for other projects: $w_{OM} = 0.5$ and $W_{BM} = 0.5$.

This distribution is explained by the intermittent generation of SPPs and WPPs and their dependence on natural factors, which reduces their possible role in replacing new capacities.

At the same time, in the absence of data or due to the peculiar characteristics of the power grid, a simplified approach is allowed, where a weighting factor of zero is used for the Build Margin.

This is the approach used for the purposes of the current study. In this case, the Combined Margin will be equal to the Operating Margin:

$$EF_{CM, grid, CO_2} = EF_{OM, grid, CO_2}$$

A similar approach was used in all previous studies on the marginal factor for the Ukrainian grid, and was also used in the development of the Methodology for Calculating Specific Carbon Dioxide Emissions from Electricity Generation at Thermal Power Plants and Consumption (see Section 2.2). This choice was justified by the fact that the Ukrainian power system is not characterised by capacity growth, and the connection of new power plants and facilities was primarily related to the development of renewable energy sources. The share of capacities built over a 5-year period is very low, and to take into account capacities that generate 20% of electricity, it is necessary to take into account the construction of power plants over a period of more than 20 years. Taking into account the nuclear power plant capacities added in 2004 is also inappropriate, since new power plant construction projects cannot influence the baseload generation by nuclear power plants, and the construction of NPPs cannot be considered representative for determining the future development of the Ukrainian power system.

However, the situation may change in the future, including due to significant damage to Ukraine's power system as a result of hostilities. In view of this, it is necessary to analyse the relevant information, separating the restoration and reconstruction of existing facilities and the construction of new power plants, and, if necessary, to revise the approach to calculating the Combined Margin in the future.



The background image shows a desk with several business-related documents. There are three pie charts at the top left, a bar chart with orange and blue bars, and a line graph with green and blue data points. A hand with pink nail polish is holding a wooden clipboard on the right side. The overall scene is a professional office environment.

6

LIST OF REQUIRED DATA AND DATA OWNERS

6.1 General Information on Data Requirements

The calculated emission factors should be based on reliable and valid data, preferably available within less than 12 months since the end of the reporting period.

In accordance with the methodological approach described above, the following basic data are required to calculate emission factors for electricity production and consumption:

- fuel consumption;
- net calorific value of the fuel;
- carbon emission factor;
- carbon oxidation rate;
- volumes of electricity supply;
- volumes of heat supplied by power plants that produce both electricity and heat;
- data on electricity losses during transmission and distribution.

For calculation purposes, data on fuel consumption and electricity output (and in some cases, fuel quality characteristics) are required for different types and groups of power plants.

For the purposes of the study, data from groups of power plants were used in accordance with the available statistical information, rather than data from individual power plants or power generating units.

6.2 Data Accessibility

There are several aspects to consider when analysing data accessibility:

- Data availability – whether information on all the necessary indicators is collected as part of government statistical observations or statistical information collection by government agencies;
- Data consistency – whether the same data is provided by different data processors and whether the data is consistent across periods;
- Data openness – whether the data is published in the public domain or can be obtained upon request;
- Data timeliness – how long it takes to analyse, aggregate and verify data and publish it or make it available on request.

In terms of data availability, gaps may relate to a general lack of a data collection system (e.g. detailed information on the types, volumes and characteristics of biomass used for electricity production) or to a lack of the required level of data disaggregation. Gaps in data availability and, in particular, the level of detail required are particularly relevant for historical periods. For example, even for the purposes of the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 1990-1997, emissions are not separated for the categories of "Electricity Generation", "Combined Heat and Power Generation" and "Boiler Houses", but are presented in a generalised way for the category "Electricity and Heat Generation".

In terms of data consistency, problems arise due to the complex system of energy statistics collection and the existence of different sources of primary information, as well as different practices for its analysis and aggregation. The situation is further complicated by frequent changes in the structure of statistical forms and the difficulty of reconciling data collected using different statistical forms or different versions of the same statistical form.

Data openness may be limited by both the provisions of the law on the protection of confidential information and the provisions of the legislation on martial law.

In particular, according to the Law of Ukraine "On Protection of the Interests of Subjects of Submission of Reports and Other Documents during Martial Law or a State of War", respondents may submit reports within three months after the termination or cancellation of martial law or a state of war, and administrative liability for failure to submit or late submission of reports does not apply. As a result, the coverage of statistical observations has decreased, and aggregated data is not published.

In terms of the timeliness of data, the time between the end of the reporting period and the availability of the data can be very significant. For example, aggregate data often becomes available at the end of the year following the reporting period.

6.3 Main Data Owners and Sources

The complexity of collecting the necessary data lies in the fact that there are different channels for collecting relevant information, which use different primary sources of information, sometimes using different definitions and methodological approaches.

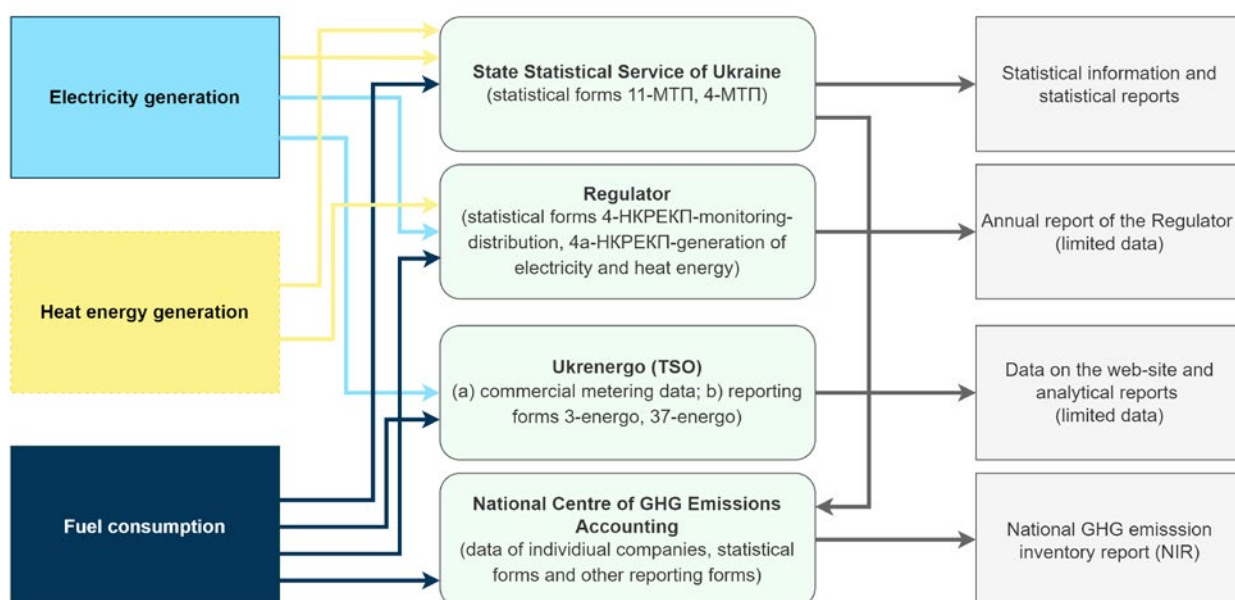


Figure 5. System for collecting information on energy production and fuel consumption

Furthermore, even within the same institution, data may be inconsistent if collected using different statistical forms (e.g. energy production and fuel consumption). As a result, data on heat and electricity production and the corresponding fuel consumption may differ from one source to another. In addition, data are published according to different schedules or not at all, resulting in the absence of relevant information or its appearance several years after the reporting period.

6.3.1 State Statistics Service

The State Statistics Service of Ukraine is a specially authorised central executive body in the field of statistics, whose activities are directed and coordinated by the Cabinet of Ministers of Ukraine and which participates in the formulation of state policy in the field of statistics and ensures its implementation.⁶⁹

The main tasks of the State Statistics Service include:

- Collection, storage, processing, analysis, protection and dissemination of official state statistical information;
- Harmonisation of the state statistics system with international and European norms and standards;
- Ensuring the relevance, accuracy and reliability, consistency and comparability, accessibility and clarity of official state statistical information.

The State Statistics Service of Ukraine also collects information on the supply and use of energy and fuel.

In accordance with the Law of Ukraine "On the Electricity Market", in order to improve the policy in the electricity sector, all business entities engaged in the production, transmission, distribution, supply, export, import of electricity, energy storage, and aggregation must provide information on their activities to the state statistics authority for the purpose of compiling energy statistics and publishing them in the annual energy balance.⁷⁰

Detailed information on the statistical forms used by the State Statistics Service to collect energy statistics is provided below.

Table 10. Statistical forms of the State Statistics Service

Statistical form	Description.
11-MTP (annual) "Report on energy supply and use"	• Report on energy supply and use (Order of the State Statistics Service of Ukraine No. 107 dated 25.05.2022 (as amended by Order of the State Statistics Service of Ukraine No. 279 dated 10.11.2022)) • Explanation of the State Statistics Service No. 19.1.2.-12/19-21 of 12 July 2021 • Submitted annually no later than 28 February Contains data, in particular, on: > Installed electric and thermal capacity as of the end of the reporting year; > The volume of electricity (excluding consumption for own production needs) and heat supply for the reporting year, in particular, by main activity producers and autoproducers (for both TPPs and CHPs); > Electricity consumption and heat consumption (steam and hot water). Aggregate data are published in statistical compilations and in statistical datasets.

69 Resolution of the Cabinet of Ministers of Ukraine of 23 September 2014 No. 481 "On Approval of the Regulation on the State Statistics Service of Ukraine", <https://zakon.rada.gov.ua/laws/show/481-2014-%D0%BF#Text>

70 Law of Ukraine "On the Electricity Market", <https://zakon.rada.gov.ua/laws/show/2019-19#Text>

Statistical form	Description.
4-MTP (annual) "Report on fuel use and stocks"	- Report on fuel use and stocks (Order of the State Statistics Service of Ukraine No. 109 dated 26.05.2022 (as amended by Order of the State Statistics Service of Ukraine No. 279 dated 10.11.2022)); - Submitted annually no later than 28 February; Contains data on: > Volumes of fuel consumption (for the reporting year) and fuel stocks (as of the end of the reporting year) by different types of fuel, including renewable energy sources; > Fuel consumption by the energy sector, including the amount of fuel consumed for conversion into heat and electricity, broken down by main activity producers and autoproducers (for both TPPs and CHPs), the amount of fuel consumed for own consumption by the energy sector and the calorific value of fuel; > End use of fuel and fuel losses. Aggregate data are published in statistical compilations and in statistical datasets.

6.3.2 Regulator

The National Energy and Utilities Regulatory Commission (the "Regulator") is a permanent central executive body with a special status established by the Cabinet of Ministers of Ukraine. The Regulator carries out state regulation, monitoring and control over the activities of business entities in the energy and utilities sectors.⁷¹

The Regulator's powers in the electricity market include monitoring, approval of reporting forms for market participants, and approval of the procedure for disclosing information to electricity consumers about the sources of energy in the overall structure of the electricity balance purchased by the electricity supplier and/or generated at its own power plants.

In addition, the Regulator's powers include providing access to information on volumes and other indicators of electricity consumption by consumers and facilitating the establishment of data exchange to ensure the development of the electricity market.

In addition, the main tasks of the Regulator in the electricity market include ensuring the functioning of the register of guarantees of origin of electricity and issuing guarantees of origin.

Information on some of the statistical forms used by the Regulator to collect information in the energy sector is presented below.

⁷¹ Law of Ukraine "On the National Energy and Utilities Regulatory Commission", <https://zakon.rada.gov.ua/laws/show/1540-19#Text>

Table 11. Statistical forms of the NEURC

Statistical form	Description
4-NKREKP-monitoring-transmission (monthly) "Report on actual volumes of electricity production and consumption"	- Reporting form No. 4-NKREKP-monitoring-transmission (monthly) "Report on actual volumes of electricity production and consumption", approved by NEURC Resolution No. 450 of 29.03.2019 - Submitted no later than the 25th day of the month following the reporting period. Contains data on: > Actual electricity production by generation type and detailed structure of renewable energy sources; > Actual electricity consumption (by consumer category); > The volume of electricity supplied by producers by trade zones and types of generation (including distribution by types of grids: TSO, DSO, SDO, direct line); > The volume of electricity supplied to consumers; > The volume of electricity consumption in the DSO's grids. Aggregated data may be published in the NEURC's Annual Report.
4a-NKREKP - electricity and heat generation (monthly) "Report on fuel/energy use and status of settlements"	- Reporting form No. 4a-NKREKP-electricity and heat generation (monthly) "Report on Fuel/Electricity Use and Status of Settlements", approved by Resolution No. 282 of 28.02.2019; - Submitted no later than the 25th day of the month following the reporting period. Contains data on: > Fuel consumption in physical terms and the calorific equivalent of conversion to energy units by fuel type, as well as other fuel characteristics; it is specified separately for heat and electricity generation; > Reference information on electricity and heat production, own use, sales, and specific consumption in energy units for electricity and heat production; > Capacity of generating equipment (thermal and electric). It applies exclusively to business entities licensed to: a) carry out economic activities for the production of electricity; b) carry out economic activities for the production of heat generated at combined heat and power plants, thermal power plants, nuclear power plants and cogeneration units.

Statistical form	Description
	In accordance with the Licensing Conditions for Electricity Generation (NEURC Resolution No. 1467 dated 27.12.2017), electricity generation activities of business entities (except for cases where electricity is produced without the purpose of selling it on the basis of a contract and is consumed for own needs or produced by a mobile (autonomous) power plant) are subject to licensing if the total installed capacity of the power generating equipment is 5 MW or more or regardless of the installed capacity of the electricity facility from alternative energy sources (and with the use of hydropower – only micro, mini and small hydropower plants), the production of electricity at which is subject to incentives in accordance with the law by setting a “green” tariff or auction price. In accordance with the Licensing Conditions for the Production of Thermal Energy (Resolution of the NEURC No. 308 of 22.03.2017), the business entities’ thermal energy production activities are not subject to licensing if the thermal energy is produced without the purpose of selling it under a contract and is consumed for own needs, or is produced by cogeneration units with a total nominal active electrical capacity (total installed thermal capacity) not exceeding 5 MW (4.3 Gcal/h) and used as a backup source of energy during power outages from the system operator’s grids for critical infrastructure facilities and/or facilities of heat supply, water supply, sewage systems, social institutions (educational and healthcare institutions (except for sanatoriums)).
No. 2-NKREKP-monitoring-transmission (annual) "Report on the characteristics of users of the electricity transmission system"	• Reporting form No. 2-NKREKP-monitoring-transmission (annual) "Report on the characteristics of users of the electricity transmission system", approved by NEURC Resolution No. 450 of 29.03.2019 • Submitted annually no later than 25 February. Contains data on: > Characteristics of transmission system users and characteristics of energy storage facilities; > Characteristics of generating units by type and type of generation, including the number and total installed capacity of electrical installations. Aggregated data may be published in the NEURC's Annual Report.

6.3.3 National Center for GHG Emission Inventory

The National Center for GHG Emission Inventory is a publicly funded institution within the Ministry of Environmental Protection and Natural Resources of Ukraine, whose key areas of activity include inventory and analysis of greenhouse gas emissions.⁷²

72 National Center for GHG Emission Inventory, <https://nci.org.ua/mission/>

The Department of Greenhouse Gas Inventory, in particular, is engaged in the inventory of greenhouse gases for the formulation of state policy in the field of climate change and to ensure compliance with the requirements of the UN Framework Convention on Climate Change. The main tasks of the department are to collect, process, systematise, analyse, accumulate and store information necessary for the preparation and support of the review of the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases, as well as to improve the national system for assessing anthropogenic emissions and sinks of greenhouse gases.

In accordance with the tasks assigned in the process of preparing the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine, the National Center for GHG Emission Inventory may request and receive information necessary for assessing anthropogenic emissions and sinks of greenhouse gases from ministries, other central and regional executive authorities, enterprises, institutions and organisations of all forms of ownership in accordance with the procedure established by law.

As a rule, the information used for the inventory is based on official aggregated statistics, but requests can also be sent to individual enterprises to collect primary statistical reporting documents and other information for use in calculating greenhouse gas emissions.

In terms of electricity generation, greenhouse gas emissions are calculated in category 1.A.1 Fuel and Energy Industry of the Common Reporting Format tables. This category includes the following subcategories:

- 1.A.1.a Public Electricity and Heat Production
 - > 1.A.1.ai Electricity Generation - data are based on information from the statistical reporting form No. 4-MTP (Section 2, column 8);
 - > 1.A.1.aid Combined Heat and Power Generation (CHP) - data are based on information from the statistical reporting form No. 4-MTP (Section 2, columns 9-11);
 - > 1.A.1.aid Heat Plants - data are based on information from the statistical reporting form No. 4-MTP (Section 2, column 12).

Emissions from combined heat and power generation are not disaggregated into components (separately for electricity generation and separately for heat generation), as there is no need for such a disaggregation for the purposes of the national emissions inventory. The national inventory also does not contain information that would allow for such a breakdown.

In addition, emissions from electricity generation by power plants of enterprises are not separately identified in the inventory, but are accounted for together with other sources of emissions from energy consumption in industry.

Thus, in terms of greenhouse gas emissions from electricity production, the national inventory separately provides data only for main activity producers operating thermal power plants. To account for emissions from coal combustion, the national methodology is used, according to which national values of the net calorific value of coal, the carbon oxidation factor in fuel and the carbon content of coal are determined (Annex A2.6.2 of the National Inventory). For natural gas, the quality characteristics (net calorific value, carbon content, density, etc.) are based on data from the data sheets of physical and chemical parameters of natural gas.

6.3.4 NPC Ukrenergo

The National Power Company Ukrenergo is a joint-stock company with 100% state-owned shares, which is managed by the Ministry of Energy of Ukraine. Ukrenergo is the transmission system operator of Ukraine with the functions of operational and technological management of the Integrated Power System of Ukraine (IPS), as well as transmission of electricity through the transmission system from generation points to distribution networks. In addition, Ukrenergo acts as a commercial metering administrator.⁷³

In accordance with its functions, NPC Ukrenergo has two sources of information on electricity generation and supply:

- Aggregated commercial electricity metering data;⁷⁴
- Data from departmental statistical forms.

Commercial electricity metering data are obtained from commercial metering devices and, if necessary, are adjusted, so they are a reliable source of information on the volume of electricity supplied to the grid.

Data from the departmental statistical forms are collected through the territorial grid maintenance departments. The departmental statistical forms are submitted in accordance with Order of the Ministry of Energy of Ukraine No. 289 dated 14 October 1999.⁷⁵

Table 12. Statistical forms of NPC Ukrenergo

Statistical form	Description
Form 37-energo Reporting electricity balance	• Form 37-energo in accordance with the Order of the Ministry of Energy of Ukraine No. 289 dated 14.10.1999 "On Approval of the List of Departmental Statistical Reporting Forms". • According to the order, it is submitted monthly by the 15th day of the month. Contains data on: > Electricity generation by type of generation and ownership of power plants; > Volumes of electricity supplied to the grid and volumes of electricity consumption; > Technological consumption of electricity for transmission and consumption for the production needs of power systems, > Flows between adjacent power systems, imports, exports, etc.

73 NPC Ukrenergo, https://ua.energy/pro_kompaniyu/

74 NEURC Resolution of 14.03.2018 No. 311 "On Approval of the Code of Commercial Metering of Electricity", <https://zakon.rada.gov.ua/laws/show/v0311874-18#Text>

75 Order of the Ministry of Energy of Ukraine No. 289 of 14 October 1999, <https://mev.gov.ua/sites/default/files/field/file/order/%D0%9D%D0%B0%D0%BA%D0%B0%D0%B7%20%E2%84%96289%20%D0%B2%D1%96%D0%B4%2014.10.1999.pdf>

Statistical form	Description
Form 2-energo Report on the operational capacity balance	- Form 2-energo in accordance with the Order of the Ministry of Energy of Ukraine No. 289 dated 14.10.1999 "On Approval of the List of Departmental Statistical Reporting Forms". - In accordance with the order, on a daily basis. Contains data on: > Capacities and status: generation, under repair, maximum consumption, etc.
Form 19-energo Power system capacity balance during the annual peak load of the IPS of Ukraine	- Form 19-energo in accordance with the Order of the Ministry of Energy of Ukraine No. 289 dated 14.10.1999 "On Approval of the List of Departmental Statistical Reporting Forms". - According to the order, it is submitted annually by 25th of January. Contains data on: > Capacity for the period of the annual load peak and its own load peak, measures to reduce the power system load peak; > A report on the operation of power plants: capacity by unit, total production, output to the grid, etc.
Form 3-energo Fuel consumption report	- Form 3-energo (layout 001) in accordance with Order of the Ministry of Energy of Ukraine No. 289 dated 14.10.1999 "On Approval of the List of Departmental Statistical Reporting Forms". - In accordance with the order, on a daily basis. Contains data on: > Types, consumption and remaining fuel (liquid, solid, gas).

6.3.5 IEA questionnaires

The questionnaires for the International Energy Agency / UN Statistics Department / UNECE / Eurostat are prepared by the State Statistics Service in accordance with the established forms and provided to the IEA Energy Statistics Division.⁷⁶ The set of questionnaires includes:

- coal questionnaire,
- oil questionnaire,
- natural gas questionnaire,
- electricity questionnaire and
- RES questionnaire.

The IEA questionnaires are prepared by the State Statistics Service of Ukraine on the basis of various sources of information. The data from the questionnaires are used by the IEA to calculate emission factors for electricity in accordance with the methodology document.⁷⁷

⁷⁶ Memorandum of Understanding between the State Statistics Committee of Ukraine and the International Energy Agency on the exchange of statistical information,

⁷⁷ IEA, Emissions Factors 2023. Database documentation, https://iea.blob.core.windows.net/assets/bf862218-7fd8-4637-aca6-5a347b6ca4f1/IEA_Methodology_Emission_Factors_2023.pdf

The IEA Methodology Document emphasises that energy statistics at the national level are often compiled using criteria and definitions that differ, sometimes significantly, from those of international organisations. Although the IEA Secretariat tries to identify and take into account such differences, they can still have a significant impact on the results of the calculations.

The IEA questionnaires are a reliable source of information, but as they are based on data from the State Statistics Service, they are subject to similar limitations in terms of data accessibility.

6.4 Required Level of Data Granularity

In accordance with the methodological approach described above, for the calculation of emission factors for electricity, data on various parameters can be based on data from individual power plants (based on individual statistical forms) or groups of power plants (based on aggregated statistical data).

If aggregate statistics are used, information on the volume of electricity supplied and fuel consumption (in case of fuel use by power plants) should be broken down by at least the following groups of power plants:

- Nuclear power plants (NPPs);
- Thermal power plants (TPPs) with a division into:
 - > Main activity producers;
 - > Autoproducers;
- Combined heat and power plants (CHPs) and cogeneration units with a distribution to:
 - > Main activity producers;
 - > Autoproducers;
- Biomass power plants;
- Biogas power plants;
- Solar power plants;
- Wind power plants;
- Hydroelectric power plants (HPPs);
- Pumped storage power plants (PSPPs);
- Household power plants using renewable energy sources.

Data on fuel use is required with reference to the above groups of power plants and in terms of at least the following fuels:

- Anthracite and lean coal;
- Bituminous and long-flame coal;
- Natural gas;
- Fuel oil.

Separately, for the future inclusion of emissions from CH₄ and N₂O in the calculation of the emission factors, it is necessary to improve the quality and completeness of data on the use of different types of biomass, including biogas, for electricity production, as well as on the qualitative characteristics of these energy sources, in particular, their net calorific value. Such information may be necessary not only to account for the operation of biomass or biogas power plants, but also other power plants in the case of simultaneous combustion of biomass and fossil fuels.

When collecting information on electricity generation and fuel consumption, it is necessary to ensure the consistency of statistics from different sources, taking into account the following aspects:

- Ensure that the structure and level of detail of electricity supply data and fuel consumption data are consistent and coherent, including the use of the same categories for collecting information in line with the recommendations above.
- Ensure the collection of information on the supply of electricity by power plants of enterprises that produce only electricity or electricity and heat and supply it to the national grid. It is important to ensure the collection of information on fuel consumption by such power plants and the possibility of calculating fuel consumption that relates specifically to the amount of electricity supplied to the grid, and not just on the total amount of electricity production. In the case of combined heat and power generation by such power plants, it is also necessary to ensure the collection of information on heat production to allocate fuel consumption and emissions between different energy products. Additionally, it is also necessary to ensure consistency in the definitions used in the collection of information, in particular the use of the terms "uni plant", "enterprises' TPPs", "enterprises' CHPs and cogeneration units", etc. This aspect is particularly important in view of the development of decentralised generation, including the use of natural gas as a fuel.
- Ensure the collection of information on heat supply from plants that produce electricity and heat in cogeneration mode; data on heat supply should be collected taking into account the operation of individual plants, as CHPs and cogeneration units may have different characteristics, operating modes and equipment configuration.
- Include information on the supply of electricity generated by households using renewable energy sources to the grid and ensure consistency of such information between different sources; currently, data are available in the data sets of NPC Ukrenergo and NEURC (with certain differences in values), but are not available in the information based on the results of state statistical observations.

6.5 Data Used and Limitations of Emission Factors Calculation

The emission factors were calculated for 2020-2023 in accordance with the methodological approach and data sources described above, subject to the limitations described in the table below.

Table 13. Data for calculating emission factors for electricity

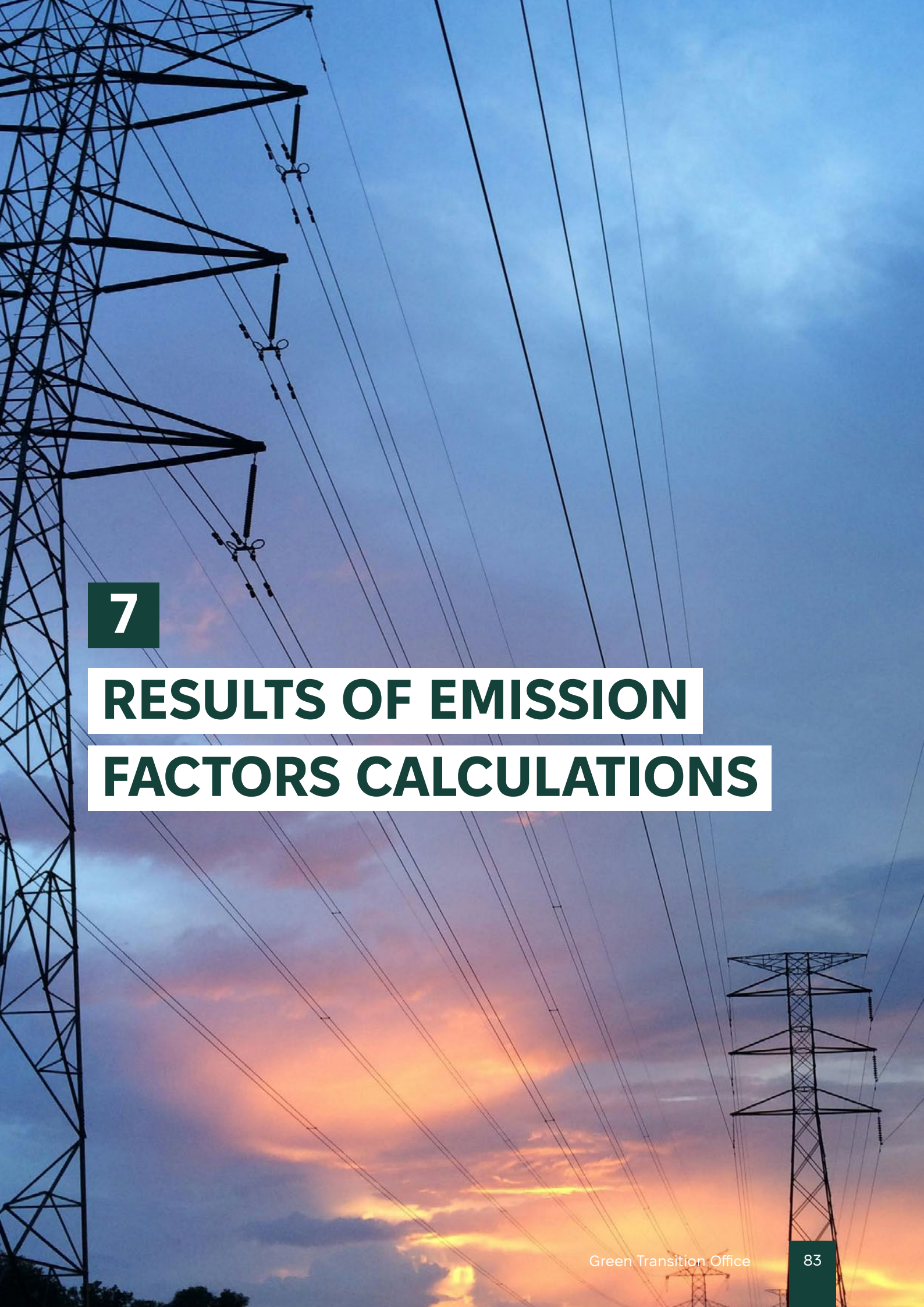
Indicator	Data source and comments on limitations
Electricity supply volume	
Nuclear power plants (NPP)	Commercial metering data from NPC Ukrenergo.
Thermal power plants (TPP) (main activity producers)	Commercial metering data from NPC Ukrenergo.
Enterprises' thermal power plants (TPP) (autoproducers)	Not included in the preliminary calculation due to lack of data. Additional analysis of category consistency, data availability and comparability of data from different sources is required.
Combined heat and power plants (CHP) and cogeneration units (main activity producers)	Commercial metering data from NPC Ukrenergo.
Enterprises' combined heat and power plants (CHP) and cogeneration units (autoproducers)	Not included in the preliminary calculation due to lack of data. Additional analysis of category consistency, data availability and comparability of data from different sources is required.
Biomass and biogas power plants	Commercial metering data from NPC Ukrenergo.
Solar power plants	Commercial metering data from NPC Ukrenergo.
Wind power plants	Commercial metering data from NPC Ukrenergo.
Hydropower plants (HPP)	Commercial metering data from NPC Ukrenergo.
Pumped storage power plants (PSPP)	Commercial metering data from NPC Ukrenergo. The volume of output is not taken into account in the calculation of emission factors, as PSPPs perform the function of energy storage rather than energy production.
Household power plants using renewable energy sources	Commercial metering data from NPC Ukrenergo.
Data on electricity supply may differ between sources due to different coverage (e.g., coverage of licensees only or exclusion of household power plants), incomplete statistical information (e.g., lack of data from operators of small-scale solar power plants), and different classification systems (e.g., for data on hydropower, biomass power plants, and separation of enterprises' power plants). The commercial metering data from NPC Ukrenergo was selected as the most complete and detailed source of information based on the results of the analysis and consultations.	

Indicator	Data source and comments on limitations
Fuel consumption for electricity generation	
Anthracite and lean coal consumption by TPPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data on total coal consumption coincide or do not differ significantly (up to 2% for some years), but do not contain a breakdown by coal grade.
Bituminous and long-flame coal consumption by TPPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data on total coal consumption coincide or do not differ significantly (up to 2% for some years), but do not contain a breakdown by coal grade.
Natural gas consumption by TPPs	NPC Ukrenergo's data based on departmental statistical reporting forms. NEURC's data coincide or differ slightly (up to 1.2%).
Fuel oil consumption by TPPs	NPC Ukrenergo's data based on departmental statistical reporting forms. For some years, the NEURC's data are close, but for some years they differ by 9-14%. The impact on the overall figures is insignificant, as the share of fuel oil in the fuel mix is very small. For consistency of data sources, the data of NPC Ukrenergo were used.
Anthracite and lean coal consumption by CHPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data on total coal consumption coincide or differ slightly or not significantly (less than 1% for most years and only about 3% for 2023), but do not contain a breakdown by coal grade.
Bituminous and long-flame coal consumption by CHPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data on total coal consumption coincide or differ slightly or not significantly (less than 1% for most years and only about 3% for 2023), but do not contain a breakdown by coal grade.
Natural gas consumption by CHPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data differs, but also includes data on cogeneration units of enterprises without separating them.
Fuel oil consumption by CHPs	NPC Ukrenergo's data based on departmental statistical reporting forms. The NEURC's data differs, but also includes data on cogeneration units of enterprises without separating them.
When choosing a source of information on fuel consumption, it is important to reconcile the data with data on electricity generation and supply, including in terms of coverage and use of the same/comparable classification.	
Net calorific value of fuel	
Anthracite and lean coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (weighted average for TPPs using only A and P grade coal). For 2022-2023, the value for 2021 was used.

Indicator	Data source and comments on limitations
Bituminous and long-flame coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (weighted average for TPPs using only G and D grade coal). For 2022-2023, the value for 2021 was used.
Natural gas	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine – the value is calculated based on the net calorific value in GJ/t and the density of natural gas. For all years, the value for 2020 was used, as the data in the inventory was not updated due to lack of information.
Fuel oil	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine (Table A2.4).
Carbon emission factors	
Anthracite and lean coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (weighted average for TPPs using only A and P grade coal). For 2022-2023, the value for 2021 was used.
Bituminous and long-flame coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (calculated by weighted average for TPPs using only G and D grade coal). For 2022-2023, the value for 2021 was used.
Natural gas	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine. For all years, the values for 2020 were used, as the data in the inventory was not updated due to lack of information.
Fuel oil	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine (Table A2.4).
Carbon oxidation factors	
Anthracite and lean coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (weighted average for TPPs using only A and P grade coal). For 2022-2023, the value for 2021 was used.
Bituminous and long-flame coal	Data from the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine for 2020-2021 (weighted average for TPPs using only G and D grade coal). For 2022-2023, the value for 2021 was used.
Natural gas	In accordance with the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine, the value is equal to 1.
Fuel oil	In accordance with the National Inventory of Anthropogenic Emissions and Sinks of Greenhouse Gases of Ukraine, the value is equal to 1.

Indicator	Data source and comments on limitations
Volume of heat supply	
Heat supply by CHP plants	The Regulator's data based on the information from the reporting form No. 4a-NKREKP-Electricity and Heat Generation (monthly) "Report on Fuel/Electricity Use and Status of Settlements".
Efficiency of heat production by an alternative method (boiler)	The default value is 90%.
When selecting data on heat supply, it is important to reconcile them with data on electricity supply from CHP plants, and to take into account only heat produced in cogeneration mode, and not individual hot water boilers that may be installed at the same facilities.	
Other parameters	
Indicator of electricity losses in the power system	For consumers of the first voltage class, a default value of 2.5% was used, which takes into account only technological losses in the transmission system with a voltage of 800-220 kV. For consumers of the second voltage class, the data of NPC Ukrenergo was used.

The selection of data sources was based on data accessibility, completeness of coverage, level of detail, accuracy and reliability of the information source. In the future, the data sources may be changed, taking into account the development of the energy statistics system and the recommendations for improving the consistency and level of detail of the data prepared as a result of the study.



7

RESULTS OF EMISSION FACTORS CALCULATIONS

7.1 Average Emission Factors

Average emission factors generally show a downward trend, which is due to the development of renewable energy sources and the active use of nuclear power plants in recent years. At the same time, the impact of the war and the destruction of energy infrastructure will need to be further assessed when calculating emission factors for the coming years.

The results of the calculation of average emission factors are shown in the figure below.

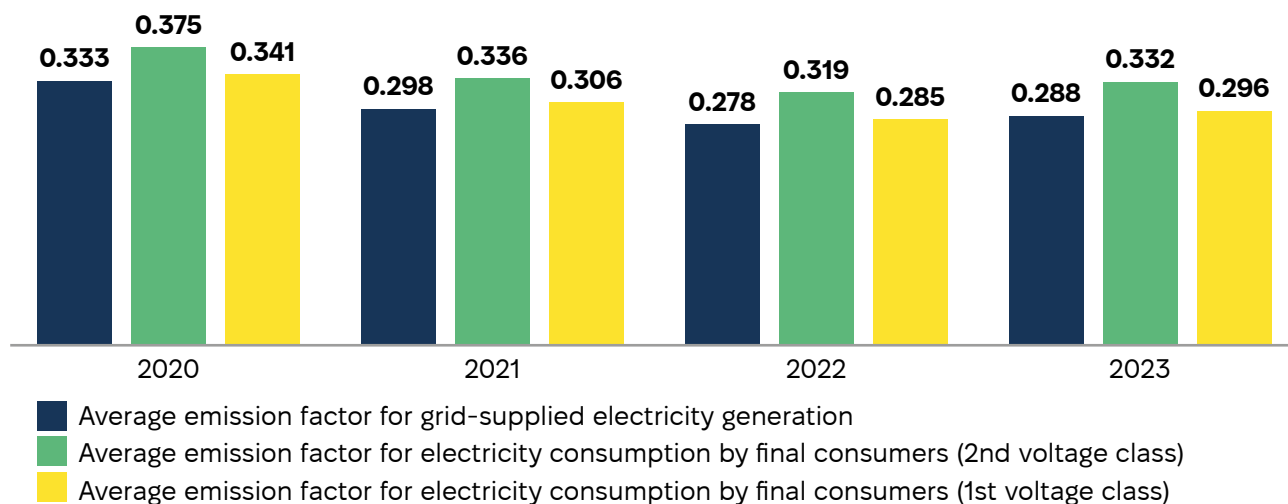


Figure 6. Average emission factors for electricity, t CO₂/MWh

Recommendations on the use of average emission factors:

- The average emission factor for electricity generation reflects the specific average emissions at the stage of electricity supply to the grid and is used to account for indirect Scope 2 emissions in accordance with the requirements of the GHG Protocol;
- Average emission factors for electricity consumption (for consumers of different voltage classes) take into account electricity losses during transportation and can be used to estimate total emissions at the consumption stage, including when determining the carbon footprint.

The requirement to use a particular type of emission factor may also be set out in separate documents of the programmes or standards for which the assessment is being made.



7.2 Marginal Emission Factors

The results of the calculation of the marginal emission factors are shown in the figure below.

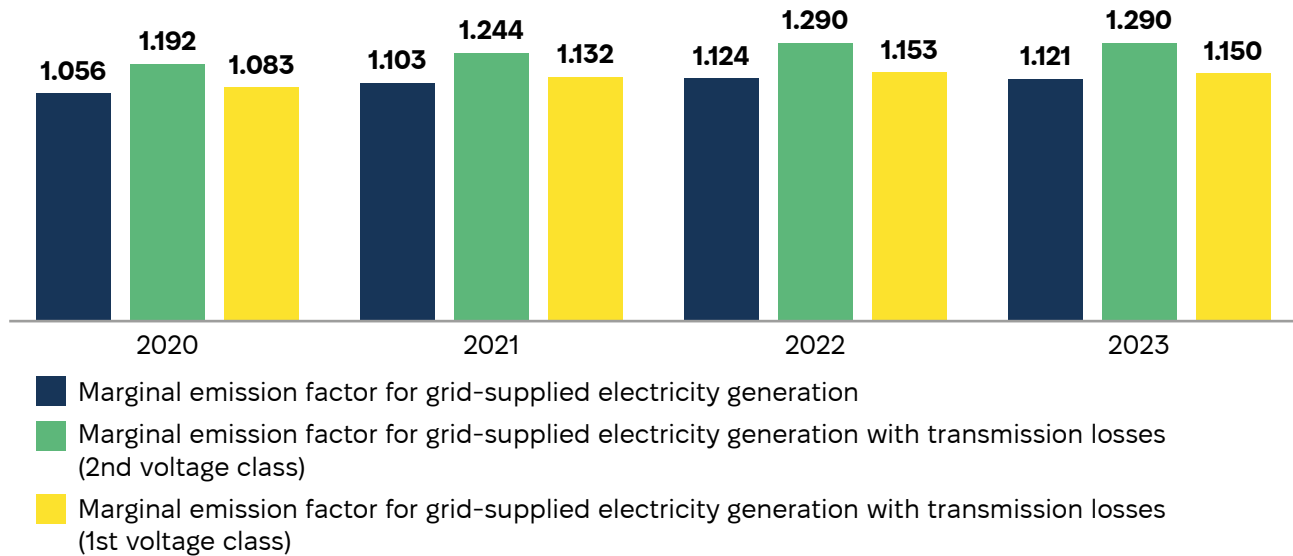


Figure 7. Marginal emission factors for electricity, t CO₂/MWh

Recommendations on the use of marginal emission factors:

- The marginal emission factor for electricity generation reflects emissions at the stage of electricity supply to the grid and can be used to estimate emission reductions from renewable energy projects;
- Marginal emission factors for electricity generation with losses taken into account (for consumers of different voltage classes) take into account electricity losses during transmission and can be used to estimate emission reductions from energy efficiency projects by end-users (taking into account voltage class).

Given that the group of low-cost/must-run power plants does not include TPPs, but includes CHPs, the marginal emission factor will differ from the average emission factor for fossil fuel power generation (covering both TPPs and CHPs).



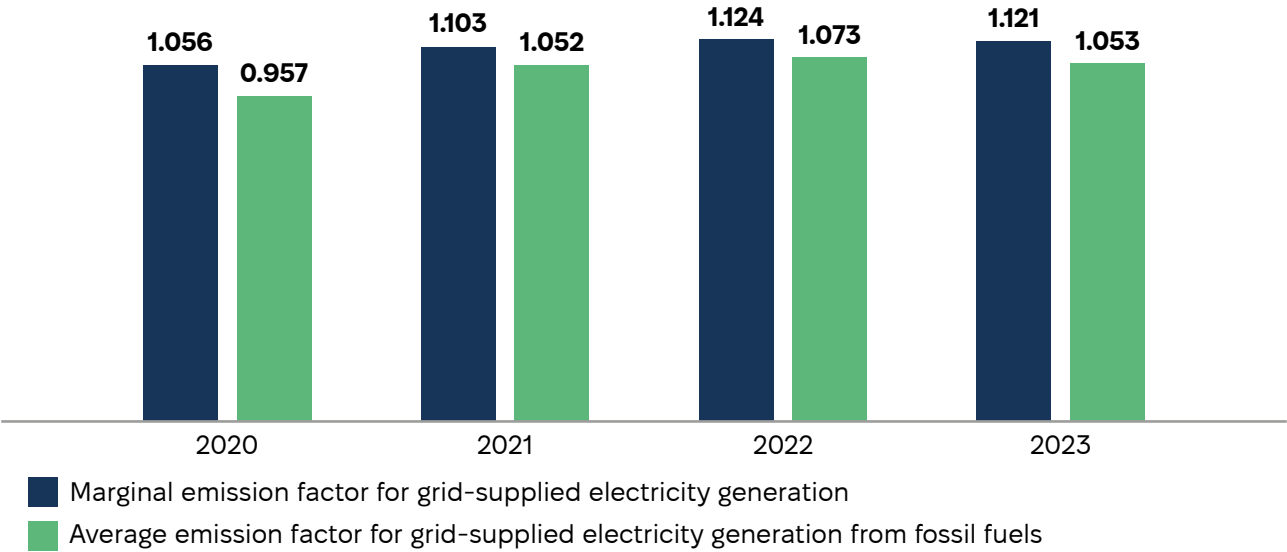


Figure 8. Comparison of marginal emission factors and average emission factors for electricity generation from fossil fuels, t CO₂/MWh

7.3 Emission Factors for Electricity Losses

For the purposes of accounting for indirect emissions in Scope 3, Category 3: Fuel- and Energy-Related Activities Not Included in Scope 1 or Scope 2⁷⁸, emission factors related to electricity losses during transmission can be used.

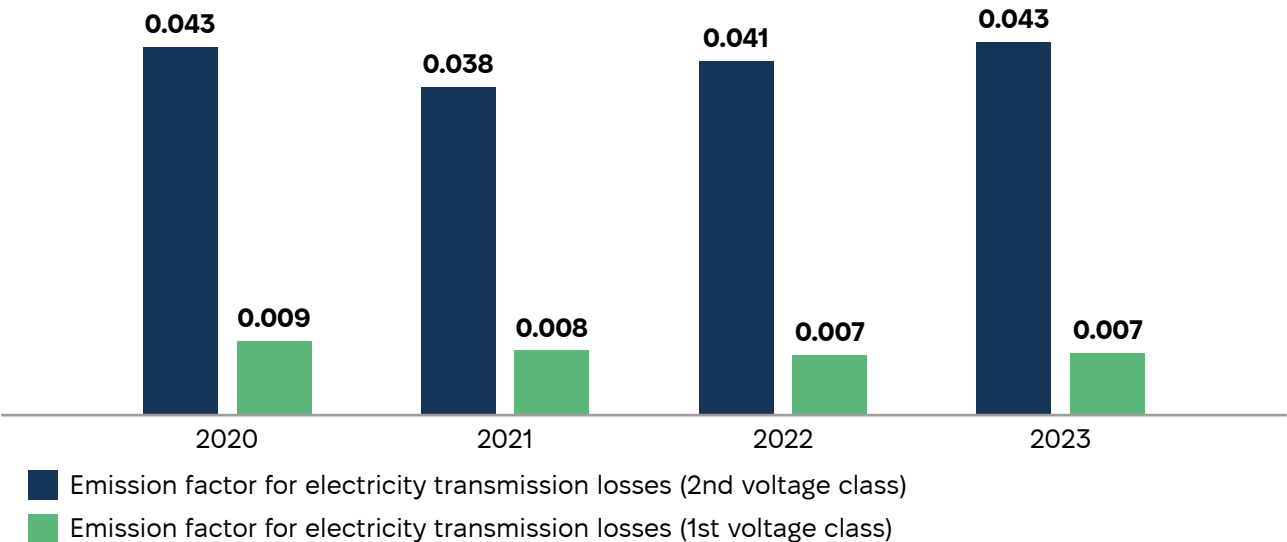


Figure 9. Emissions associated with electricity losses during transmission

78 GHG Protocol, https://ghgprotocol.org/sites/default/files/ghgp/standards_supporting/Chapter3.pdf

7.4 Limitations and Uncertainties

The presented calculation results reflect different emission factors for the Integrated Power System of Ukraine in accordance with the methodological approaches and limitations described above. Given the limitations associated with the quality and completeness of the data, the presented results of the calculation of emission factors are characterised by a certain uncertainty, but its level is not significant. The main sources of emissions from electricity generation are related to the operation of thermal power plants for which complete and reliable data are available.

In the absence of data for a particular year, it is common practice to use emission factors for the year closest to the reporting year (e.g., the previous year or earlier).

Emissions from electricity generation by non-grid-connected facilities are not included in the calculation. Due to the extensive damage to Ukraine's power grid, including generation facilities, the number and capacity of backup power sources, in particular diesel generators, has increased dramatically. Although the emissions per unit of electricity generated by generators are significantly higher than those of electricity from the grid, their share in the total production during the year is insignificant.⁷⁹ If such backup sources of electricity generation are used, emissions should be calculated on a case-by-case basis based on the amount of fuel used and the relevant fuel emission factors.⁸⁰ The use of backup power sources for greenhouse gas accounting purposes is accounted for separately from indirect emissions associated with the consumption of electricity from the grid.

7.5 Comparison of Average Emission Factors with EU Countries

The average emission factors for electricity in Ukraine are showing a downward trend due to the use of nuclear power plants and the development of renewable energy sources. According to the study, the average emission factor is close to the average in the EU (EU-27). It is noteworthy that during 2020-2022, the average emission factors in Ukraine and the EU showed opposite trends. In the EU, after a steady downward trend in recent years, the average has been increasing, while in Ukraine it has continued to decline.

79 According to the Initiative on GHG Accounting of War, the share of generators in electricity generation fluctuated between 2.4% and 5.5% in October-December, 2022 due to large-scale attacks on the power grid and prolonged power outages, but averaged around 1% in 2022. The total capacity of diesel and petrol generators is measured in several gigawatts. See Climate Damage Caused by Russia's War in Ukraine: 24 February 2022 - 23 February 2023, <https://ecoaction.org.ua/vplyv-ros-vijny-na-klimat-2.html>

80 See, e.g., the approach described in section 6.2.1.2 of the TOOL05 manual. Methodological tool. Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation. Version 03.0, <https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-05-v3.0.pdf>

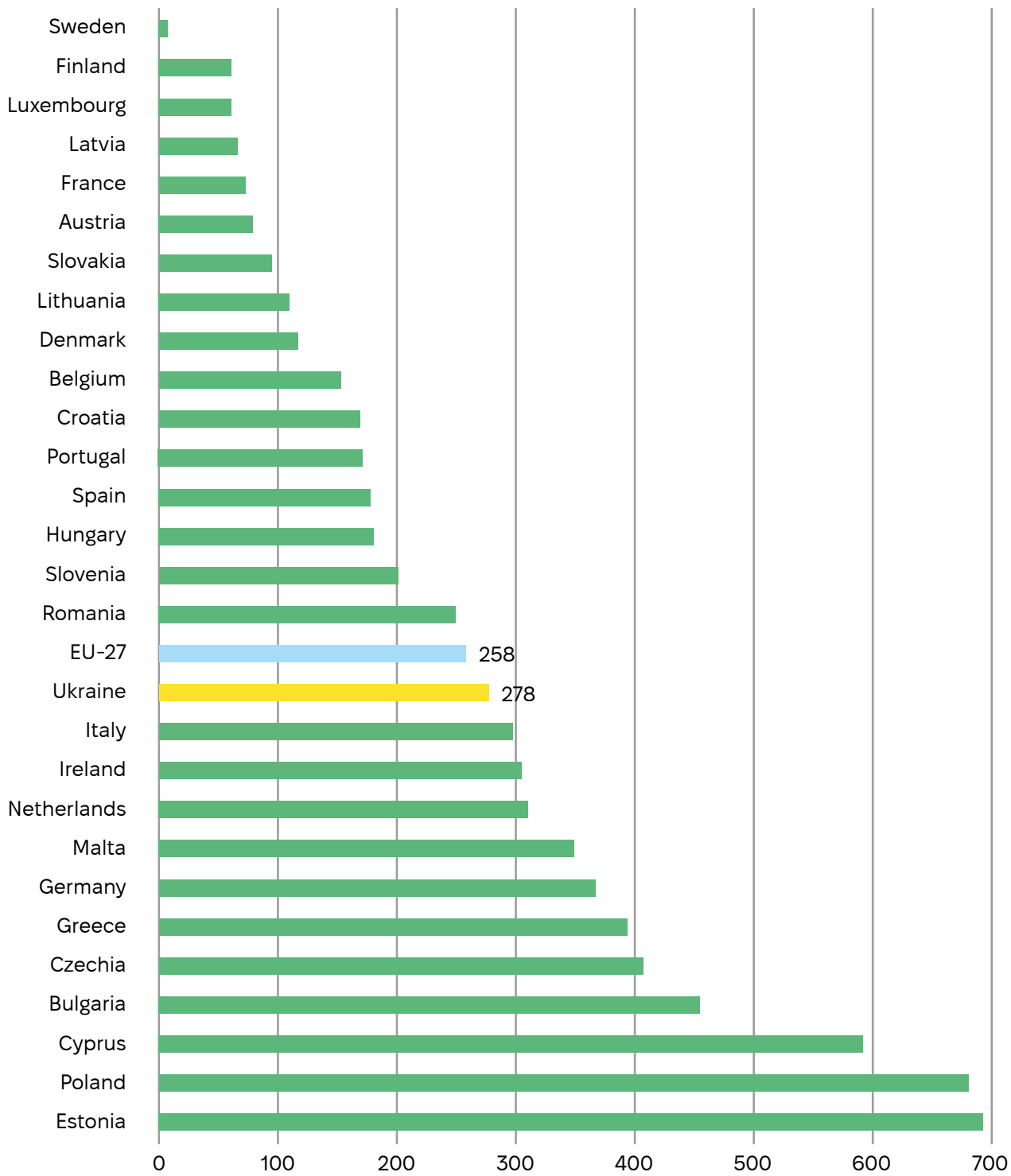


Figure 10. Comparison of average emission factors in Ukraine and EU countries in 2022 (kg CO₂/MWh)

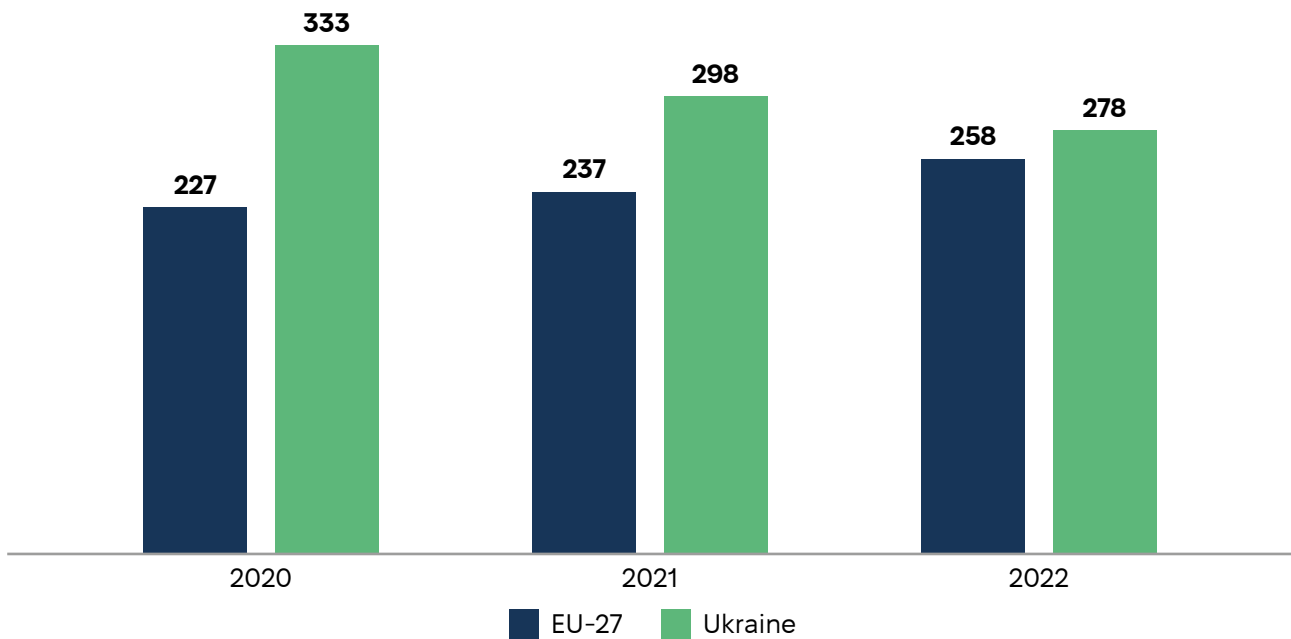


Figure 11. Comparison of average emission factors in Ukraine and the EU-27 (kg CO₂/MWh)

Source: EU data - based on data from the European Environment Agency.⁸¹

To meet the EU's emission reduction targets, the average emission factor for electricity generation must be further reduced and, according to various estimates, reach 110-118 kg CO₂ eq./MWh by 2030.





8

INTERNATIONAL EXPERIENCE IN PUBLISHING EMISSION FACTORS

8.1 Canada - Publication of Data as Part of the National Inventory

Canada publishes data on emissions from electricity generation as an annex to its national greenhouse gas emissions inventory.⁸² The annex includes detailed information on greenhouse gas emissions associated with electricity generation in the Public Electricity and Heat Production category (IPCC Category 1.A.1.a) at the national, provincial and territorial levels.

The dataset includes information on:

- Average emission factor for electricity production in terms of individual greenhouse gases (CO₂, CH₄, N₂O) and in CO₂ equivalent in g per kWh; calculated on the basis of data on fuel consumption, emission factors and electricity production;
- Data related to the transmission and distribution of electricity, including electricity losses and SF₆ emissions from electrical equipment (reported in the Industrial Processes and Product Use category);
- Average emission factors for electricity consumption, which are calculated taking into account transmission losses (losses are subtracted from electricity production in the calculation) and SF₆ emissions (emissions are added to total emissions).

The data covers companies whose primary business is electricity generation (NAICS code 2211). Companies that produce electricity partially or fully for their own needs or as a by-product of production (autoproducers) have other classifications of economic activity and are not included in the calculations, unless a separate legal entity is established to supply electricity.

8.2 UK – Department for Energy Security and Net Zero

In the UK, information on emission factors is published annually by Department for Energy Security and Net Zero,⁸³ and the calculation approach is described in detail in the relevant methodology document.⁸⁴ The set of emission factors is mainly published for corporate reporting by companies and contains a large number of indicators for various sources of direct and indirect emissions in addition to emission factors for electricity.

Emission factors for electricity are used by companies to account for Scope 2 emissions (indirect emissions from electricity consumption). The main average emission factors reflect emissions from electricity supplied to the grid and do not include emissions associated with transmission and distribution losses. At the same time, the dataset also contains emission factors to account for electricity losses in transmission and distribution and life cycle emission factors (WTT conversion factors) that account for emissions from the extraction, processing and transportation of fuels for electricity generation. Such emission factors can be used by companies to account for other indirect Scope 3 emissions.

The average emission factors are based on information on direct emissions of CO₂, CH₄ and N₂O from

82 <https://canada.ca/ghg-inventory%20National%20Inventory%20Report%20%E2%80%93%202023%20Edition%20Part%203>

83 Department for Energy Security and Net Zero, Greenhouse gas reporting: conversion factors 2024, <https://www.gov.uk/government/publications/greenhouse-gas-reporting-conversion-factors-2024>

84 2024 Government Gas Conversion Factors for company reporting. Methodology Paper for Conversion factors. Final Report, <https://assets.publishing.service.gov.uk/media/66a9fe4ca3c2a28abb50da4a/2024-greenhouse-gas-conversion-factors-methodology.pdf>

public and business power stations in the UK, and take into account net electricity imports by individual interconnectors with Ireland, the Netherlands, France, Belgium and Norway and the corresponding emissions per unit of electricity imported. Emission factors can vary significantly from year to year, depending on fuel costs and other factors that determine the volume of electricity produced from different sources and the volume of imports. For imported electricity, emission factors are based on various available data sources, including official national figures. For years in which the UK is a net exporter of electricity, emissions from imported electricity are not included in the calculations.

Emission factors for electricity are based on emissions from national reporting in categories 1A1ai (power stations) and 1A2b/1A2gviii (autoproducers) of the national greenhouse gas emissions inventory. At the same time, the factors published in 2024 are based on 2022 emissions data. However, the national inventory data in the specified categories contain information only on emissions from power plants of enterprises using coal and natural gas, and do not include emissions from power plants using petroleum products and other fossil fuel emissions (e.g. blast furnace gas, coke oven gas, municipal solid waste, etc.). In view of this, additional information for the calculations included other energy statistics data (Digest of UK Energy Statistics - DUKES). The calculations take into account the share of electricity generated by the enterprises' power plants that is supplied to the general grid. This figure may vary significantly from year to year.

In the case of cogeneration, the 1/3 : 2/3 method of energy statistics is used to allocate fuel consumption and emissions to heat and electricity.

The results of the calculations are presented separately for different greenhouse gases and for total greenhouse gas emissions, as well as separately for the following categories:

- Electricity generated (including imports);
- For transmission and distribution losses (calculated on the basis of the loss factor and equal to the difference between the emission factor for electricity consumed and electricity generated);
- For electricity consumed (includes transmission and distribution losses).

8.3 Poland – Institute of Environmental Protection

In Poland, data on emission factors for electricity are published by the National Centre for Emissions Balancing and Management (KOBiZE - Krajowy Ośrodek Bilansowania i Zarządzania Emisjami), which is a separate centre within the Institute of Environmental Protection – National Research Institute.⁸⁵ Among the main tasks of KOBiZE are administration of the EU emissions trading system, administration of the database on emissions of pollutants and greenhouse gases into the atmosphere, and preparation of national emission inventories in accordance with the UNFCCC. KOBiZE is supervised by the Minister of Climate and its tasks are financed from the National Fund for Environmental Protection and Water Management.

The factors are calculated on the basis of information entered by users into the National Database of Greenhouse Gas and Other Substances Emissions for the relevant year. It should be emphasised that data from both facilities that produce only electricity and facilities that produce combined heat and power are taken into account.

85 Krajowy Ośrodek Bilansowania i Zarządzania Emisjami (KOBiZE), <https://www.kobize.pl/>

The report contains information on emission factors not only for CO₂, but also for SO₂, NO_x, CO and total dust. Data on the following factors are published:

- Emissions per 1 MWh of electricity generated exclusively by plants using fuel combustion technology;
- Emissions per 1 MWh of electricity generated by all electricity generation facilities, including electricity supplied to the grid from renewable energy sources and taking into account losses and balance differences, or in other words, the emission factor for electricity used by end consumers.
- For example, according to 2022 report⁸⁶, the CO₂ emission factors are as follows:
- 788 kg CO₂ per MWh of electricity generated in fuel combustion plants;
- 685 kg CO₂ per MWh for final electricity consumption.

According to the explanation, emission factors can be used to assess changes in the environmental performance of individual sectors of the economy and to calculate the environmental effect of modernisation or new projects that lead to emission reductions. It is noteworthy that for the purposes of corporate greenhouse gas emissions accounting under the GHG Protocol, the factor for final electricity consumption should be further divided to calculate the factor excluding electricity losses (Scope 2) and the factor reflecting such losses (Scope 3).

Plant operators submit to the national database all the information necessary for the calculations, including:

- Information on CO₂, SO₂, NO_x, CO and total dust emissions from fuel combustion plants for electricity and heat generation,
- Information on the volume of electricity and heat generation in fuel combustion plants,
- Information on the consumption of fuels used for electricity and heat generation and their main quality indicators (calorific value, sulphur content in fuel, ash content of fuel).

The reports also contain brief methodological information, in particular, on the approach for allocating emissions for combined heat and power plants. For combined heat and power plants, emissions are allocated using the energy method in proportion to the heat and electricity production in total production, without regard to the qualitative characteristics of the energy forms.

Information on emission factors is published annually in the form of reports (2016-2023 reports are available on the website).⁸⁷ However, information on emission factors is published with a one-year delay – the 2023 report was published in December 2023 and contains information on emission factors for 2022.

86 Wskaźniki emisyjności CO₂, SO₂, NO_x, CO i pyłu całkowitego dla energii elektrycznej na podstawie informacji zawartych w Krajowej bazie o emisjach gazów cieplarnianych i innych substancji za 2022 rok,

87 KOBiZE, Wskaźniki produktowe dla energii elektrycznej, <https://www.kobize.pl/pl/fileCategory/id/28/wskazniki-emisyjnosci>

8.4 France - Publication of Data by the Transmission System Operator

In France, information on emission factors for electricity is published by the transmission system operator (RTE), and such information is published, among other things, in real time for each 15-minute period.⁸⁸

RTE, as a transmission system operator, has access to data on electricity consumption and production and has created the éco2mix tool, which is freely available on the internet and via a mobile application and provides information on various indicators, including CO₂ emissions from electricity production at the country and regional level.

The CO₂ emissions indicator represents emissions from the consumption of primary fuels by power plants in France and does not take into account indirect emissions, such as those from the construction of power plants or the extraction and supply of fuels. The emissions figure also does not take into account the exchange of electricity through interconnectors with other countries (imports and exports).

Emission factors are calculated in real time based on defined indicators for each type of power plant:⁸⁹

- 986 kg CO₂ per MWh for coal-fired power plants;
- 777 kg CO₂ per MWh for oil-fired power plants;
- 429 kg CO₂ per MWh for gas-fired power plants;
- 494 kg CO₂ per MWh for waste-to-energy power plants.

For other types of power plants, emissions are assumed to be zero.

These indicators will be updated from time to time, taking into account the development of technologies and modernisation of power plants.

The final emissions figures based on consolidated data are calculated on the basis of two sources of information:

- Data on emission factors for different fuels (natural gas, coal and oil products) based on the ADEME database;
- ENTSO-E guidelines for determining standard performance indicators for power plants.

8.5 Data from Consulting Companies

Ember energy think tank⁹⁰ collects and publishes datasets and analyses in the energy sector, including the Electricity Data Explorer⁹¹. This tool allows you to view and analyse data on electricity demand, generation, capacity and CO₂ emissions by country. The data collection methodology is described in a separate document.⁹² In addition to general methodological approaches, the document also contains comments on the availability and sources of data for individual countries. All data are publicly available and free for download and further processing.

The emissions per unit of electricity produced are calculated based on fuel consumption data and standard emission factors in accordance with the IPCC 5th Assessment Report Annex 3 (2014). The

88 RTE, <https://www.rte-france.com/en/eco2mix>

89 RTE, <https://www.rte-france.com/en/eco2mix/co2-emissions#>

90 Ember, <https://ember-climate.org/about/>

91 Ember, Electricity Data Explorer, <https://ember-climate.org/data/data-tools/data-explorer/>

92 Core Data Methodology, <https://ember-climate.org/app/uploads/2022/03/Ember-Methodology.pdf>

emissions calculation includes not only direct but also indirect emissions associated with fuel extraction and transportation, as well as all greenhouse gases converted to CO₂ equivalent, in particular:

- for coal - 820 g CO₂ eq./kWh;
- for natural gas - 490 g CO₂ eq./kWh;
- for other fossil fuels - 700 g CO₂ eq./kWh;
- for wind power - 11 g CO₂ eq./kWh;
- for solar energy - 48 g CO₂ eq./kWh;
- for bioenergy - 230 g CO₂ eq./kWh;
- for hydropower - 24 g CO₂ eq./kWh;
- for other renewable energy (based on data for geothermal energy) - 38 g CO₂ eq./kWh;
- for nuclear power - 12 g CO₂ eq./kWh.

While the advantage of this dataset is its wide coverage and openness, it has a number of limitations that affect the accuracy and representativeness of emission factors:

- Standard emission factors for fossil fuels are used, whereas the characteristics of a fuel, such as coal, can vary significantly between countries or between different coal grades within a country;
- Indirect emissions associated with fuel extraction, which may also vary from country to country, and standardised factors may not take into account the latest available research on emission intensity; emissions from biomass also depend on the type of biomass and many other factors and may differ significantly from standardised values; and the inclusion of such emissions may not meet some needs for using emission factors for electricity;
- Standardised energy efficiency indicators are used, which do not take into account the diversity of technologies and differences in the efficiency of power plants of different generations and in different countries;
- Heat production for power plants using combined heat and power technologies is not taken into account.

8.6 Data from Electricity Suppliers

Directive (EU) 2019/944 on common rules for the internal market for electricity...⁹³ in Article 18 stipulates that bills and billing information shall fulfil the minimum requirements set out in Annex 1 of the Directive. The Annex, on the other hand, contains a clause on disclosure of information on energy sources. In particular, suppliers must indicate in their bills the contribution of each energy source to the electricity purchased by the end consumer under the electricity supply agreement. Among other things, the information contained in the bill or provided with the bill must include environmental impact data and at least the average CO₂ emissions from electricity generation for the total electricity mix of the supplier in question for the previous year.

93 Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU (recast), <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32019L0944>. Unofficial translation into Ukrainian: Directive (EU) 2019/944 of the European Parliament and of the Council of 5 June 2019 on common rules for the internal market for electricity and amending Directive 2012/27/EU, <https://energysecurityua.org.ua/brify/dyrektyva-yes-2019-944-yevropeyskoho-parlamentu-i-rady-vid-05-chervnia-2019-roku/>

EU members have transposed the provisions of the directive into national law, and suppliers publish the relevant impact indicators in their bills or on their websites.⁹⁴ Suppliers receive information from electricity producers or other suppliers and make the relevant calculations for their own electricity mix. In Poland, for example, bills must contain data on the composition of fuels and other energy sources, as well as information on the place where information on environmental impacts in terms of CO₂, SO₂, nitrogen oxides, dust and radioactive waste is available. Such information may be available on the electricity supplier's website or in other materials.

Other EU documents also contain provisions on the need to inform consumers about the share of renewable energy and the greenhouse gas emission factor for the supplied electricity.⁹⁵ In the future, such information should become available in real time.

8.7 Other Sources of Information

There are also many other sources of information and databases that collect emission factor indicators for electricity for different countries, using different approaches and methodologies.

The main sources of additional data on marginal emission factors can include scientific studies, commercial products, governmental organisations and grid operators. Scientific studies typically provide detailed methodologies and data, but are designed to examine specific issues based on historical data and may not always be suitable for decision-making purposes. At the same time, scientific approaches can often be adapted and used in commercial products or official publications by government bodies.⁹⁶

Examples of other sources of information:

- AIB (Association of Issuing Bodies) data;⁹⁷
- database of the Institute for Global Environmental Strategies, Japan;⁹⁸
- eGRID database;⁹⁹
- data on international emission factors for electricity from Carbon Footprint;¹⁰⁰
- Electricity Maps data.¹⁰¹

94 For example, in Poland, the relevant requirement is contained in § 44 Rozporządzenia Ministra Klimatu i Środowiska z dnia 22 marca 2023 r. w sprawie szczegółowych warunków funkcjonowania systemu elektroenergetycznego (Dz. U. z 2023 r. poz. 819 z dnia 28 kwietnia 2023 r. z późniejszymi zmianami) and detailed data requirements in Annex 2 to the regulation, <https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20230000819>.

95 See, in particular, paragraph 51 and Article 20a of Directive (EU) 2023/2413 of the European Parliament and of the Council of 18 October 2023 amending Directive (EU) 2018/2001, Regulation (EU) 2018/1999 and Directive 98/70/EC as regards the promotion of energy from renewable sources, and repealing Council Directive (EU) 2015/652, <https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32023L2413&qid=1699364355105>

96 CEBI. Guide to sourcing marginal emissions factor data, <https://cebi.org/wp-content/uploads/2022/11/Guide-to-Sourcing-Marginal-Emissions-Factor-Data.pdf>

97 AIB, European Residual Mix, <https://www.aib-net.org/facts/european-residual-mix>

98 Institute for Global Environmental Strategies, IGES List of Grid Emission Factors, <https://www.iges.or.jp/en/pub/list-grid-emission-factor/en>

99 EPA, <https://www.epa.gov/egrid>

100 Carbon Footprint, International Electricity Factors, https://www.carbonfootprint.com/international_electricity_factors.html

101 Electricity Maps, <https://www.electricitymaps.com/methodology#carbon-intensity-and-emission-factors>

8.8 Summary of Practices for Publishing Emission Factors for Electricity

The analysis shows that there is no uniform practice of publishing data on greenhouse gas emission factors for electricity generation and consumption. Different countries may use different approaches, and different government agencies may be responsible for publishing data. These may include transmission system operators, ministries of environment or specialised environmental agencies, as well as electricity suppliers and other organisations.





9

USE OF EMISSION FACTORS

9.1 Use for the Purposes of the Carbon Border Adjustment Mechanism (CBAM)

In terms of electricity production and consumption, the Carbon Border Adjustment Mechanism (CBAM) provides for two separate approaches to estimating greenhouse gas emissions. The general rules for calculating emissions are set out in Article 7 and Annex IV of the CBAM Regulation (Regulation 2023/956).¹⁰²

The first approach is used for electricity exporters, and the second approach is used to estimate indirect emissions for all other goods that use electricity in their production.

Indirect emissions are emissions that occur during the production of electricity, which is used in the production of goods subject to the Carbon Border Adjustment Mechanism.

Accordingly, for the purposes of Annex IV of the Regulation (as well as for the purposes of Annexes V and VI), two main definitions related to emission factors for electricity are used:

- The emission factor for electricity is a default value expressed in CO₂ eq. that reflects the specific emissions for electricity used in the production of goods.
- The CO₂ emission factor is a weighted average of specific CO₂ emissions for electricity generated from fossil fuels within a geographic area. This CO₂ emission factor is calculated by dividing the CO₂ emissions from the electricity generation sector by the total electricity generation from fossil fuels within the relevant geographical area (calculated in tonnes of CO₂ per MWh).

These definitions are similar with regard to terms and wording, but the values of the factors themselves can differ significantly within the same geographical area. The first factor reflects the average emissions for all electricity produced and takes into account electricity production from renewable energy sources and nuclear power plants. In contrast, the second factor reflects average emissions only for electricity from fossil energy sources and can be considered a marginal emission factor under certain conditions.

9.1.1. Indirect Emissions for Goods (Excluding Electricity)

Article 7(2) of the CBAM Regulation stipulates that embedded emissions from the production of goods other than electricity shall be determined based on the actual emissions (in accordance with the methods set out in Annex IV, paragraphs 2 and 3) and indirect emissions should be calculated by reference to default values in accordance with the methods set out in point 4.1 of Annex IV.

It is noteworthy that for the transitional period, indirect emissions monitoring is envisaged for all products, while for the period of full operation of the mechanism, the requirement to monitor indirect emissions will apply only to certain products (Annex II to the CBAM Regulation contains a list of products for which only direct emissions are determined).

Indirect emissions from the use of electricity are taken into account when calculating the embedded emissions of both simple and complex goods if electricity is used in their production.

Approaches to estimating indirect emissions may differ depending on the source of electricity supply (e.g., national grid, direct contract supply, or own generation), but for the purposes of this study, only the use of electricity from the national grid is considered.

¹⁰² Regulation (EU) 2023/956 of the European Parliament and of the Council of 10 May 2023 establishing a carbon border adjustment mechanism, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R0956>

Default values for embedded indirect emissions should be determined on the basis of (paragraph 4.3 of Annex IV of the Regulation):

- a default value calculated as the average value of the emission factor of the Union electricity grid; or
- a default value calculated as the average of the emission factor of the country of origin electricity grid; or
- CO₂ emission factor of price-setting sources in the country of origin of the electricity used for the production of a good.

At the same time, if a country demonstrates to the European Commission (EC) on the basis of reliable data, that the average electricity mix emission factor or CO₂ emission factor of price-setting sources in the country of origin is lower than the default value for indirect emissions, an alternative default value based on that average CO₂ emission factor shall be established for this country.

Commission Implementing Regulation (EU) 2023/1773¹⁰³ (section D.4. of Annex III) specifies that during the transitional period, indirect emissions from electricity consumption in the production of goods should be determined on the basis of one of the following approaches:

- the average value of the emission factor for the electricity grid of the country of origin based on the International Energy Agency data provided by the EC in the CBAM Transitional Registry; or
- any other emission factor for the electricity grid of the country of origin calculated on the basis of publicly available data and reflecting either an average emission factor or a CO₂ emission factor.

In some cases, where electricity is generated directly on-site or supplied through a direct line (and under certain conditions, under a direct sales contract), actual emission factors for electricity consumed in the production of goods may be used (see Annex III, Sections D.4.1 and D.4.3).

The detailed methods for calculating the default values must be approved by the EC by 30 June 2025. The default values will also be periodically reviewed on the basis of the most recent information available, including information provided by third countries, in order to avoid carbon leakage and ensure the environmental objectives of the Carbon Border Adjustment Mechanism.

In accordance with Article 3 of Regulation 2023/1773, for indirect emissions, the declarant must include in the report, inter alia, information on the amount of electricity consumption per tonne of goods produced, the use of default emission factors or actual emissions, and the values of the relevant emission factors for electricity consumed.

Thus, for the purposes of calculating indirect greenhouse gas emissions from electricity consumption, the calculated average emission factor for electricity can potentially be used.

9.1.2. Direct Emissions for Electricity

The inclusion of electricity in the Carbon Border Adjustment Mechanism was justified by the sector's high share in total EU emissions, the significant difference in carbon charges in the EU and third countries, and, accordingly, the risk of significant carbon leakage due to increased imports of electricity, a high share of which is generated from coal. This risk was exacerbated by the progress in interconnecting the energy systems of the EU and neighbouring countries.

At the same time, given the specifics of electricity as a commodity, in order to avoid the risk of circumvention

¹⁰³ Commission Implementing Regulation (EU) 2023/1773 of 17 August 2023 laying down the rules for the application of Regulation (EU) 2023/956 of the European Parliament and of the Council as regards reporting obligations for the purposes of the carbon border adjustment mechanism during the transitional period, <https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32023R1773>

and improve the tracking of actual CO₂ emissions from electricity imports, the CBAM Regulation limits the possibility of calculating actual emissions from electricity generation to a list of clearly defined requirements. These requirements include, among others, the need to demonstrate a firm nomination of the allocated interconnection capacity and the existence of a direct contractual relationship between the buyer and the producer of renewable electricity or between the buyer and the producer of electricity with emissions below the default values.

In terms of electricity, Annex I of the Regulation provides for the consideration of CO₂ emissions only.

Article 7 (3) of the CBAM Regulation stipulates that emissions for electricity imported into the EU shall be determined on the basis of default values in accordance with the methods described in paragraph 4.2 of Annex IV, unless the declarant can demonstrate compliance with the criteria for estimating emissions based on actual emissions as set out in paragraph 5 of Annex IV.

In accordance with Article 3 of Regulation 2023/1773, the declarant must include in the report information on the emission factor for electricity (tonnes CO₂ eq./MWh) and the data source or calculation method used to determine the emission factor.

Determining a default value of the emission factor for electricity

Paragraph 4.2 of Annex IV defines the following options for determining the default value of emission factor for electricity for a country, a region within a country or a group of countries:

- 1) use of a specific default value in the form of a CO₂ emission factor determined by the EC for a country, group of countries or region within a country based on the best available data to the EC (paragraph 4.2.1); or, if no such factor is available,
- 2) use of an alternative default value determined on the basis of the CO₂ emission factor for the European Union (clause 4.2.2); or
- 3) use of another alternative default value if it can be demonstrated on the basis of reliable data that the CO₂ emission factor for the defined area is lower than the one calculated on the basis of the previous two options (paragraph 4.2.2).

For option 3, Regulation 2023/1773 (section D.2.3 of Annex III) specifies that the declarant must provide datasets from alternative official sources, including national statistics for the 5-year period ending two years before reporting (see Equation 46 in section D.2.3 of Annex III). To take into account the impact of decarbonisation policies and different weather conditions in different years, the CO₂ emission factor should be used as a weighted average of these 5 years. For each year, the CO₂ emission factor is calculated based on the emission factor for each individual fossil fuel technology, the total electricity production of that technology, and the total electricity production of all fossil fuel technologies (Equation 45 in Section D.2.3. of Annex III). If the factors calculated in this way are lower than those calculated under options 1 and 2 and the data are considered reliable, then such factors can be used for the purposes of the Carbon Border Adjustment Mechanism.

It is worth recalling that the Regulation defines the CO₂ emission factor as a weighted average of specific emissions for electricity generated from fossil fuels within a geographical area. Accordingly, this definition should be applied for all three options, and the default values correspond to the average emission factors for electricity generated from fossil fuels in the country of origin.

For options 1 and 2 above, Regulation 2023/1773 (section D.2.1. and section D.2.2. of Annex III) specifies that for the transitional period, such emission factors shall be based on data from the International Energy Agency and shall be provided by the EC in the CBAM Transitional Registry.

Therefore, the factors are not publicly available, but are available to declarants reporting through the CBAM Transitional Registry. The default values in the registry for the transitional period correspond to the average CO₂ emissions for the five-year period from 2016 to 2020. These default values can only be used until 31 December 2025, and for subsequent periods the default values will be updated by the EC during 2025.¹⁰⁴

It is worth noting that according to the methodology document¹⁰⁵, the IEA emission factor dataset does not contain separate average emission factors for electricity generated from fossil fuels. Instead, it contains only the average emission factor for all electricity and emission factors for individual fossil fuels. Thus, the emission factors defined for CBAM purposes can be calculated from IEA data, but are not contained in the relevant database.

Determining the actual value of the emission factor for electricity

Section 5 of Annex IV of the Regulation sets out the conditions under which actual embedded emission factors may be used for electricity imported into the EU. In this case, there is no need to use the default values of emission factors, but a number of requirements must be met:

- the amount of electricity for which the use of actual embedded emissions is claimed is covered by a power purchase agreement between the authorised CBAM declarant and a producer of electricity located in a third country;
- the installation producing electricity is either directly connected to the Union transmission system or it can be demonstrated that at the time of export there was no physical network congestion at any point in the network between the installation and the Union transmission system;
- the installation producing electricity does not emit more than 550 grammes of CO₂ of fossil fuel origin per kilowatt-hour of electricity;
- the amount of electricity for which the use of actual embedded emissions is claimed has been firmly nominated to the allocated interconnection capacity by all responsible transmission system operators in the country of origin, the country of destination and, if relevant, each country of transit, and the nominated capacity and the production of electricity by the installation refer to the same period of time, which shall not be longer than one hour;
- the fulfilment of the above criteria is certified by an accredited verifier, who shall receive at least monthly interim reports demonstrating how those criteria are fulfilled.

Moreover, if the actual emissions option is used for electricity exports from a country, this volume should be taken into account when determining the default values of CO₂ emission factors. The entire volume of electricity and the corresponding actual greenhouse gas emissions should be excluded from the calculation of emission factors for the country (section 5 of Annex IV of the CBAM Regulation).

Other provisions

In addition, Article 2(8) of the CBAM Regulation, among the conditions for the termination of the exemption for electricity imports, contains a clause (c), which provides for the termination of the exemption if the EU has evidence that an increase in electricity exports to the EU will lead to an increase in emissions per kWh of electricity produced by more than 5% compared to 1 January 2026.

104 Default values for the transitional period of the CBAM between 1 October 2023 and 31 December 2025 (December 2023), https://taxation-customs.ec.europa.eu/news/commission-publishes-default-values-determining-embedded-emissions-during-cbam-transitional-period-2023-12-22_en

105 IEA. Emissions Factors 2023. Database documentation, https://iea.blob.core.windows.net/assets/bf862218-7fd8-4637-aca6-5a347b6ca4f1/IEA_Methodology_Emission_Factors_2023.pdf

9.2 Use for Corporate Greenhouse Gas Emissions Accounting

The generally accepted standard for accounting for emissions from companies' operations is the GHG Protocol¹⁰⁶, which consists of several separate standards and guidelines, including a separate guidance for accounting for indirect emissions from electricity consumption – Scope 2 emissions.¹⁰⁷

Indirect emissions from electricity consumption are calculated by multiplying the volume of electricity consumption by the electricity emission factor (see also Section 3.5).

The average emission factors for electricity generation provided in this report can be used for the location-based calculation method. It should be emphasised that the marginal emission factors cannot be used to account for corporate greenhouse gas emissions from electricity consumption.

The emission factors for the market-based calculation under the GHG Protocol depend on the contractual instruments available on the market and may be based on the consideration of guarantees of origin for the electricity from renewable sources, emission factors for electricity generation by a specific producer in the case of a direct contract, emission factors for the selected electricity supplier or a residual emission factor if available. In the absence of any sources of information on contractual instruments, it is allowed to use the average emission factor for the grid, similar to the location-based calculation method.

In addition, the average emission factor can be used to calculate other indirect Scope 3 emissions associated with electricity losses during transmission.

Currently, corporate greenhouse gas emissions reporting in Ukraine is voluntary and is implemented by individual companies that find it important to comply with international best practices in corporate reporting and climate governance (due to lender requirements, the importance of positions in international rankings, or other reasons). Over time, however, such reporting may become mandatory, in particular, after joining the EU, which has a Corporate Sustainability Reporting Directive (CSRD).

9.3 Assessing the Effectiveness of Climate Policy

Reliable information on emission factors for electricity is necessary to determine the effectiveness of government policy measures to reduce greenhouse gas emissions. In particular, this applies to measures to develop renewable energy sources, improve energy efficiency, demand management, electrification of transport and development of electric charging infrastructure, electrification of heating, etc.

Ukrainian legislation currently does not explicitly require the use of emission factors for electricity production and consumption to assess the impact of policy measures. At the same time, recent changes to Ukrainian legislation provide for the development of nationwide weighted emission factors for greenhouse gases generated by final energy consumption in terms of CO₂ emissions. The calculation methodology must be approved by the central executive body responsible for the development and implementation of state policy in the field of environmental protection.¹⁰⁸ Although these provisions do not explicitly mention emission factors for electricity, electricity is one of the key energy types in the structure of final energy consumption.

¹⁰⁶ GHG Protocol, <https://ghgprotocol.org/>

¹⁰⁷ GHG Protocol, Scope 2 Guidance, <https://ghgprotocol.org/scope-2-guidance>

¹⁰⁸ On Amendments to Certain Laws of Ukraine on Regulation of Powers of Central Executive Authorities in the Field of Energy Efficiency, <https://zakon.rada.gov.ua/laws/show/3764-20#Text>

9.4 Use for the Needs of EU Taxonomy

An understanding of the GHG emissions for electricity generation and consumption is also important in the context of assessing the compliance of projects with the EU taxonomy or the relevant national taxonomy, if adopted.

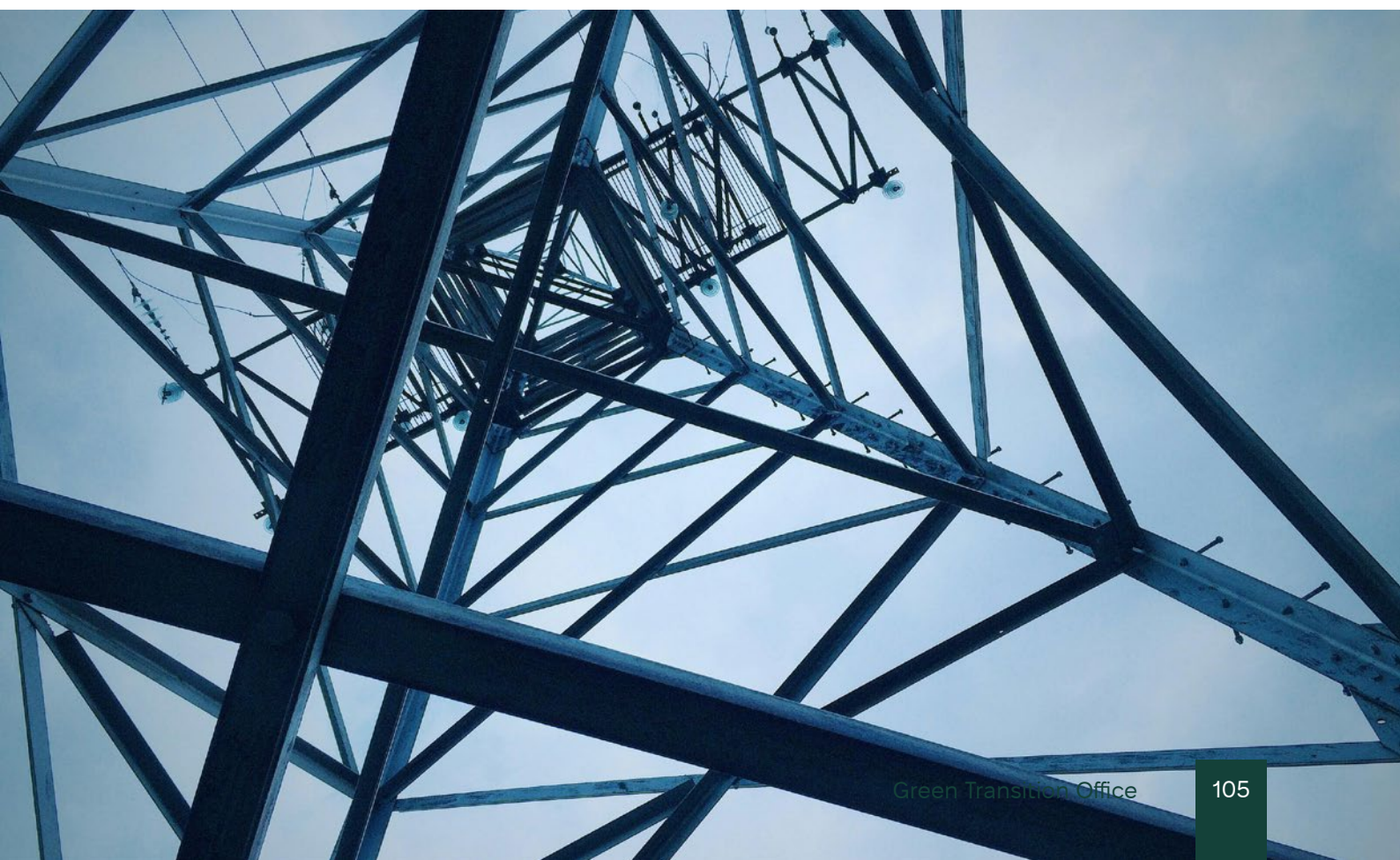
The EU taxonomy uses an emission factor for electricity production both in the context of indirect emissions from electricity consumption (e.g. for aluminium production, electricity transmission and distribution, chlorine production) and in the context of emissions from electricity production by specific installations (e.g. electrical equipment production and installation activities, hydropower production, electricity production from renewable gases and renewable fuels).

In the context of calculating emission factors for electricity, it is the first option that is important, which is discussed in more detail in the table below.

Table 14. Use of emission factors for the purposes of the EU taxonomy

Activities	Criteria
Aluminium production (subsection 3.8)	In order to make a significant contribution to climate change mitigation, primary aluminium production must meet the following criteria after 2025 (two of them before 2025): - greenhouse gas emissions do not exceed 1,484 tonnes of CO₂ eq. per tonne of aluminium produced; <u>the average indirect greenhouse gas emission factor from electricity consumption</u> does not exceed 100 g CO₂ eq. per kWh (indirect emissions are calculated based on the entire life cycle of electricity used to produce primary aluminium); - Electricity consumption for production processes does not exceed 15.5 MWh per tonne of aluminium. In order to meet the 'Do No Significant Harm' ('DNSH') criterion, the relevant thresholds are 1,604 tonnes of CO₂ eq. per tonne of aluminium produced, 270 g CO₂ eq. per kWh and 15.5 MWh per tonne of aluminium.

Activities	Criteria
Electricity transmission and distribution (subsection 4.9)	To make a significant contribution to climate change mitigation, an activity must meet one of the following criteria: • infrastructure or equipment for the interconnected European system; • more than 67% of new capacities in the system over the past 5 years have emissions below the level of 100 g CO₂ eq. per kWh, taking into account the entire life cycle; • <u>the average emission factor for grid electricity generation</u> over the last 5 years, calculated by dividing all emissions from electricity generation by grid-connected power plants by the total amount of electricity generated in the grid, is less than 100 g CO₂ eq. per kWh; • infrastructure and equipment for direct connection or extension of an existing connection between a substation or grid and a power plant. In order to meet the 'Do No Significant Harm' ('DNSH') criterion, infrastructure and equipment shall not be used to directly connect or extend an existing connection between a substation or grid and a power plant with direct emissions of more than 270 g CO₂ eq. per kWh.
Chlorine production (subsection 3.13)	In order to meet the 'Do No Significant Harm' ('DNSH') criterion, electricity consumption for electrolysis and other chlorine treatment processes should not exceed 2.45 MWh per tonne of chlorine. Average direct greenhouse gas emissions for electricity generation used for chlorine production should not exceed 270 g CO₂ eq. per kWh.





10

RECOMMENDATIONS ON THE NEXT STEPS

Based on the study, the following recommendations can be made to ensure regular estimation and publication of electricity emission factors for Ukraine, improvement and expansion of the methodological approach, and improved data quality:

- 1. Determine the authority that will be responsible for calculating and publishing emission factors for electricity** on a regular basis (e.g., the Ministry of Environmental Protection and Natural Resources of Ukraine or the National Energy and Utilities Regulatory Commission (Regulator)).

The choice of the responsible government agency should take into account institutional capacity and synergies with the area of responsibility and existing processes for collecting, analysing and publishing electricity and greenhouse gas emissions data. The designation of the responsible authority should be formalised in a relevant regulatory document to ensure sustainable data collection and publication processes.

It should be borne in mind that regardless of the choice of the authorised body, the collection of information will require cooperation and coordination of various institutions and organisations, including the State Statistics Service of Ukraine, Ukrenergo and others.

- 2. Approve the methodology for calculating emission factors for electricity by a regulatory act** defining roles and responsibilities, as well as the frequency of calculation and publication of emission factors. The methodology is proposed to be based on the methodological approach described in this study. To meet the needs of different stakeholders, the methodology should include all types of emission factors for electricity, including average emission factors for electricity generation and consumption and marginal emission factors. It is recommended to publish data on the results of calculating emission factors for electricity by the end of the year following the reporting year.

The approved methodology can be updated and improved, taking into account further development of the power system and the process of restoring power capacities, in particular in terms of determining the group of low-cost/must-run power plants, determining the built margin emission factor and the combined marginal emission factor, as well as covering power plants and cogeneration units of enterprises (autoproducers).

- 3. Share the methodology and results of the emission factor calculations** with interested bodies and organisations, including the European Commission, to discuss the possibility of using the national average emission factor as an emission factor for electricity for the purposes of the Carbon Border Adjustment Mechanism. Other stakeholders could include the IFI Technical Working Group (TWG) on GHG Accounting and the Covenant of Mayors on Climate & Energy secretariat to incorporate the results into relevant databases and guidelines.

- 4. Work to improve the energy statistics system and the consistency of different data sources.** As the data used for the calculation are currently collected by different authorities and using different methods, there are quite significant differences and a high degree of uncertainty, exacerbated by different classifications, different approaches to coverage in different years, errors and other factors. In particular, it is necessary to agree on and use common classifications of power plant types, distinguishing between main activity producers and autoproducers, fuel types and their characteristics, and defining certain parameters, etc. In case of different coverage of the information collection system (e.g., due to the inclusion of only the Regulator's licensees), the differences in coverage of installations with other statistical data collection systems should be clearly outlined. In addition, it is advisable to harmonise the timeframe for collecting and processing information to synchronise the periods of availability of data from different sources for calculating emission factors for electricity and publishing the data within 12 months after the reporting period. Additional recommendations on data disaggregation are also provided in section 6.4.

Such an analysis can also identify opportunities to optimise statistical data collection by taking into account the needs of different government agencies and avoiding parallel data collection processes.

It is also necessary to consider the improvement of the energy statistics system and the identified optimal sources of information on electricity generation and supply by type of power plant and other indicators when developing energy balances and filling in the IEA questionnaires, as these questionnaires are the basis for calculating emission factors published by the IEA in accordance with the methodology common to all countries.

- 5. Investigate the possibility of using data from individual plants to calculate emission factors.** For a more accurate calculation of emission factors for electricity, it is necessary to use data from individual power plants or power units, rather than groups of power plants, on fuel consumption, electricity output, heat output (in the case of combined heat and power production) and other indicators. Such an approach will allow for a more accurate accounting of the technical and technological features of electricity generation in Ukraine, in particular, at CHP plants. In addition, this approach may create conditions for including data from power plants of enterprises in the calculation. At the same time, the implementation of this approach will require processing of primary reporting data and can best be achieved with the introduction of electronic systems for automated data analysis.

The use of data from individual plants and installations will also allow the calculation of a simple adjusted operating margin, which can more accurately take into account the specifics of the power system. As a result, the value of the marginal emission factor will be more accurate and lower than the specific emissions from thermal power plants alone.

- 6. Expand the scope of emission factors** to include other greenhouse gases (CH_4 and N_2O), including their emissions from biomass combustion. Information on emission factors may be published separately broken down by greenhouse gas, as well as in the form of a total emission factor in CO_2 equivalent. The inclusion of CH_4 and N_2O emissions from biomass combustion will require improved accessibility of data on the use of different types of biomass and biogas for electricity production. For transparency purposes, it is also necessary to include information on the global warming potential indicators that will be used in the calculations.
- 7. Integrate the use of emission factors into the assessment of the results of the implementation of state policy measures** in the field of energy efficiency and renewable energy, as well as individual projects, including public investments. Examples of measures and policies for which it is important to consider the emission factors for electricity are the development of electric mobility, electrification of urban passenger transport and rail transport, energy efficiency measures in industry and buildings etc.
- 8. Increase the transparency and openness of information in the energy sector**, taking into account the restrictions related to the legal regime of martial law and national security. Increasing transparency and openness of information in the energy sector concerns not only the publication of data in the public domain, but also the exchange of information between different statistical data owners to ensure consistency of data on fuel consumption, electricity and heat production and supply. Considering the potential commercial sensitivity of some data, the dissemination of information in the public domain and between different authorities may be in an aggregated form, but with the possibility of distinguishing groups of power plants and fuel types that meet the needs of different users.

