Methodology for Calculating Greenhouse Gas (GHG) Emission Factors for Electricity (2026)

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Introduction

This document outlines the methodology used to calculate Greenhouse Gas (GHG) emission factors for electricity generation, transmission and distribution (T&D) wire losses, well-to-tank (WTT) lifecycle inputs, and residual mix factors across global energy grids.

This methodology document accompanies the 2026 GHG emission factors published on CaDI, Carbon Data Intelligence (https://www.carbondi.com), and should be consulted when using these factors for GHG accounting, corporate carbon disclosure, and compliance review. These factors are designed to support organisations and individuals in compiling robust, traceable carbon inventories that can support audit review and transparent reporting.

Data Availability

The calculated GHG emission factors are made available via commercial subscription license for use in corporate GHG inventory reporting, target setting, and Net Zero pathway design.

Granular data is provided for over 200 countries. Specific data for the UK, Canada, the US[1], and Australia are provided at sub-national levels (e.g., state or province) to reflect distinct geographic grid boundaries.

Updates from the 2025 Emissions Factor Methodology

To align with evolving international sustainability reporting standards, such as CSRD and SECR, Carbon Footprint Ltd has implemented an upgrade to its methodology for the 2026 factor set. The 2025 methodology relied on calculating global production factors from fuel fractions using generalised, static power station efficiencies. The 2026 release transitions to direct localised operational tracking data where available, improving database accuracy, geographical fidelity, and audit traceability:

1. **Direct Local Generation Efficiencies:** Previously, operational generation factors were manually calculated by applying rigid UK Government (Defra) combustion constants to global fuel percentages, adjusted by static efficiency indicators. For 2026, we utilize direct operational carbon intensities from Ember, which natively capture the real-world thermodynamic efficiencies and specific fuel grades (such as lignite versus anthracite coal) unique to each nation's thermal fleet.
2. **Comprehensive CO_2e Scaling:** The 2026 grid methodology integrates dynamic combustion gas uplift metrics to explicitly incorporate methane (CH_4) and nitrous oxide (N_2O) volumes, establishing full CO_2e accounting at the generation baseline.
3. **Streamlined Residual Mix Engineering:** Moving away from back-calculations of residual percentages, the 2026 model directly utilizes the global data tables provided via the tracking standard registries (AIB and the unified International I-Track frameworks). These baseline values are upscaled based on the fuel mix for each country to incorporate non-CO_2 gases for Scope 2 reporting.

[1] Due to the delay in EPA (eGrid) publishing USA Regional data, the US regional data is not available in time for this years initial release of the 2026 factors.

4. **Dynamic Scope 3 Separations:** Our Scope 3 Transmission & Distribution (T&D) loss models now systematically calculate country-specific up-to-date data for national grid loss statistics from the World Bank and Eurostat.

Data Sources

The following data repositories have been used to compile the 2026 emission factor database:

- **Electricity Production & Generation Mix Data**: Sourced directly from Ember's comprehensive global electricity dataset for the 2026 release, using the latest verified calendar-year grid operations available for each geography, primarily 2024 operating data.
- **UK Grid (National Override):** Grid average electricity conversion factors for the United Kingdom are sourced directly from the UK Government's official dataset published by the Department for Energy Security and Net Zero (DESNZ / Defra) for the current reporting cycle. Because the UK Government has moved to an accelerated timeline incorporating newer 2025 energy mix metrics and distinct interconnector import boundaries, the calculated Ember-pipeline values for the UK are overwritten with the official national published figures to maintain alignment with domestic UK statutory reporting schemes.
- **International Residual Mix Parameters:** Sourced directly from the Association of Issuing Bodies (AIB) annual dataset for European networks and the I-TRACK Foundation tracking standard repositories via ResidualMix.org.
- **GHG Conversion Ratios and Upstream Constants:** Baseline fuel combustion properties, non-CO2 gas configurations, and upstream fuel supply chain vectors are derived from the UK Government's Department for Energy Security and Net Zero (DESNZ / Defra) standard environmental disclosure parameters, which are based on IPCC AR5 (Fifth Assessment Report) 100-year Global Warming Potentials (CH_4 = 28, N_2O = 265).
- **National Grid Delivery Infrastructure & Distribution Losses:** Local transmission and distribution network losses are extracted dynamically from the World Bank Open Data repository (*"Electric power transmission and distribution losses (% of output)"*) and Eurostat regional grid balance sheets, providing localized loss factors.
- **Sub-National Advanced Registries:** Local state and provincial metrics are compiled directly from originating government bodies, including the Australian Government (by State), and the Government of Canada (by Province).

Calculation Methodology

Our multi-tiered data pipeline processes raw physical inputs through sequential calculation loops to output separate, unblended factors for corporate Scope 2 and Scope 3 compliance:

1. Scope 2 Market-Based & Location-Based Generation Factors ($kgCO_2e/kWh$)

The foundation of the generation factor reflects the physical carbon intensity exiting the plant stack line, factoring in localized operational configurations:

- **Baseline Capture:** Raw country-specific generation intensities (gCO_2/kWh) are extracted from Ember or the relevant tracking authority (AIB/I-TRACK). For renewables (such as geothermal and hydro), these figures accurately include natural non-condensable gas venting and reservoir biogenic outgassing metrics.
- **CO_2e Upscaling:** To align with GHG Protocol reporting principles, a fuel-weighted combustion gas expansion ratio is applied to the baseline data. This integrates the global warming potential of CH_4 and N_2O gases into the final generation factor:

  $$\text{Scope 2 Factor } (kgCO_2e/kWh) = \text{Raw Operational } CO_2 \text{ Factor} \times \text{Combustion Gas Uplift Multiplier}$$

  The Combustion Gas Uplift Multiplier is calculated using IPCC AR5 100-year Global Warming Potentials: $CH_4 = 28$ and $N_2O = 265$. In line with the GHG Protocol Corporate Standard's requirement to disclose the GWP source used, all factors in this dataset are calculated on an AR5 basis.
- **Zero-Emission Sources:** True wind and solar energy sources are assumed to have zero direct operational GHG emissions.

2. Scope 3 Well-to-Tank (WTT) Generation Factors ($kgCO_2e/kWh$)

To capture upstream Scope 3 lifecycle activities under Scope 3 Category 3: fuel- and energy-related activities, we account for the energy expended to extract, process, refine, and transport fuels before combustion. This is modelled by mapping each country's residual or production fuel fraction against upstream well-to-tank (WTT) factors for each fuel type.

$$\text{Scope 3 WTT Factor} = \sum (\text{Fuel Share \%} \times \text{Fuel-Specific Upstream WTT Constant})$$

3. Scope 3 Transmission & Distribution (T&D) Loss Factors ($kgCO_2e/kWh$)

When electricity travels across grid wires, energy is lost as heat. A consumer must account for the emissions of the extra power generated to cover this loss. The physical grid loss percentage (L) for each nation is used to compute this standalone Scope 3 overhead:

$$\text{Scope 3 T\&D Loss Factor} = \text{Calculated Scope 2 Generation Factor } (CO_2e) \times \left(\frac{L}{1-L}\right)$$

4. Residual Mix Emissions Calculation

Residual mix emission factors are calculated from residual mix fuel data provided by the Association of Issuing Bodies (AIB) and the I-TRACK Foundation for countries listed in these databases. They are intended for market-based Scope 2 electricity reporting where contractual instruments, supplier-specific factors, or certificate-backed claims are absent or incomplete. Where residual mix data is not available, the generation emission factor for that location is provided as a fallback, and users should document the basis for factor selection.

5. Special Adjustments: Addressing Regional Data Anomalies (The Israel Protocol)

International open-source energy repositories occasionally experience localized tracking interruptions when a country undergoes rapid, complex grid structural overhauls. A notable example occurs within the Ember tracking framework for Israel, where absolute emission totals

and derived carbon intensities (gCO_2/kWh) have remained unpopulated in their master data files since 2018. This data gap is primarily driven by changes in local accounting definitions following Israel's swift transition toward offshore natural gas and highly integrated industrial co-generation (CHP) networks, creating classification conflicts regarding specific oil-to-gas fuel blending volumes.

To maintain a completely uninterrupted global dataset for our commercial subscribers, Carbon Footprint Ltd deploys a mathematical proxy loop for Israel:

- **Asset Fraction Extraction:** We extract the raw physical electricity generation volumes (expressed in TWh) that remain fully tracked and verified by Ember for Israel.
- **Algorithmic Fuel Mapping:** Our pipeline isolates these underlying generation fractions (Gas, Coal, Solar, etc.) and maps them directly through our core 2026 calculation loop.
- **High-Fidelity Synthesis:** By applying localised combustion constants, dynamic CO_2 to CO_2e gas uplifts, and country-specific Scope 3 expansions directly to these verified generation shares, we synthesise a complete suite of factors. This helps avoid blank database fields while maintaining a transparent and mathematically documented methodology.

Potential Limitations & Data Quality Indicators (DQIs)

In corporate carbon accounting, transparency and data consistency are important for audit review and reporting confidence. Users should note the following structural boundaries within this dataset:

1. **Temporal Data Lag:** In alignment with standard tracking protocols used by international bodies, the 2026 data tables generally use empirical grid observations compiled from the 2024 operating year. This reflects the time required for international registries to collect, verify, and reconcile country-wide data inputs. Where 2024 data is unavailable or where a recognised exception applies, the latest suitable verified data year is used and should be interpreted in line with the accompanying database notes.
2. **Upstream Supply Chain Proxies:** While generation efficiencies and network line losses are completely country-specific, upstream fuel extraction (WTT) constants utilize a global fuel-fraction proxy model due to the extreme complexity of tracking real-time international coal and gas shipment routes.
3. **Physical vs. Contractual Boundaries:** Location-based factors focus on physical generation boundaries. Conversely, residual mix factors account for virtual attribute transactions, such as Guarantees of Origin or I-RECs. Users should apply dual reporting as required by the GHG Protocol, keeping location-based and market-based inventories separate.

Methodological Boundaries

These factors are provided as technical inputs for greenhouse gas accounting and reporting. They do not constitute legal, tax, regulatory, or assurance advice. Users remain responsible for selecting the appropriate factor for their reporting purpose, jurisdiction, organisational boundary, contractual electricity claim, and applicable reporting framework.

Residual Mix Emissions and System Discrepancies Explained

The Core Concept

Residual mix emission factors are based on the fuel sources that remain after accounting for all claims on specific energy generation. The residual mix typically contains a higher share of high-carbon fuels like coal and gas than the grid average mix. This means that the emission factors of the residual mix are usually higher than those of the grid average mix.

Tracking mechanisms, such as Guarantees of Origin (GOs) in Europe or Renewable Energy Certificates (RECs) in other regions, are used to certify and track the generation and sale of renewable electricity. Residual mix emission factors should be used for market-based Scope 2 electricity reporting where supply-specific factors, contractual instruments, or certificate-backed claims are not available or are incomplete.

Why Operational Grid Factors for 100% Renewable Systems Can Be Greater Than Zero (The Iceland Phenomenon)

A common point of confusion in carbon accounting is why a nation whose physical grid infrastructure is virtually 100% renewable can still carry a non-zero emission factor in tracking databases. This occurs due to two distinct realities: one physical and one contractual.

A. Physical Operational Realities

Even in pure production tracking models (such as Ember's generation-based datasets), renewable assets are rarely absolute zero-emission generators during operation. Taking **Iceland** as a prime example:

- **Geothermal Outgassing:** Approximately 30% of Iceland's grid is powered by volcanic geothermal energy. Tapping underground volcanic steam reservoirs naturally releases deep-seated, non-condensable gases trapped in the bedrock. As a result, small volumes of natural carbon dioxide CO_2 and methane CH_4 are continuously vented through the turbines, averaging a low but distinct operational footprint of ~38 gCO_2/kWh globally.
- **Hydropower Reservoir Flooding:** The remaining ~70% of Iceland’s power is derived from hydro installations. The creation of large hydro reservoirs floods organic valley vegetation. Over decades, this organic matter decays anaerobically underwater, generating methane bubbles that rapidly vent into the atmosphere when the water passes through the pressure drop of the power station turbines.

B. Contractual Attribute Realities (Market-Based Deficits)

When analyzing the **Residual Mix** or **Total Supplier Mix** via regulatory tracking frameworks like the Association of Issuing Bodies (AIB) or the tracking standard registries (ResidualMix.org), the factor rises even higher due to market-based attribute trading:

- **The Attribute Deficit:** Iceland virtually exports all its "greenness" by selling Renewable Energy Guarantees of Origin (GOs) to corporate buyers in mainland Europe.

- **The European Attribute Mix (EAM):** To prevent double-counting under market-based Scope 2 rules, once Iceland sells those certificates abroad, the green attribute leaves the island. The AIB is contractually obligated to fill Iceland's untracked residual grid with the leftover statistical attributes of mainland Europe—which are heavily composed of fossil fuels and nuclear tracking balances.

Therefore, for **Location-Based** metrics, the grid carries a tiny, physical non-zero factor due to geothermal/hydro outgassing; for **Market-Based** reporting, it carries a substantial fossil-fuel footprint unless the reporting company explicitly buys and cancels domestic Icelandic green certificates.

Units and Inventory Calculations

The reported GHG emission factors are expressed in kilograms of carbon dioxide equivalent per kilowatt-hour ($kgCO_2e/kWh$). This represents the amount of GHG emissions associated with generating and delivering one kilowatt-hour of electricity.

To convert consumption metrics directly into absolute corporate inventory tonnes (tCO_2e), environmental analysts must apply the following standard formula:

tCO_2e = Electricity Consumption in kWh x Emission Factor in $kgCO_2e/kWh$ / 1,000

Complete Boundary Example:

A facility operating within a country possesses an annual electricity meter reading of **100,000 kWh** on an untracked tariff, with the 2026 CaDI database indicating the following factors:

- **Scope 2 Generation Factor:** 0.40000 $kgCO_2e/kWh$
- **Scope 3 WTT Factor:** 0.05000 $kgCO_2e/kWh$
- **Scope 3 T&D Loss Factor:** 0.03500 $kgCO_2e/kWh$

Inventory Entry

Scope 2 Market-Based (Generation) = (100,000 x 0.40000) / 1,000 = 40.00 tCO_2e

Scope 3 Category 3 (WTT Input) = (100,000 x 0.05000) / 1,000 = 5.00 tCO_2e

Scope 3 Category 3 (T&D Losses) = (100,000 x 0.03500) / 1,000 = 3.50 tCO_2e

Annual Updates and Temporal Considerations

The emission factors are typically calculated using electricity generation data from two years prior. For the 2026 database release, the primary target baseline is the **2024 calendar year operating data** sourced via Ember. However, due to variable international reporting deadlines, data availability, and specific country-level exceptions, a tiered preference structure is applied:

The emission factors are typically calculated using electricity generation data from two years previous. For the 2026 database release, the primary target baseline is the **2024 calendar year operating data** sourced via Ember. However, due to variable international reporting deadlines and data lag, a tiered preference structure is applied:

- For major industrial and data-complete nations, **2024 data** is applied.

- For smaller, remote, or island economies (e.g., Bermuda, Falkland Islands, Comoros, Vanuatu) where 2024 matrices are not yet finalized, the database automatically references the latest available **2023 data arrays**.
- For specific geopolitical or grid-disrupted regions where historical baselines do not reflect current operating reality (explicitly **Ukraine**), the latest **2025 data profiles** are integrated.

This approach aligns with the standard practice followed by international governmental bodies, recognizing the time lag in data availability and reporting.

Frequently Asked Questions (FAQ) & Compliance Guidance

FAQ 1: Why do CaDI's grid average generation factors sometimes differ from the raw intensities published by Ember?

While CaDI utilises Ember's global energy tracking arrays as a primary structural input, final published metrics may be higher where boundary expansions are applied for corporate reporting:

1. **The CO_2 vs. CO_2e Expansion:** Ember tracks direct CO_2 stack emissions. To align with the GHG Protocol Corporate Standard, CaDI applies dynamic combustion gas uplifts to integrate the global warming potentials of methane (CH_4) and nitrous oxide (N_2O) - see AR5 basis, page 4.
2. **Boundary Harmonisation:** CaDI cross-references and adjusts baseline denominators using gross/net generation reporting alignments where appropriate, supporting a more consistent translation of raw energy data into corporate emission profiles.

FAQ 2: Why do CaDI's factors differ from country-specific government published factors (e.g., UK Defra vs. Ember)?

Divergences between international data tools and specific national government publications are almost always driven by **interconnector accounting boundaries**.

For instance, the UK Government (DEFRA/DESNZ) includes imported electricity in its default grid factor. In recent years the UK has imported significant volumes of lower-carbon electricity from France (nuclear) and Norway (hydro), which heavily diluted the domestic denominator and pulled the official DEFRA factor down significantly. Conversely, production-based models like Ember isolate the physical emissions of power stations operating strictly on domestic soil. CaDI utilizes unblended production baselines to ensure your underlying fuel-fraction metrics remain completely synchronized, preventing the accidental double-counting of cross-border certificate attributes.

FAQ 3: When is it best to use CaDI factors versus national government-issued factors?

- **Use Government Factors (Location-Based):** When a company is reporting standard **Scope 2 Location-Based** footprints inside a country whose government mandates a specific localized calculation tool for national compliance schemes (e.g., using DEFRA factors for standard UK operations, or EPA eGRID factors for the US).
- **Use CaDI Factors (Market-Based & Scope 3):** CaDI is a useful source for **Scope 2 market-based** accounting through AIB and I-TRACK residual mix datasets, and for comprehensive **Scope 3 Category 3: fuel- and energy-related activities** data. Many national governments do not calculate international residual mixes or provide country-specific, fuel-fraction-dependent well-to-tank (WTT) and transmission and distribution (T&D) loss factors. CaDI helps fill these tracking gaps and can support audit review when applied with appropriate documentation.

FAQ 4: How should our organization handle the year-on-year variance caused by CaDI's 2026 methodology upgrade?

Moving toward higher-precision data pipelines can occasionally affect historical timeline consistency, as the 2026 model integrates localised power station efficiencies rather than generalised regional proxies. Under **Chapter 5 of the GHG Protocol Corporate Standard**, organisations tracking progress against a fixed environmental baseline should avoid mixing historical proxy-derived data with modern asset-specific profiles without documenting the recalculation approach. To support consistency, clients can license (via purchasing) retroactively processed historical tracking sets compiled under the new 2026 logic, allowing base year inventories to be updated cleanly and consistently.

FAQ 5: What are "Full Disclosure" countries and how do they impact our factor selection?

Certain European jurisdictions (including Austria, Switzerland, and the Netherlands) operate under a strict "Full Disclosure" regulatory framework. In these economies, all electricity generation is legally required to be tracked via certificates, leaving no "untracked" generic power on the grid. Consequently, a **Residual Mix factor ceases to exist** for these nations. For operations within Full Disclosure countries, corporate entities that do not purchase specific green certificates are contractually required by market regulators to utilize the **Total Supplier Mix** factor provided in our database rather than a traditional residual mix factor.

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