CREA EU CO2 Tracker Methodology

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Overview

The CREA EU CO2 Tracker estimates the CO2 released by burning fossil fuels in the EU, with results available sooner than complete official annual statistics. It combines reported energy data with other timely datasets to fill reporting gaps, then converts the estimated use of coal, oil and gas into emissions. Recent estimates rely more heavily on assumptions and projections and may therefore be revised as more complete data become available.

The tracker covers emissions from fossil-fuel combustion. It does not cover emissions from industrial processes that do not involve fuel combustion, agriculture, or land use, land-use change and forestry (LULUCF).

Weather correction - The tracker provides weather-corrected estimates that adjust for the influence of meteorological conditions (temperature, wind, solar irradiance) on energy demand and renewable generation, allowing users to isolate underlying emission trends.

1. Fossil fuel consumption

Energy statistics generally report how much fuel is supplied or used rather than the resulting CO2 emissions. We therefore first estimate the consumption of coal, oil and gas, including which sectors use them. This section explains which fuel categories are included and how overlapping records are reconciled so that the same fuel is not counted twice.

Fossil fuel consumption is derived from EUROSTAT's Supply, Transformation, and Consumption data[1], separated into three categories: solid, liquid and gas.

1.1 Solid Fossil Fuels

Coal statistics include both raw fuels and products made from them. The method therefore follows fuels through transformation processes, such as the conversion of hard coal into coke, and adjusts overlapping records so that the same carbon is not counted more than once.

We included the following solid fossil fuels:

- Hard coal
- Brown coal
- Coke oven coke
- Brown coal briquettes
- Peat
- Oil shale

During the **coking process**, hard coal is transformed into coke oven coke, with coke oven gas generated as a byproduct. To avoid double counting while still accounting for all emissions, we analyzed the relationship between hard coal inputs and resulting energy content. We estimate that coke oven gas emissions downstream represent approximately 8% of the equivalent hard coal emissions. Therefore, we retain 8% of the coal input to coking plants in our accounting to represent these coke oven gas emissions, while subtracting the remaining 92% to prevent double counting with the coke oven coke that is tracked separately in consumption statistics.

1.2 Liquid fossil fuels

Oil is reported through both broad totals and specific products such as petrol, diesel, fuel oil and jet fuel. We use the detailed categories where available, reconcile them with aggregate totals, and remove biofuel quantities and other overlaps so that the estimate represents fossil oil consumption only.

The tracker accounts for these key oil products:

- Oil products (aggregate): The overall category encompassing all petroleum products
- Fuel oil: Heavy residual oil used in industry and shipping
- Heating gasoil: Oil used primarily for heating in buildings and industry
- Road diesel: Diesel fuel used in road transportation
- Motor gasoline: Gasoline used primarily in road transportation
- Jet fuel (kerosene): Fuel used in aviation
- Aviation gasoline: Specialized gasoline for small aircraft
- Oil used for electricity and CHP heat production is included; fuel oil and heating gasoil volumes used in these sectors are deducted from aggregate oil power rows to avoid double counting.

We also track **biofuels** (biogasoline and biodiesel) to subtract them from fossil fuel totals and assume no associated emissions for those.

1.3 Gas fossil fuels

Gas emissions are mainly estimated from fossil gas, with coke oven gas also included where it is produced and consumed. As with solid and liquid fuels, the aim is to count the fossil fuel ultimately used without double counting fuels produced through transformation processes.

The tracker accounts for the following gaseous fuels:

- Fossil gas
- Coke oven gas.

2. Missing-data imputation

Official energy data arrive at different times and with different levels of detail. Annual data are more complete but substantially delayed, while monthly data are available sooner but contain more gaps and fewer sector categories. To produce recent estimates, the tracker follows a hierarchy that uses reported data where possible, then fills the remaining gaps using historical relationships, external indicators and statistical forecasts.

Our approach follows a hierarchical structure, applying imputation method in the following order:

2.1 Sectoral attribution in monthly data

Monthly statistics do not always identify which sectors used a fuel. We therefore allocate recent consumption to sectors using patterns observed in detailed annual data. Statistical analysis of historical data shows strong correlations and minimal year-to-year variation. These assumptions apply only to recent monthly data and are replaced when detailed yearly figures become available, typically after a delay of 1–2 years.

Aggregate 'all' rows are removed when disaggregated sector rows exist. Residuals are assigned to 'others' only when all known sub-sectors are available; otherwise, they are marked as 'unknown'.

2.1.1 Oil products and transport

- **Motor gasoline and diesel allocation**: A constant proportion of a country's gasoline and diesel supply (after excluding petrochemical use) is used for road transportation (a distinct proportion per fuel and country is applied).
- **Aviation fuel distribution**: The split between domestic and international aviation for kerosene-type jet fuel is assumed to be constant year-on-year for each country. Similarly, aviation gasoline is almost exclusively used for domestic flights, with this pattern holding steady over time.
- **Transport fuel composition**: Motor gasoline, road diesel, and kerosene together account for the vast majority (typically >95%) of transport sector oil consumption. This consistency allows us to estimate total transport emission trends from these major components.

- **Non-energy use**: The proportion of oil products used for non-energy purposes (like chemical feedstocks) relative to total deliveries is constant for each country.

2.1.2 Fossil gas

- **Non-energy use of gas**: For petrochemical feedstock use, we apply the historical ratio between non-energy use and total gas consumption from annual data.

2.2 Filling data gaps

Some reported series contain isolated gaps, discontinued reporting or apparent anomalies. We apply the least intrusive suitable correction in each case, such as treating a missing value as zero, interpolating a short gap, or applying a documented country-specific adjustment supported by another data source.

2.2.1 Zero-Value Imputation

When a country reports consecutive small values (below the 5th percentile for that fuel x country) followed by missing data, we impute zeros. This approach is particularly useful for countries phasing out certain fuels (e.g., Slovenia's hard coal use for electricity) which stop publishing figures.

2.2.2 Interpolation for Stable Consumption Patterns

For countries with stable consumption patterns (coefficient of variation < 10%), we use interpolation to fill small gaps (up to 3 months). This method is applied for instance with coking coal in Finland.

2.2.3 Manual Fixes for Reporting Issues

Country-specific fixes are applied for manually detected reporting anomalies (e.g., France's intermittent reporting of hard coal for electricity, Greece wrongly declaring that none of its brown coal is used for electricity). These fixes are based on cross-validation with other data sources (e.g., ENTSOE power generation data).

2.3 EU Aggregation for the latest months

An EU total can sometimes be estimated before every member state has reported. When EU-level data are missing, available member-state data can be used to estimate the EU total where historical agreement is sufficiently strong and country coverage is adequate.

For the latest EU months, estimates may also be stabilized using member-state sums where historical agreement remains close. Alternatively, seasonal year-on-year ratios are used where backtesting shows that they outperform a Holt-Winters forecast. Where both approaches are suitable, the validated member-state sum takes precedence.

2.4 Proxy-Based Projections

For the newest months, direct Eurostat observations may not yet be available. We then use faster indicators that measure related activity, such as electricity generation, gas demand or industrial production. A proxy is used only when historical data show that it tracks the relevant fuel use or emissions series closely enough.

2.4.1 Power Generation from EMBER and ENTSO-E

Electricity sector emissions are projected using monthly power generation data from EMBER. ENTSO-E daily data is scaled to Ember monthly totals and adjusted to Ember yearly totals; scaling ratios are outlier-filtered with MAD and extended with ETS or last-value carry-forward. Ember-only fallback series are distributed uniformly across days. Peat is separated internally; peat and oil electricity are projected using the 'Other fossil' power proxy, then recombined into coal.

Imputation is performed when the power generation and emissions trends demonstrate a strong linear relationship ($R^2 > 0.7$).

2.4.2 Gas Consumption from ENTSO-G

Daily gas demand is estimated from several ENTSOG-based approaches, including reported consumption and distribution flows and apparent demand from imports, production and storage changes. An additional apparent-demand estimate uses AGSI storage data.

Candidate series are retained only where they closely match historical Eurostat data (R^2 > 0.95 and RRSE < 0.3). The selected series is then used as a proxy for gas-sector emissions, subject to the standard proxy projection threshold of R^2 > 0.7.

2.4.3 Industrial Production Indices

Industrial coal and oil use is projected using monthly industrial production indices. Sector-specific indices (e.g., iron and steel, chemicals) are matched to relevant fuel types, capturing economic activity impacts on emissions beyond the power sector. Proxy projection functions use a threshold of min_r2 = 0.7.

2.5 Time Series Forecasting with Uncertainty

Where no sufficiently reliable external indicator is available, recent values are projected from the historical series itself using statistical time series models that incorporate seasonal patterns, longer-term trends and recent observations. Confidence intervals reflect increasing uncertainty for longer projection periods. Models are recalibrated and projections are replaced as new reported data become available.

3. Weather Correction

Weather can cause emissions to rise or fall even when underlying behaviour, economic activity and technology have not changed. Cold weather can increase heating demand, while wind, sunshine and water conditions affect renewable generation and therefore the amount of fossil power required. Weather-corrected estimates remove the modelled effect of unusual weather so that changes between periods are more directly comparable.

3.1 Purpose and Approach

Weather correction does not replace observed emissions with a wholly modelled estimate. It starts with the actual value and adjusts only the component that the statistical models associate with weather, preserving the remaining difference between the observed and fitted values. “Normal weather” means the historical average conditions for the same time of year.

Methodology distinguishes between demand-component Generalized Additive Models (GAMs) used for decomposition and the direct CO2 weather-correction path. CO2 weather correction utilizes linear models: electricity demand includes HDD/CDD, weekday, and HDD/CDD-by-year terms; gas demand uses weekday, gas-fired power generation, and HDD predictors.

The correction is:

$$corrected = actual + (fitted\_normal\_weather - fitted\_actual\_weather)$$

The fitted values come from the statistical models described below.

3.2 Demand Correction

Weather affects energy demand primarily through heating and cooling. Separate models estimate how electricity demand and non-power gas demand respond to temperature, while accounting for recurring patterns such as differences between weekdays. The difference between estimated demand under actual and typical weather provides the correction.

3.2.1 Electricity Demand

Electricity demand is represented by ENTSO-E total electricity generation. For the direct CO_2 weather correction, this series is corrected using a linear regression model:

$$demand \sim HDD + CDD + weekday + HDD{:}year + CDD{:}year$$

where:

- HDD (Heating Degree Days): captures increased demand during cold periods
- CDD (Cooling Degree Days): captures increased demand during hot periods
- weekday: controls for weekly consumption patterns

Daily correction factors are computed by comparing fitted demand at actual weather versus fitted demand at climatological average weather (mean HDD/CDD for each day-of-year over the historical period).

Separately, the corrected-demand / demand-components workflow decomposes electricity demand using a GAM:

demand ~ s(date) + s(date, by = HDD) + s(date, by = CDD) + weekday + HDD:weekday + CDD:weekday

Components are calculated using counterfactual predictions:

- Other demand is predicted with HDD and CDD set to zero.
- Heating demand is the additional fitted demand associated with HDD.
- Cooling demand is observed demand minus the prediction with CDD set to zero. Model residuals are therefore included in the cooling component.
- Weather-corrected heating and cooling replace actual HDD and CDD with their climatological day-of-year means. Other demand is unchanged.

3.2.2 Gas Demand Correction and Decomposition

For weather-corrected CO_2 emissions, gas demand outside the power sector is corrected using a linear model.

demand ~ weekday + gas_power_generation + HDD

The model is fitted using observed gas-fired power generation. For the weather correction, fitted demand under actual and climatologically normal weather is calculated with gas-fired power generation set to zero. The corrected value is:

corrected = actual + (fitted_normal_weather - fitted_actual_weather)

This isolates the estimated weather effect on non-power gas demand while preserving other differences between observed and fitted demand.

Separately, the corrected-demand / demand-components workflow decomposes gas demand using a GAM:

demand ~ s(date) + s(date, by = HDD) + weekday + HDD:weekday + gas_power_generation

Components are calculated using counterfactual predictions:

- Non-heating demand is predicted with HDD and gas-fired power generation set to zero.
- Power-sector gas demand is the difference between predictions using actual and zero gas-fired power generation, with HDD set to zero.

- Heating demand is observed demand minus predicted demand with HDD set to zero and actual gas-fired power generation retained. Model residuals are therefore included in the heating component.
- Weather-corrected heating demand replaces actual HDD with the climatological mean HDD for that day of the year. The non-heating and power-sector components are unchanged by weather correction.

3.3 Renewable Generation Correction

Weather affects the amount of electricity generated from wind, solar and hydropower. The method estimates what generation would have been under typical conditions, using an approach suited to each technology.

3.3.1 Wind

Wind generation is corrected using a Gradient Boosting Machine (GBM):

$$generation \sim year + ws + ws^2 + ws^3 \times inv\_temp$$

where:

- **ws**: wind speed at 50m (from NASA POWER)
- **inv_temp**: inverse temperature (1/K), capturing air density effects on turbine output
- **year**: accounts for capacity additions over time

Weather variables are collected at turbine locations identified in the Global Energy Monitor wind tracker. Because the model is non-linear, weather-corrected generation is computed by averaging predictions across all historical weather conditions for each day-of-year, rather than predicting at average weather.

3.3.2 Solar

Solar generation is corrected using a GBM:

$$generation \sim year + solar\_radiation$$

where **solar_radiation** is surface solar irradiance from ERA5 (direct + diffuse). The same averaging approach as wind is applied to handle non-linearity.

3.3.3 Hydropower

Hydro generation is normalized using historical capacity factors rather than a weather model. Unlike wind and solar, hydro output depends on factors operating over longer timescales: seasonal precipitation, snowmelt timing, glacier melt, reservoir management, and competing water demands (irrigation, cooling). These factors make daily weather-based correction impractical.

Instead, we normalize to average capacity factor over the historical period (since 2015):

$$corrected = actual \times (average\_CF / actual\_CF)$$

This approach removes year-to-year hydrological variability but does not isolate specific meteorological drivers.

3.4 Power Sector CO2 Correction

A weather-related change in renewable generation affects emissions through the fossil-fuel generation that it replaces. We translate the estimated renewable correction into an equivalent change in thermal generation and use this to adjust power-sector CO2. Safeguards limit implausible corrections in countries where thermal generation is very low.

Weather-corrected renewable generation is converted to a CO2 correction factor by assuming 1 MWh of additional renewable generation displaces 1 MWh of thermal generation:

$$thermal\_corrected = thermal\_actual - (renewable\_corrected - renewable\_actual)$$

The correction factor is the ratio of weather-corrected thermal share to actual thermal share:

$$correction\_factor = thermal\_share\_corrected / thermal\_share\_actual$$

To avoid unreasonable results in countries with very low thermal generation, corrected thermal generation is capped at the maximum observed since 2015.

3.5 Combined CO2 Correction

Different parts of the energy system require different weather adjustments. Power-sector emissions are corrected for both electricity demand and the generation mix, while non-power gas emissions are corrected for heating-related demand. These effects are combined as a first-order approximation, without attempting to model every possible interaction between demand and the electricity mix.

Weather corrections are applied to CO2 emissions as follows:

Sector	Fuel	Correction Applied
Power	All	Demand correction (electricity) × Power mix correction
Non-power	Gas	Demand correction (gas)

4. CO2 Emissions

Once fossil-fuel consumption has been estimated, it is converted into CO2 emissions. Different fuels release different amounts of CO2 for the same amount of energy produced. Reported fuel quantities are first converted into a common energy unit using net calorific values.

Emission factors are taken from the Intergovernmental Panel on Climate Change (IPCC) Emission Factor Database.[2] Table 1 lists the emission factors used, expressed in tonnes of CO2 per terajoule of net calorific value. The net calorific values (NCVs) are taken from the IEA World Energy Statistics conversion factors.

Fuel	Value (t_{CO2} / TJ)
Hard coal	92.8
Brown coal	113.1
Brown coal briquettes	99.0
Peat	117.8
Oil shale	108.0
Oil products	72.3
Fuel oil	77.7
Heating gasoil	73.33
Motor gasoline	72.1
Road diesel	72.1
Natural gas	55.7
Coke oven coke	113.0
Coke oven gas	41.2
Kerosene	72.7
Aviation gasoline	70.6

Table 1 - **CO2 emission factors considered from the IPCC**

5. Validation

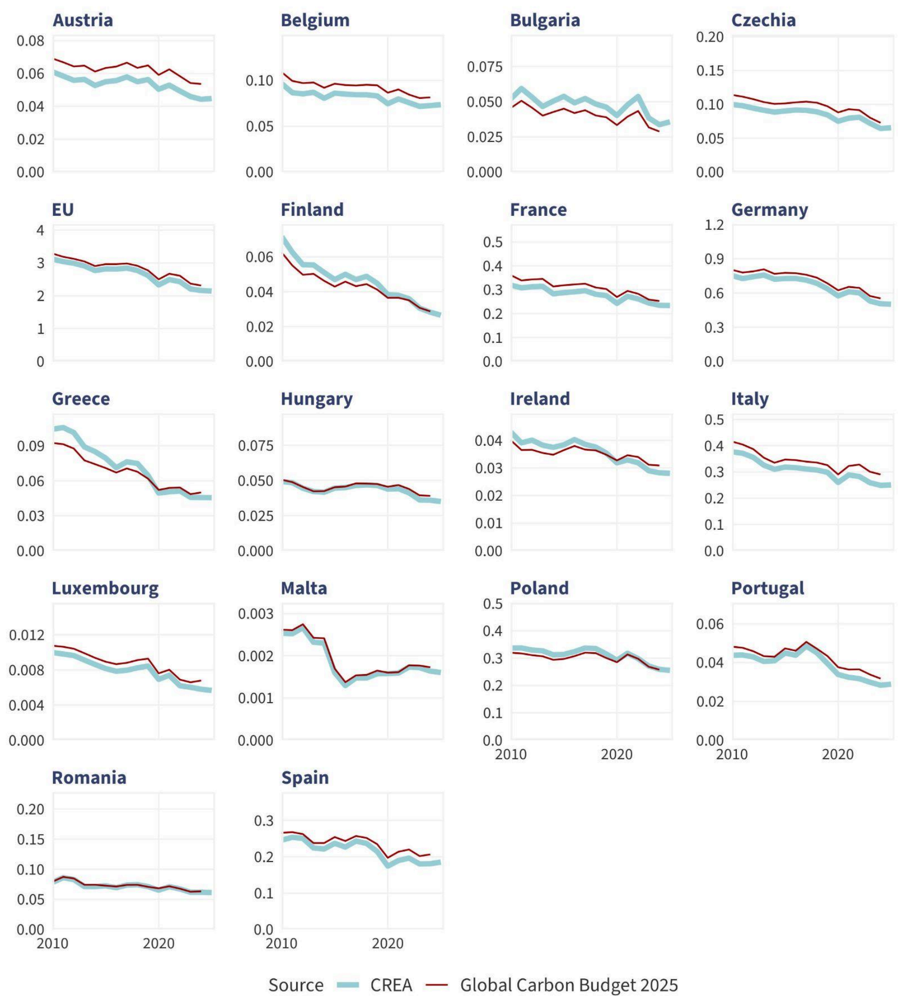
Validation assesses whether the tracker produces plausible emissions levels and trends when compared with an independent dataset. Agreement does not establish that either dataset is exact, because their data sources, coverage and methods differ. However, the comparison can identify systematic differences or periods that require further investigation.

5.1 Comparison with Global Carbon Budget 2025

We compare national coal, oil and gas emissions with the corresponding Global Carbon Budget series, excluding its separate cement, flaring and other categories. The results are not expected to match exactly because the datasets differ in their source data and scope. For example, the Global Carbon Budget includes some emissions from the oxidation of fuels used as chemical feedstocks, while the CREA tracker estimates emissions from fossil-fuel combustion.

The Global Carbon Budget data are from Friedlingstein et al. (2025).[3]

Figure 1 - **CO2 emissions from fossil fuels - Comparison with Global Carbon Budget**
Billion tonne CO2 per year



Source: CREA analysis and Global Carbon Budget 2025 (Friedlingstein et al., 2025).

Remaining limitations

Recent estimates are necessarily less certain than historical estimates because they rely more heavily on incomplete monthly data, assumptions and projections. The limitations below identify circumstances in which the method may not immediately capture rapid changes in fuel use, economic activity or reporting practices. Estimates are updated as more complete and detailed data become available.

Monthly data limitations

Monthly Eurostat data are available sooner than annual energy balances but include fewer fuel and sector categories. The tracker therefore carries forward some relationships observed in the latest annual data. This approach works best when those relationships change gradually and may be less accurate during sudden changes in industrial activity, transport patterns or national reporting.

To provide recent estimates, we have assumed that certain characteristics remains constant since the latest available data point (see section 2. Missing-data imputation), namely:

- The share of motor gasoline, road diesel and aviation gasoline used by the transport sector is assumed constant in the last year.
- The non-energy use of liquid fossil fuels is directly proportional to the amount used by the petrochemical industry and the ratio remains constant.

These assumptions have been softly validated using historical data. Changes in industrial mix may therefore lead to overestimating or underestimating most recent trends in emissions.

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References

1. Statistics | Eurostat | Supply, transformation and consumption - commodity balances. https://ec.europa.eu/eurostat/databrowser/explore/all/envir?lang=en&subtheme=nrg.nrg_quant.nrg_quantm.nrg_cb_m&display=list&sort=category.

2. IPCC. IPCC Emission Factor Database. https://www.ipcc-nggip.iges.or.jp/EFDB/find_ef.php.

3. Friedlingstein, P., M. O'Sullivan, M. W. Jones, et al. "Global Carbon Budget 2025." Earth System Science Data Discussions 2025 (2025): 1–139. https://doi.org/10.5194/essd-2025-659.