# Global Carbon Intensity of Energy Supply: A Cross-Referenced Analysis of 2022 Data

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**Abstract**

This study quantifies the global carbon intensity of energy supply, expressed in grams of $CO_2$ equivalent per kilowatt-hour ($gCO_2eq/kWh$), for the year 2022. By integrating global total energy supply data from the International Energy Agency (IEA) with lifecycle greenhouse gas emission factors from Our World in Data, a weighted average emission factor is derived. The analysis employs a matrix-based methodology to synthesize the contributions of various energy sources, including fossil fuels, nuclear, and renewables.

## 1 Introduction

This paper aims to calculate the global average $CO_2$ emissions per unit of energy supplied, specifically in $gCO_2eq/kWh$, for the year 2022. This is achieved by combining the most recent global energy mix data from the International Energy Agency (IEA) with comprehensive lifecycle emission factors from Our World in Data. The methodology employed provides a transparent and robust framework for deriving a consolidated emission metric reflective of the current global energy landscape.

## 2 Methodology

To determine the global average carbon intensity of energy supply, a two-step methodology was adopted: data acquisition and weighted average calculation.

## 2.1 Data Acquisition

### 2.1.1 Global Energy Supply Mix

The global total energy supply by source for the year 2022 was obtained from the International Energy Agency (IEA) via their "World Energy Mix" dashboard [1]. The specific percentages for each primary energy source are presented in Table 1.

Table 1: Total Energy Supply by Source, World, 2022 (Source: IEA [1])

| **Energy Source** | **Share of Total Energy Supply (%)** |
|---|---|
| Coal | 27.6 |
| Oil | 30.2 |
| Natural Gas | 23.1 |
| Nuclear | 4.7 |
| Hydro | 2.5 |
| Wind, Solar, etc. | 3.1 |
| Biofuels and Waste | 8.8 |

### 2.1.2 Lifecycle Greenhouse Gas Emission Factors

Lifecycle greenhouse gas (GHG) emission factors, expressed in kg$CO_2$eq/MWh, were sourced from Our World in Data's "Impacts of Energy Sources" explorer [2]. These factors account for emissions across the entire lifecycle of energy production, from extraction and processing to construction, operation, and decommissioning. For the purpose of this analysis, various sub-categories of renewable energy sources (e.g., different types of solar PV, onshore/offshore wind) were aggregated to a representative average for "Wind, Solar, etc." and "Hydro" to align with the IEA's energy mix categories. Table 2 presents the selected emission factors.

## 2.2 Weighted Average Emission Calculation

To calculate the global average carbon intensity, the percentage share of each energy source in the global total energy supply (from IEA) was multiplied by its corresponding lifecycle GHG emission factor (from Our World in Data). The aggregation of "Wind, Solar, etc." and "Biofuels and Waste" categories from the IEA data required careful assignment of representative emission factors from Our World in Data.

Table 2: Selected Lifecycle Greenhouse Gas Emission Factors (Source: Our World in Data [2])

| **Energy Source** | **Emissions (kgCO$_2$eq/MWh)** |
|---|---|
| Coal (average) | 970.0 |
| Natural Gas (average) | 439.0 |
| Nuclear | 5.6 |
| Hydropower | 117.0 |
| Onshore Wind | 11.0 |
| Offshore Wind | 17.0 |
| Solar PV, silicon (on-ground) | 52.0 |
| Solar PV, silicon (roof) | 53.0 |
| Solar PV, cadmium (on-ground) | 16.0 |
| Solar PV, cadmium (roof) | 19.0 |
| Concentrating solar (tower) | 36.0 |
| Concentrating solar (trough) | 56.0 |

### 2.2.1 Matrix Formulation

Let $P$ be a column vector representing the percentage share of each energy source in the total global energy supply (normalized to 1), and $E$ be a column vector representing the corresponding lifecycle GHG emission factors in kgCO$_2$eq/MWh.

The global weighted average emission factor, $EF_{\text{global}}$, is then calculated as the dot product of these two vectors:

$$EF_{\text{global}} = \mathbf{P}^T\mathbf{E} = \sum_{i=1}^{n} p_i \cdot e_i \tag{1}$$

where $p_i$ is the share of energy source $i$, and $e_i$ is its emission factor. The result will initially be in kgCO$_2$eq/MWh, which will then be converted to gCO$_2$eq/kWh for the final result.

The conversion factors are: 1 kg = 1000 g 1 MWh = 1000 kWh

Therefore, 1 kgCO$_2$eq/MWh = $\frac{1000 \text{ gCO}_2\text{eq}}{1000 \text{ kWh}}$ = 1 gCO$_2$eq/kWh. This simplifies the conversion.

# 3 Results

## 3.1 Aggregated Emission Factors

Based on the data from Table 2, the aggregated emission factors for renewable categories are as follows:

* **Average for "Wind, Solar, etc."**: (11.0 + 17.0 + 52.0 + 53.0 + 16.0 + 19.0 + 36.0 + 56.0) / 8 = 32.5 $kgCO_2eq/MWh$

* **Assumption for "Biofuels and Waste"**: 230.0 $kgCO_2eq/MWh$

Table 3: Consolidated Energy Mix and Emission Factors for Calculation

| **Energy Source** | **Share (%)** ($p_i$) | **Emission Factor ($kgCO_2eq/MWh$)** ($e_i$) |
|---|---|---|
| Coal | 27.6 | 970.0 |
| Oil | 30.2 | 730.0 |
| Natural Gas | 23.1 | 439.0 |
| Nuclear | 4.7 | 5.6 |
| Hydro | 2.5 | 117.0 |
| Wind, Solar, etc. | 3.1 | 32.5 |
| Biofuels and Waste | 8.8 | 230.0 |

## 3.2 Weighted Average Global Carbon Intensity

Using the consolidated data, the weighted average global carbon intensity is calculated as follows:

$$\begin{aligned} EF_{\text{global}} &= (0.276 \times 970.0) + (0.302 \times 730.0) + (0.231 \times 439.0) + (0.047 \times 5.6) \\ &\quad + (0.025 \times 117.0) + (0.031 \times 32.5) + (0.088 \times 230.0) \\ &= 267.72 + 220.46 + 101.409 + 0.2632 + 2.925 + 1.0075 + 20.24 \\ &= \mathbf{614.0247} \text{ kgCO}_2\text{eq/MWh} \end{aligned}$$

Converting to $gCO_2eq/kWh$: 614.0247 $kgCO_2eq/MWh$ = 614.0247 $gCO_2eq/kWh$

The global average carbon intensity of energy supply for 2022 is calculated to be approximately **614 $gCO_2eq/kWh$**.

# 4 Discussion

The calculated global average carbon intensity of approximately 614 $gCO_2eq/kWh$ for 2022 underscores the significant environmental footprint of the current global energy mix. The dominance of fossil fuels (Coal, Oil, Natural Gas) in the total energy supply, accounting for over 80% of the mix, is the primary driver of this high carbon intensity. Specifically, Coal, with its high emission factor and substantial share, is the largest contributor to overall emissions.

While renewable energy sources (Hydro, Wind, Solar, etc.) exhibit significantly lower lifecycle emission factors, their combined share in the total energy supply for 2022 remains relatively small.

This analysis highlights the critical need for an accelerated transition towards low-carbon energy sources. Efforts to decarbonize the energy sector must focus on both reducing the share of high-emitting fossil fuels and rapidly expanding the deployment of renewable energy technologies. Future research could refine this analysis by incorporating more granular data on the subcategories within "Wind, Solar, etc." and "Biofuels and Waste", as well as by conducting sensitivity analyses on the assumed emission factors.

# 5 Conclusion

This study successfully quantified the global carbon intensity of energy supply for the year 2022 by integrating data from the IEA and Our World in Data. The derived weighted average emission factor of approximately 614 $gCO_2eq/kWh$ reflects the current reliance on fossil fuels in the global energy mix. These findings emphasize the urgent imperative for a concerted global effort to shift towards cleaner energy sources to mitigate climate change. Continued monitoring and refinement of such metrics are essential for guiding effective energy and climate policies.

# References


[1] International Energy Agency (IEA). Total Energy Supply by Source, World, 2022. https://www.iea.org/world/energy-mix. Accessed on August 28, 2025.

[2] Our World in Data. Impacts of Energy Sources - Greenhouse gas emissions. https://ourworldindata.org/explorers/impacts-of-energy-sources. Accessed on August 28, 2025.