# $CO_2$ Emissions Report

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## Introduction

Monitoring carbon dioxide ($CO_2$) emissions from fossil fuel combustion, non-energy use of fossil fuels, and other industrial processes is essential for addressing anthropogenic climate change. $CO_2$ is a major greenhouse gas contributing to global warming, and its continued accumulation in the atmosphere poses severe risks to ecosystems, economies, and societies worldwide. Fossil fuel combustion, including the use of coal, oil, and natural gas, remains the largest source of $CO_2$ emissions. In addition, industrial processes such as cement production and gas flaring further contribute to the atmospheric burden of $CO_2$.

Understanding the magnitude and sources of $CO_2$ emissions is crucial for devising effective strategies to mitigate climate change. By systematically monitoring and analyzing $CO_2$ emissions, particularly across various sectors and countries, policymakers can identify key drivers of emissions and develop targeted interventions. Furthermore, tracking emissions over time allows for evaluating the effectiveness of policies and measures aimed at reducing emissions.

In this report, we examine historical $CO_2$ emissions data, focusing on contributions from different types of fossil fuels—solid, liquid, and gas—as well as emissions from cement production and gas flaring. We also analyze emissions on a per capita basis to assess the relative carbon footprints of different countries and how these change over time. The aim is to provide insights into the current state of global $CO_2$ emissions, highlight trends, and identify potential areas for emissions reduction.

## Dataset Description

I merged two datasets from `https://doi.org/10.3334/CDIAC/00001_V2017`. The dataset contains the following columns:

1. **Year**: The year for which the data was recorded.
2. **Country**: The country for which the data was collected.
3. **Total**: The total emissions (possibly in terms of $CO_2$ or other pollutants).
4. **Solid Fuel**: Emissions from solid fuel (e.g., coal).
5. **Liquid Fuel**: Emissions from liquid fuel (e.g., gasoline or oil).

6. **Gas Fuel**: Emissions from gas fuel (e.g., natural gas).
7. **Cement**: Emissions from cement production.
8. **Gas Flaring**: Emissions from the burning of excess gas during oil extraction.
9. **Per Capita**: Emissions per person.
10. **Bunker Fuels (Not in Total)**: Emissions from bunker fuels, which may not be included in the total value.

# Method and Result

The dataset includes changes of stock for all fuels used in both energy and non-energy uses, along with per capital data. CDIAC-FF is to estimate $CO_2$ emissions by focusing on emissions from different types of fuel. The formula we are using to analysis the $CO_2$ emission is

$$CO_2 = P_i FO_i C_i$$

Figure 1. The change in estimated global $CO_2$ emission by using the change in stocks, not directly from energy source data. In early 1900s to Mid-1900s, emission changes appear relatively small, suggesting that industrial activities and energy usage had a modest and gradual impact on emissions globally during this period. There is a sharp increase in emission changes, indicating rapid industrialization, urbanization, and increased reliance on fossil fuels, particularly post-World War II. Between the 1960s and 1970s, global emissions increased by an average of 3.2% per year, with solid fuels contributing to nearly 60% of this increase. In contrast, post-2000s changes slowed to around 1.12% annually, reflecting modern efforts to transition to cleaner energy sources.

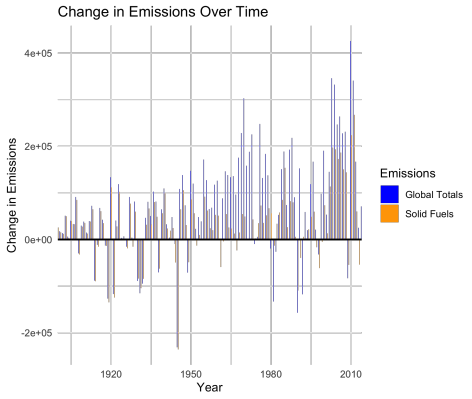

Figure 2. The total emissions show a steep rise starting in the late 19th century, with a dramatic acceleration post-1950 ("Great Acceleration"). Solid emissions (black) appear to be $\frac{1}{3}$ of gas emissions (yellow), highlighting a major shift in energy systems where natural gas has become a dominant contributor to $CO_2$ emissions, surpassing coal by a significant margin. Gas (yellow) is the largest single contributor to emissions, and cement (gray) is a close second in proportional terms. Together, they represent the majority of emissions, reflecting industrialization and the transition to alternative fuels.

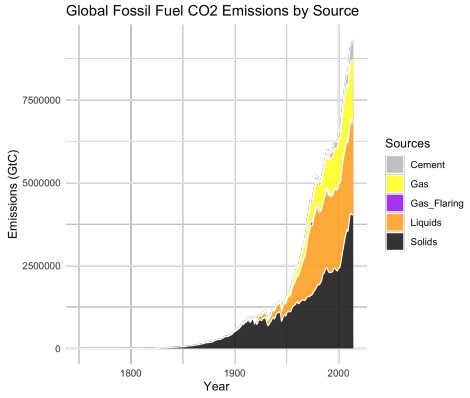


Table 1. The table highlights the top 10 $CO_2$-emitting countries, emphasizing the differences in emissions, population trends, and per capita contributions. China ranks first, contributing nearly twice the $CO_2$ emissions of the United States, the second-largest emitter. However, China's per capita emissions are less than half of those in the United States, reflecting its larger population base and relatively lower emissions intensity per individual. In contrast, India, ranked third, emits less than half the $CO_2$ of the United States and only about a fifth of China's emissions, yet its emissions growth is over five times faster than that of most developed nations, indicating its rapid industrialization.

| Rank | Country | Total_CO2_Emissions | Population | Emissions_Change | Population_Change(%) | Per Capita_2014 |
|---|---|---|---|---|---|---|
| 1 | CHINA (MAINLAND) | 2806634 | 5753599.7 | 0.3306661 | 0.3306661 | 2.05 |
| 2 | UNITED STATES OF AMERICA | 1432855 | 6347547.6 | 1.8436779 | 3.0062770 | 4.43 |
| 3 | INDIA | 610411 | 286893.2 | 10.0073529 | 20.2405950 | 0.47 |
| 4 | RUSSIAN FEDERATION | 465052 | 1506768.5 | -4.1165483 | -8.0880522 | 3.24 |
| 5 | JAPAN | 331074 | 864103.1 | -2.6046692 | -5.1485771 | 2.61 |
| 6 | GERMANY | 196314 | 477043.0 | -4.9423545 | -9.7695006 | 2.43 |
| 7 | ISLAMIC REPUBLIC OF IRAN | 177115 | 402051.0 | 4.7924740 | 8.6205096 | 2.27 |
| 8 | SAUDI ARABIA | 163907 | 870346.2 | 11.0894981 | 20.6309274 | 5.31 |
| 9 | REPUBLIC OF KOREA | 160119 | 512380.8 | -0.9017428 | -2.1251781 | 3.20 |
| 10 | CANADA | 146494 | 603555.3 | 3.8736164 | 6.9898249 | 4.12 |