Assessing the relationship between renewable energy consumption and CO_2 emissions across nations

I. Introduction

The combustion of fossil fuels such as coal, petroleum, and natural gas emits a significant amount of carbon dioxide (CO_2), accounting for the largest share of greenhouse gases, which are associated with global warming. To reverse or at least mitigate climate change, many countries are shifting their main energy source away from fossil fuels and towards renewable, sustainable alternatives such as solar or wind energy. This project aims to analyze the global consumption of renewable energy and assess its influence on the total CO_2 emissions, exploring how renewable energy supports the fight against climate change. The main question of this project is:

What is the correlation between renewable energy consumption and CO_2 emissions in various countries?

II. Data Sources

The overview of data sources can be summarized in the table below:

Dataset	CO_2 Emission	Renewable Energy Consumption
Geographical Coverage	266 countries/associations	266 countries/associations
Temporal Coverage	1990 - 2020	1990 - 2021
Unit	kt	% of total final energy consumption
License	CC BY-NC 4.0	CC BY-4.0
Source	Climate Watch – Historical GHG Emissions (1990–2020) (2023, Washington, DC: World Resources Institute)	IEA, IRENA, UNSD, World Bank, and WHO (2023 Tracking SDG 7: The Energy Progress Report, Washington DC)
Provider	The World Bank	The World Bank

Adaptation and Changes:

- The time period for the Renewable Energy Consumption Dataset is set to 1990 – 2020.
- Countries/Associations without records have been excluded.
- Only countries/associations present in both datasets are selected.
- Missing values are filled using the first available value for each country/association.

Result:

- The final datasets encompass 238 countries and associations from 1990 – 2020.
- These datasets are stored in 2 tables within an SQLite database, saved locally (Figure 1).

data > MADE_Project.sqlite

CO2_Emission

Filter 2 tables...

Tables

- CO2_Emission
- Renewable_Energy_Consumption
  - ROWID
  - Country Name
  - 1990
  - 1991
  - 1992
  - 1993
  - 1994
  - 1995
  - 1996
  - 1997
  - 1998

Rows: 239

	Country Name	1990	1991	1992	1993
1	Africa Eastern and Southern	60.9100030584341	62.1839240619363	63.9830201533289	64.7124603508772
2	Afghanistan	23	23.69	27.38	28.5
3	Africa Western and Central	85.9285141294439	85.3189802570062	83.8747986481954	85.1721749136939
4	Angola	72.26	71.89	72.72	71.28
5	Albania	25.5	32.98	46.78	51.12
6	Andorra	14.05	14.05	14.08	13.72
7	Arab World	7.43882276752897	7.34962257694742	6.98156458024041	6.83182616992136
8	United Arab Emirates	0	0	0.19	0.15
9	Argentina	8.57	8.42	9.01	9.68
10	Armenia	2.12	2.31	6.68	12.93

Figure 1. Local SQLite database

III. Analysis

To analyze the correlation between CO_2 emissions and Renewable Energy Consumption from 1990 to 2020, we will follow a structured approach. First, we will examine the overall global CO_2 emissions and Renewable Energy Consumption to identify significant changes and overall trends over the 30-year period.

In Figure 2, global CO_2 emissions have shown a steady increase from 1990 to 2020. Overall, it is readily apparent that the world's CO_2 emissions saw a significant rise of 57.7%. However, towards the end of the period, there was a modest decline of about 5%.

Figure 3 shows there is a steady increase in average renewable energy consumption with respect to the total energy consumption globally, peaking around 2000. Following this peak, there is a noticeable decline until approximately 2010, with a few minor fluctuations. After 2010, the trend reverses, showing a significant and consistent increase in renewable energy consumption, leading to a sharp rise towards the end of the period in 2020. Overall, the chart indicates a long-term upward trend in the adoption of renewable energy, despite the mid-period decline.

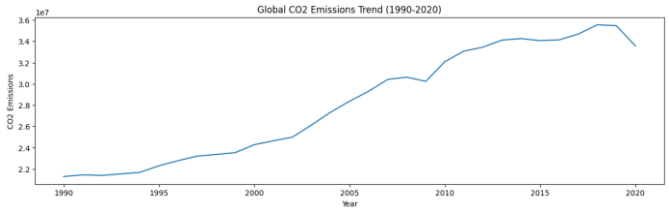

Figure 2. Global CO_2 Emissions Trend

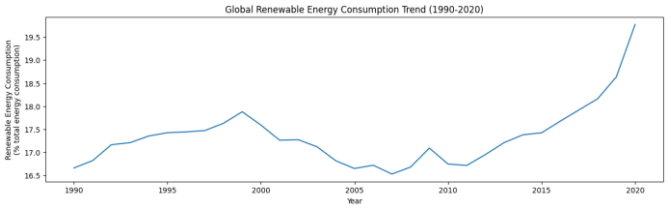

Figure 3. Global Renewable Energy Consumption Trend

Next, we will break down the contributions by country, highlighting the top 10 emitters and their relative shares. After getting the top 10 emitters, we will examine their corresponding Renewable Energy Consumption.

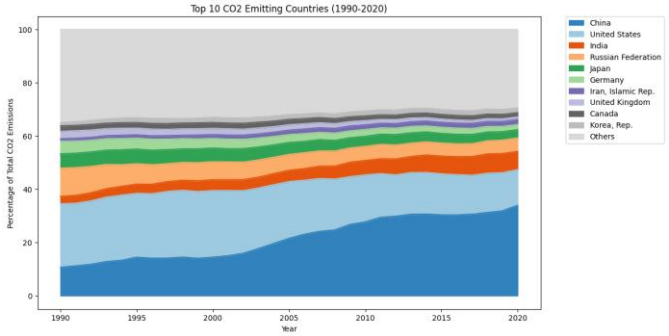

Figure 4. Top 10 CO_2 Emitting Countries

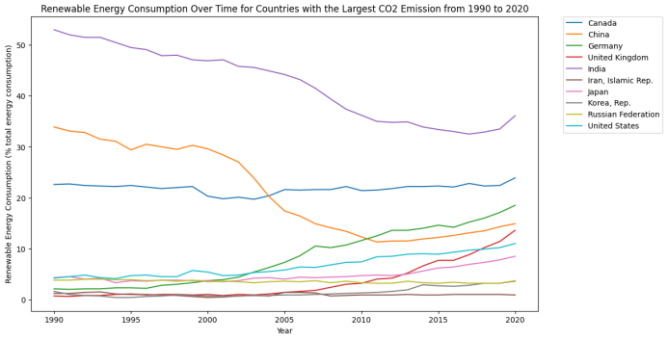

Figure 5: Renewable Energy Consumption

of Top 10 CO_2 Emitting Countries

In Figure 4, it is evident that approximately 60% of the world's CO_2 emissions originate from 10 countries, with China and the United States being the largest contributors from 1990 to 2020.

China's share of CO_2 emissions has increased significantly, growing by four times. While the United States has consistently held a substantial share of emissions, its relative contribution has decreased in recent years. As an emerging country, India's share of CO_2 emissions has gradually increased.

According to the renewable energy consumption data shown in Figure 5, among the top 10 emitters, China has seen a dramatic decline in renewable energy consumption (from 33.9% in 1990 to 14.9% in 2020), as has India (from 53% in 1990 to 36% in 2020). In contrast, other countries have shown a steady increase in renewable energy consumption. These changes in usage of clean energy sources somewhat reflect the emissions.

Then, we will identify the countries that have achieved the most significant reductions in CO_2 emissions and observe their corresponding Renewable Energy Consumption.

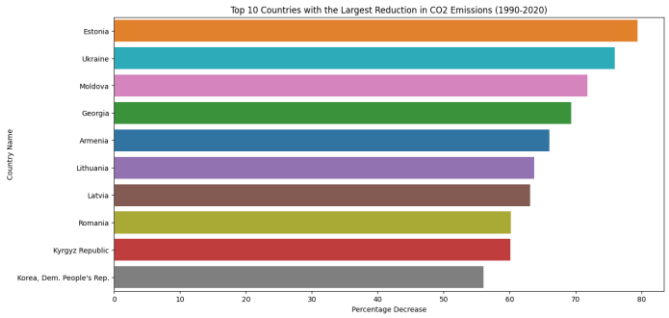

Figure 6. Countries with the Largest Reduction in CO2 Emissions

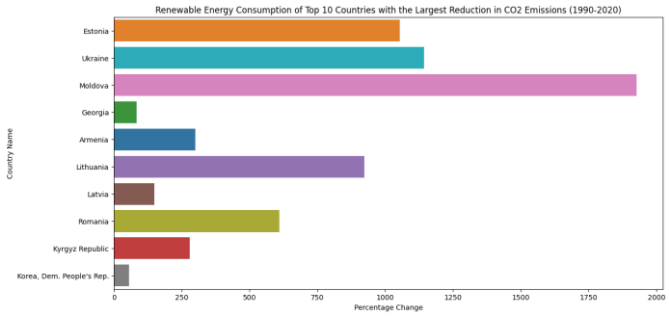

Figure 7. Renewable Energy Consumption Change of Countries with the Largest Reduction in CO_2 Emissions

Figures 6 and 7 show that Estonia has increased its use of renewable energy by 1000% and reduced CO_2 emissions by 80%. Similarly, Ukraine, Moldova, Lithuania, and Romania have also demonstrated significant increases in renewable energy usage and substantial decreases in CO_2 emissions.

Finally, we will compare emissions trends among high-income, middle-income, and low-income countries to understand how economic development impacts CO_2 emissions.

Figure 8 shows that middle-income countries have seen a significant and continuous rise in CO_2 emissions, surpassing high-income countries in 2005 and continuing to increase until 2020. High-income countries exhibit a slight upward trend in emissions up to around 2010, after which their emissions start to gradually decline. Low-income countries have consistently maintained very low CO_2 emissions throughout the entire period, showing minimal change.

Figure 9 reveals that low-income countries lead in renewable energy consumption, with an increasing trend and an average of 60%-75%. Surprisingly, high-income countries are at the bottom, with only around 10%-20% of their total energy consumption coming from renewable sources. Middle-income countries are seeing a decline in their use of renewable energy.

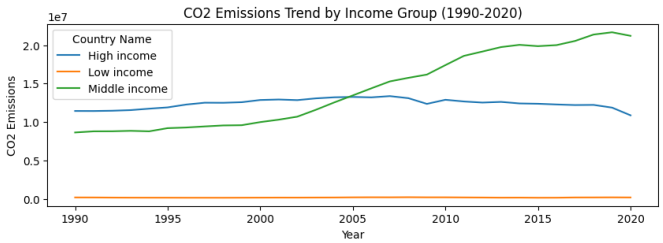

Figure 8. CO_2 Emission by Income Group

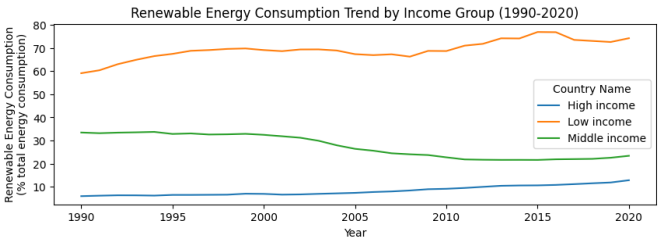

Figure 9. Renewable Energy Consumption by Income Group

IV. Conclusion

The correlation between renewable energy consumption and CO_2 emissions varies significantly across different countries and economic groups. While global trends show an increase in renewable energy adoption and a beginning decline in CO_2 emissions, it's too early to draw a definitive correlation.

By analyzing the top 10 CO_2 emitters, it appears that renewable energy is playing a crucial role in controlling emission rates in the United States, China, and India. However, in other countries, despite a shift towards clean energy sources, CO_2 emissions remain largely unaffected.

Looking at countries with the most significant CO_2 emission reductions, we see an increase in the share of renewable energy. These countries, primarily in Europe (excluding North Korea), have implemented numerous regulations targeting CO_2 emissions. Therefore, other factors may also be contributing to the reduction.

The analysis of renewable energy consumption and CO_2 emissions across different income groups was the one that clearly exhibited the correlation between these two indicators. High-income countries, despite having lower renewable energy consumption, are beginning to show a decline in emissions as they transition to cleaner energy. Middle-income countries face the dual challenge of rising emissions and decreasing renewable energy shares. This raises serious concerns about climate change and the need for regulations and restrictions to help protect the environment. Low-income countries, with high renewable energy consumption, contribute minimally to global CO_2 emissions. However, in comparison to high-income countries, low-income countries do not heavily invest in production plants and their economies, and therefore do not produce a lot of CO2 emissions.

In conclusion, the question remains open as other factors, such as regulations and technologies, may play more significant roles in limiting CO_2 emissions. Additionally, reporting biases due to political or economic reasons, as well as inaccuracies in measured values, could affect the analysis. Moreover, the renewable energy consumption dataset consists of relative measurements, potentially obscuring the true scale of renewable energy adoption in different countries. Further investigation into renewable energy output, country-specific regulations, and advanced energy technologies would be beneficial in answering the target question.