THE DYNAMICS OF GLOBAL CO₂ EMISSIONS: ECONOMIC GROWTH, SECTORAL CONTRIBUTIONS, AND THE TRANSITION TO RENEWABLE ENERGY

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## Introduction

The rising impact of climate change has heightened the global imperative to reduce CO₂ emissions, primarily generated by industrial activities, transportation, and energy production. These sectors drive economic growth but also contribute significantly to greenhouse gas emissions, intensifying issues like rising global temperatures, extreme weather, and ecological disruptions. To address these challenges, there is a growing emphasis on renewable energy adoption as a sustainable alternative.

The dashboard offers a comprehensive analysis of CO₂ emissions, trends in renewable energy, and their economic intersections across different regions. It examines historical and current data on CO₂ emissions per capita, renewable energy generation by resource type, and the relationship between emissions and GDP. By analyzing these metrics, the dashboard highlights not only the countries and economies with the highest levels of emissions but also those that are leading in renewable energy initiatives and achieving economic growth through cleaner energy solutions. This analysis aims to enhance the understanding of the global movement toward a low-carbon, sustainable future that balances economic prosperity with environmental responsibility.

### Ambitiousness of the Project

This project integrates data from multiple sources, including Our World in Data and the World Bank, to examine the relationship between economic growth, CO₂ emissions, and renewable energy generation. It goes beyond straightforward analyses by analyzing cross-regional trends, offering a deeper and more nuanced understanding of these interconnected issues.

Additionally, the project leverages Tableau to create dynamic and insightful visualizations such as scatter plots, heatmaps, and line graphs, addressing complex research questions. This project provides a robust and multifaceted analysis by exploring the intersection of environmental sustainability and economic development.

### Research Questions

**1. What are the trends in annual CO₂ emissions across different countries and globally over time?**

This question investigates how annual CO₂ emissions per capita have evolved globally and regionally, examining differences among countries. The analysis includes visualizing historical and current emissions data and identifying patterns and variations by country. By tracking these trends, the analysis highlights which countries have successfully reduced emissions and which are still increasing, providing insight into the impact of various economic, political, and technological factors on global emission levels. Additionally, the dashboard includes a timeline animation, showing changes in CO₂ emissions over time, helping to contextualize global and regional emission patterns in relation to other factors**.**

**2. How has renewable energy generation evolved over time, and how does it vary by resource?**

This analysis focuses on the growth of renewable energy, segmented by resource types such as hydro, solar, wind, and other renewables, over time. It explores the expansion of each renewable resource, tracking trends across decades to understand their adoption rates and impact on energy generation. The dashboard includes a detailed chart of renewable resource trends, revealing how different resources have contributed to the total renewable energy generation and which have experienced significant growth.

**3. What is the relation between annual CO₂ emissions and renewable energy generation across regions?**

This question examines the relationship between renewable energy adoption and CO₂ emissions per capita, investigating if countries with higher renewable energy output have correspondingly lower emissions. Using scatter plots and trend charts, the analysis assesses correlations between renewable energy capacity and emission reductions, identifying countries where increased renewable energy generation may be contributing to emission declines. By highlighting both high and low-emission countries, this analysis explores how different areas are transitioning to renewable energy and its effectiveness in reducing carbon output.

**4. What role does economic status play in annual CO₂ emissions levels?**

This question delves into the relationship between economic indicators, like GDP per capita, and CO₂ emissions levels per Capita across countries. By comparing GDP against emissions data, the analysis investigates whether wealthier nations generally have higher or lower emissions and how economic growth affects emissions in both developed and developing countries. The dashboard includes a comparison chart of CO₂ emissions against GDP, showing trends and potential correlations over time, and a scatter plot illustrating this relationship across different economies, providing insights into how economic status influences environmental impact and sustainability efforts.

## Methodology

To address these research questions, I will be utilizing the following datasets:

#### **Renewable Energy**

* Ritchie, H., & Roser, M. (2020). Renewable energy. Our World in Data. Retrieved November 11, 2024, from <https://ourworldindata.org/renewable-energy>
* modern-renewable-energy-consumption.csv 🡪

<https://ourworldindata.org/grapher/modern-renewable-energy-consumption.csv?v=1&csvType=full&useColumnShortNames=true>

* share-electricity-renewables.csv 🡪

<https://ourworldindata.org/grapher/share-electricity-renewables.csv?v=1&csvType=full&useColumnShortNames=true>

* **Description:**

The dataset monitors global renewable energy generation, categorized by resource type, including solar, wind, hydro, and other renewables over the years. This dataset is essential for identifying trends in renewable energy generation and understanding the transition from fossil fuels to clean energy.

#### **Electricity generation from renewables Per capita**

* Ember (2024); Energy Institute - Statistical Review of World Energy (2024); Population-based on various sources (2023) – with major processing by Our World in Data, from <https://ourworldindata.org/grapher/renewable-electricity-per-capita?time=latest>
  + - renewable-electricity-per-capita.csv 🡪

<https://ourworldindata.org/grapher/renewable-electricity-per-capita.csv?v=1&csvType=full&useColumnShortNames=true>

* **Description:**

This dataset offers detailed yearly data on electricity generation across more than 200 geographies. It provides valuable insights into the energy sector, enabling an in-depth analysis of electricity production trends. Covering a wide range of regions and metrics, the dataset facilitates a comprehensive exploration of global energy demand patterns.

#### **GDP per capita (current US$)**

* World Bank. (n.d.). GDP per capita (current US$). World Bank. Retrieved November 11, 2024, from <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD>
* GDP per capita.csv 🡪 <https://data.worldbank.org/indicator/NY.GDP.PCAP.CD>

• **Description:**

This data set provides annual GDP per capita figures for countries around the world. The data is expressed in current US dollars and allows for the analysis of economic growth relative to the population size. This dataset is used to examine how economic prosperity influences CO₂ emissions, particularly in high-income countries.

#### CO₂ emissions

* Ritchie, H., & Roser, M. (2020). CO₂ emissions. Our World in Data. Retrieved November 11, 2024, from <https://ourworldindata.org/co2-emissions>

1. co-emissions-per-capita.csv 🡪

<https://ourworldindata.org/grapher/co-emissions-per-capita.csv?v=1&csvType=full&useColumnShortNames=true>

* **Description:**

This dataset provides a comprehensive record of global CO₂ emissions over the years, detailing emissions by country and region. The data includes total annual CO₂ emissions per capita offering insights into how emissions have evolved globally and regionally. This dataset is crucial for understanding which countries are major contributors to global emissions and how emissions patterns correlate with economic activities.

#### Data Cleaning and Processing:

The data preprocessing phase involved addressing missing values, standardizing data formats, and ensuring consistency across periods and entities. To streamline the analysis, all relevant resources were consolidated into a single column where appropriate. For the GDP dataset, the original columns were reviewed and reduced to four key columns to facilitate visualization and maintain consistency with other tables. Additionally, the co-emissions-per-capita.csv dataset included data up to 2022 at the time of download. To ensure uniformity across all datasets, the analysis was focused on the period from 2000 to 2022.

## Visual Analysis of Insights

In recent years, global concern about climate change has intensified, with carbon emissions becoming a focal point in environmental discussions. Visual data such as global heat maps, trend graphs, and resource allocation charts, effectively illustrate the story of our CO₂ emissions. In this analysis, each insight contributes to a clear narrative of the challenges, achievements, and trends in the fight against CO₂ emissions.

### Research question 1. What are the trends in annual CO₂ emissions across different countries and globally over time?

**Annual CO₂ Emissions Per Capita (Log Scale) Timeline Animation:**

This animated heat map illustrates the global distribution of annual CO₂ emissions per capita over time. To better visualize the large disparities in per capita emissions between countries, a **logarithmic scale** was used. This allows for a clearer distinction between nations with smaller and larger emissions. The map reveals a stark contrast between regions with high emissions, primarily concentrated in developed countries like the United States, China, and European nations, and those with lower emissions, such as many African and South American countries. As we move through the timeline, we observe a general trend of increasing emissions, particularly in industrialized nations. This rise is largely driven by factors like economic growth, population increase, and the increasing reliance on fossil fuels for energy generation and transportation.

*A map of the world

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**Annual CO₂ Emissions per Capita – Trends in Top Economies:**

Moving from a global view to a more specific analysis, the **Annual CO₂ Emissions per Capita by Top Economies Trend** highlights how emissions among the top economies, reveal striking variations. Countries like the United States stand out, where the per capita emissions are notably high despite recent green energy initiatives. Meanwhile, India, while being the largest emitter overall, shows lower per capita emissions relative to other economies. This trend line provides a clearer view of how emissions relate to a country's lifestyle, infrastructure, and energy consumption. It emphasizes the disparities in individual carbon footprints, shedding light on where lifestyle changes and policy adjustments could have the greatest impact on a per-person basis.

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### Research question 2. How has renewable energy generation evolved over time, and how does it vary by resource?

**Global Trends in Renewable Energy Generation by Resource Over the Years:**

The line chart illustrates the global trends in renewable energy generation by resource from 2000 to 2022. The data provides valuable insights into the evolution of renewable energy and the increasing diversity of energy sources.

Initially, hydropower was the dominant source of renewable energy, however, starting in the late 2000s, there has been a remarkable increase in the generation of solar and wind energy. This surge has been driven by technological advancements, decreasing costs, and supportive government policies.

While hydropower still plays a key role, other renewable resources, such as biomass and geothermal energy, have also seen some growth, although their contributions remain smaller in comparison. The increasing diversity of renewable energy sources promises a sustainable future.

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**Regional Generation of Renewable Energy by Resources:**

The bar chart illustrates the regional distribution of renewable energy generation by resources. The data provides valuable insights into the global landscape of renewable energy and the variations in regional adoption rates.

Asia emerges as the leading region in renewable energy generation, driven by significant investments in hydro, solar, and wind power. Europe and North America follow closely, with a strong focus on solar and wind energy, supported by supportive policies and technological advancements.

Africa and South America, while contributing smaller shares to the global renewable energy mix, are gradually increasing their renewable energy generation capacities.

The disparities in renewable energy generation across regions emphasize the need for customized policies, international collaboration, and the transfer of technology to speed up the transition to a sustainable energy future.

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Research question 3. What is the relation between annual CO₂ emissions and renewable energy generation across regions?

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Description automatically generated*  
This visualization delves into a critical question: **Is there any relation between CO₂ emissions and renewable energy?**

The scatter plot illustrates the relationship between annual CO2 emissions per capita and renewable energy consumption per capita for various countries.

Overall, visualization reveals a complex relationship between CO2 emissions and renewable energy consumption, most countries cluster in the lower left of the plot, indicating low levels of renewable energy consumption. *A graph with green and orange lines

Description automatically generated*

The line chart compares the trends in average annual CO2 emissions per capita and renewable energy consumption per capita over time. While CO2 emissions have remained stable, renewable energy consumption has shown a significant upward trend. This suggests a potential link between increased renewable energy adoption and reduced CO2 emissions. However, it is important to note that other factors, such as economic growth and technological advancements, also influence these trends.

### Research question 4. What role does economic status play in annual CO₂ emissions levels?

**Is There Any Relation Between CO₂ Emissions vs GDP per Capita - Correlation**  
The scatter plot illustrates the relationship between annual CO2 emissions per capita and GDP per capita for various countries. The data provides valuable insights into the impact of economic development on environmental sustainability.

Overall, visualization indicates a positive correlation between CO2 emissions and GDP per capita, suggesting that wealthier countries have higher emissions due to factors like industrial activity, consumption, and transportation. However, there are significant exceptions to this trend. However, some high-income countries, especially those with robust environmental policies and investments in renewable energy, have successfully decoupled economic growth from carbon emissions.

Developing countries, on the other hand, often face a challenging trade-off between economic growth and environmental sustainability. While their per capita emissions are generally lower, their rapid industrialization and urbanization can lead to significant increases in emissions.

To address the challenges of balancing economic growth with environmental protection, policymakers need to adopt sustainable development strategies that prioritize energy efficiency, renewable energy, and low-carbon technologies.

A graph with blue dots

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This is addressed by the line chart which compares the trends in average global annual CO2 emissions per capita and GDP per capita over time.

While GDP per capita has shown a steady increase over the years, CO2 emissions per capita have remained relatively stable, with some fluctuations. This suggests that economic growth is not necessarily directly linked to increased CO2 emissions. There may be several factors contributing to this trend, such as increased efficiency, technological advancements, and shifts towards cleaner energy sources. However, further analysis is needed to fully understand the underlying causes.

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### Other Visualizations:

**Global Renewable Energy Production Per Capita (Log Scale) - Heat Map Animation**

The heat map visualizes the global distribution of renewable energy production per capita. To better represent the wide range of values across countries, a logarithmic scale has been used. This allows for a clearer distinction between nations with significantly higher and lower renewable energy production per capita.

The map reveals variations in renewable energy adoption across different regions. While some countries, particularly in Europe and North America, exhibit higher levels of renewable energy production per capita, many other regions, especially in Africa and parts of Asia, have lower levels. This visualization highlights the disparities in renewable energy development and underscores the need for further efforts to promote sustainable energy solutions globally.

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**Renewable Electricity Share in Top Economies**

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The bubble chart illustrates the share of renewable electricity in the top economies in 2022. The size of each bubble represents the percentage of electricity generated from renewable sources in that country.

As shown in the chart, the United Kingdom leads with the highest share of renewable electricity in 2022, followed by China and the United States. India and Japan also have significant shares, while Russia has a lower proportion of renewable energy in its electricity mix.

This visualization highlights the varying levels of renewable energy adoption among these major economies and provides a quick comparison of their progress toward cleaner energy sources.

## Conclusion

Climate change and CO₂ emissions present an unprecedented global challenge that requires immediate action and international cooperation. My analysis reveals several critical insights that can inform policy decisions and drive meaningful changes:

1. **Key Findings**

* CO₂ Emissions Disparities: There is a significant disparity in CO₂ emissions per capita among countries. Nations like Qatar, Kuwait, and the UAE have exceptionally high emissions, driven by oil dependency, while low-income countries such as Afghanistan and the DRC emit almost negligible levels.
* Renewable Energy Growth: While renewable energy sources like hydropower, wind, and solar are gaining momentum, adoption varies greatly by region. Asia, Europe, and North America lead in renewable energy generation per capita, whereas Africa lags significantly due to infrastructure and financial constraints.
* Emissions vs. Economic Growth: Higher GDP is often correlated with higher emissions, as seen in affluent countries like the USA. However, nations like Iceland and Bhutan show it’s possible to maintain low emissions with strong investments in renewables.
* A negative correlation exists between the increase in renewable energy usage and CO₂ emissions in countries that prioritize sustainable energy.

1. **Recommendations and Implementation**

* Investment in Renewable Energy: Countries should enhance investment in renewable energy infrastructure, focusing on cost-effective sources like solar and wind.
* Economic Incentives for Low-Carbon Technologies: Provide tax breaks and subsidies to companies investing in renewable energy and carbon capture technologies. This can motivate industries to transition away from fossil fuels.
* Developing economies should receive support for renewable energy adoption, as they contribute less to emissions but are disproportionately affected by climate impacts.
* Monitoring and Accountability: A global monitoring system should be established to track CO₂ emissions and renewable energy progress, ensuring transparency and accountability in meeting climate goals.

1. **Conclusion**

The data highlights the world at a critical turning point. The significant disparities in CO₂ emissions per capita emphasize the urgent need for targeted action. Wealthy, oil-rich nations contribute disproportionately to global emissions, while developing countries, despite their minimal environmental impact, face substantial obstacles in adopting sustainable energy solutions.

The rapid growth of renewable energy sources offers a promising glimpse of a greener future. However, this transition demands more than isolated efforts; it requires global cooperation, significant investments, and policy changes. To achieve sustainability, it is essential to bridge the energy gap, particularly in underdeveloped regions.

By implementing innovative policies, fostering public-private partnerships, and encouraging individual action, we can reduce emissions without stifling economic growth. The choices made today will shape the legacy we leave for future generations, a world resilient against climate change or one that continues down a path of environmental decline.

### Additional Research Questions

* How do urbanization and industrialization levels impact regional CO₂ emissions?
* How does the adoption of renewable energy sources impact job creation and economic stability in regions heavily reliant on fossil fuels?
* What roles do technological innovations in the energy sector play in accelerating the transition to renewable energy?