CO2 Emissions Analysis Report

Introduction

This report analyzes global CO2 emissions data to answer three key questions related to climate change and energy transition. The analysis uses data from Our World in Data and employs Python with data science libraries to process information, identify patterns, and make predictions.

Methodology & Assumptions

Data Sources:

- CO2 emissions per capita data
- GDP per capita data (World Bank)
- Energy mix data (per capita consumption by source)
- Levelized cost of energy (LCOE) data for various technologies

General Assumptions:

- Recent data (2023 where available) represents current conditions
- Per capita metrics account for population differences between countries
- Historical trends can inform future projections

Question 1: Biggest Predictor of CO2 Output

a. Analysis Approach

We examined several potential predictors of CO2 emissions per capita:

- GDP per capita
- Fossil fuel energy consumption per capita
- Nuclear energy consumption per capita
- Renewable energy consumption per capita

b. Key Findings

The analysis revealed that fossil fuel consumption per capita is the strongest predictor of CO2 emissions with a correlation coefficient of 0.97, far outweighing other factors:

Factor	Correlation with CO2 Emissions
Fossil fuels per capita	0.97
GDP per capita	0.38
Nuclear per capita	0.09
Renewables per capita	0.08

The regression analysis demonstrates a clear linear relationship between fossil fuel consumption and CO2 emissions ($R^2 = 0.94$), making it the most influential driver of carbon emissions across countries.

c. Interpretation

This strong relationship validates the fundamental climate science principle that burning fossil fuels is the primary source of carbon emissions. Economic development (GDP) shows a moderate correlation but is less directly linked, while both nuclear and renewable energy sources show very weak correlation with emissions.

Question 2: Biggest Strides in Decreasing CO2 Output

a. Analysis Approach

We calculated percentage reductions in CO2 emissions per capita between 2000 and 2023 for all countries with available data, accounting for population changes by using per capita metrics.

b. Key Findings

The top 10 countries with the largest percentage reductions in CO2 emissions per capita are:

Aruba	(-70.01%)
Yemen	(-68.21%)
Curacao	(-68.18%)
Syria	(-66.80%)
Macao	(-57.60%)
Denmark	(-54.92%)
Gabon	(-54.67%)
United Kingdom	(-53.89%)
Finland	(-48.75%)
Luxembourg	(-47.30%)

c. Interpretation

Several nations have achieved significant emissions reductions, with Aruba showing the most dramatic decrease at over 70%. The results reflect a combination of factors including policy changes, energy transition efforts, economic restructuring, and in some cases complex socioeconomic factors like political instability (Yemen, Syria). The presence of smaller economies (Aruba, Curacao, Macao) alongside larger ones (UK, Denmark) shows that substantial emissions reductions are achievable across different economic scales.

Question 3: Best Future Price for Non-Fossil Fuel Energy

a. Analysis Approach

We forecasted future prices of various non-fossil fuel energy technologies using:

- Historical LCOE (Levelized Cost of Energy) data
- Linear regression with weighted recent data
- Technology-specific learning curves that account for deployment scaling
- Different learning rates for different technologies (e.g., 25% for solar PV, 15% for onshore wind)

b. Assumptions

- Technologies follow historical learning rates where cost decreases with cumulative deployment

- Solar PV has the highest learning rate (25%), compared to offshore wind (20%) and onshore wind (15%)
- Annual capacity growth is estimated at 15% for deployment projections
- Recent trends are weighted more heavily in the regression model

c. Key Findings

Our analysis projects that solar photovoltaic will have the lowest LCOE in the future, making it the most cost-effective non-fossil fuel energy technology. The projections show continued cost declines across most renewable technologies, with solar photovoltaic showing particularly steep cost reductions due to its higher learning rate.

d. Interpretation

The projected cost advantage of solar PV is driven by its superior learning rate (25% cost reduction per doubling of deployment), which outpaces other technologies despite potentially higher starting costs. This aligns with industry observations of rapidly declining solar costs over the past decade and expectations of continued improvements in manufacturing scale and efficiency.

Conclusion

This analysis provides clear insights into the drivers and trends of global CO2 emissions:

1. Fossil fuel consumption is overwhelmingly the strongest predictor of carbon emissions, highlighting the critical importance of transitioning away from fossil energy sources.
2. A diverse group of nations has made substantial progress in reducing emissions over the past two decades, with Aruba, Yemen, and Curacao leading with reductions of over 68%.
3. Solar photovoltaic is projected to be the most cost-effective non-fossil energy technology in the coming years, benefiting from the highest learning rate among renewable technologies.

These findings underscore the importance of accelerating the transition away from fossil fuels, learning from countries that have successfully reduced emissions, and continuing to invest in and deploy cost-effective renewable energy technologies.

Code Repository

The complete analysis code is available at: https://github.com/grimloch-ai/DataAnalyticsPython/blob/CO2_Emissions_Assignment/CO2_Emissions_v1_0_RS.ipynb

The Python code uses pandas for data manipulation, matplotlib for visualization, scikit-learn for regression analysis, and implements modular, reusable functions with comprehensive error handling to ensure robust analysis across all three questions.