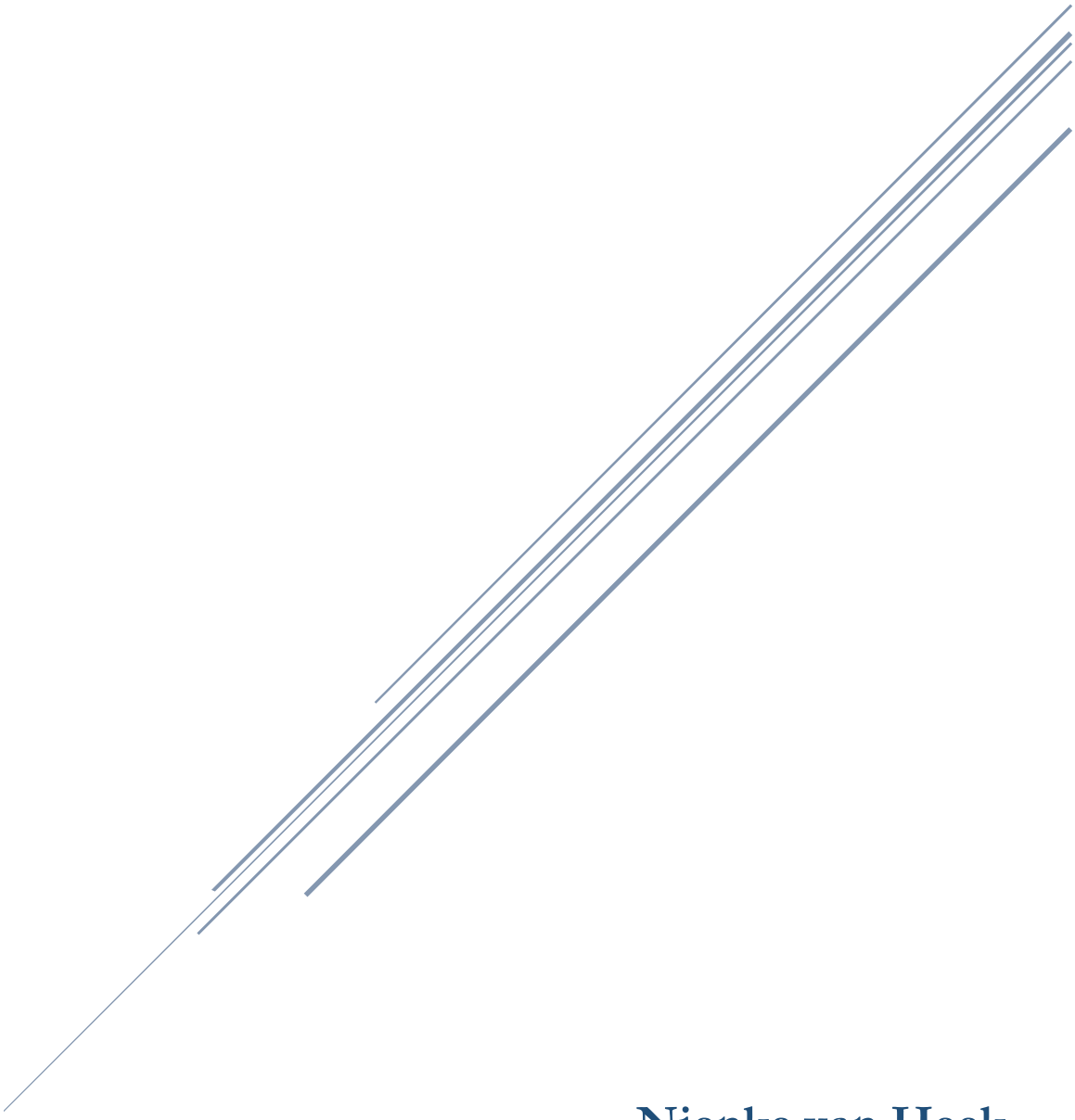
ANALYSIS CO2 EMISSIONS

Final Assignment 'Data Analytics with Python', WINC Academy



Nienke van Heek

August 2023

1. Introduction

This report presents the findings of a data analytics project on CO2 emissions, conducted in August 2023, using various datasets sourced from 'Our World in Data'[1] and 'World Bank Open Data'[2]. The project is the final assignment of the course 'Data Analytics with Python, offered by WINC Academy, a Dutch institution that provides post-graduate tech courses.

The analysis provides insights into three key questions:

1. What is the biggest predictor of a large CO2 output per capita of a country?
2. Which countries are making the biggest strides in decreasing CO2 output?
3. Which non-fossil fuel energy technology will have the best price in the future?

The upcoming section will delve into the research findings related to each of these three questions, with section 2.1. looking at factors predicting high CO2 output per capita. Section 2.2. will analyze countries that have made significant strides in reducing CO2 emissions by analyzing the relative change in CO2 output between 2004 and 2021. Lastly, section 2.3. will assess the anticipated pricing of non-fossil fuel technologies between 2020 and 2030. The report will summarize the findings in section 3.

2. Research findings

2.1. Predictors of large CO2 output per capita

The initial analysis examined the countries with the highest and lowest CO2 emissions per capita.[3] In 2021, the countries with the highest CO2 emissions per capita were: [1] Qatar (35.6 Mt), [2] Bahrain (26.7 Mt), [3] Kuwait (25.0 Mt), [4] Trinidad and Tobago (23.7 Mt), and [5] Brunei (23.5 Mt). The countries with the lowest CO2 emissions per capita were: [1] Malawi (0.08 Mt), [2] Burundi (0.06 Mt), [3] Central African Republic (0.04 Mt), [4] Somalia (0.04 Mt), and [5] Democratic Republic of Congo (0.03 Mt).

Countries with the lowest CO2 emissions are African nations with lower GDP's. This suggests a connection between GDP per capita and CO2 emissions. Conversely, countries with the largest CO2 output are oil-producing countries and/or countries with oil refineries. This observation implies a potential connection between a country's dominant economic sectors and its CO2 emissions. Additionally, two factors were identified as potentially of influence on CO2 emissions: the proportion of renewable energy sources within the energy mix and the energy consumption per capita within a given country. The analysis was conducted based on these ideas.

[1] 'Our World in Data', https://ourworldindata.org/, last visited August 31, 2023

[2] 'World Bank Open Data', https://data.worldbank.org/, last visited August 31, 2023

[3] The dataset used in this analysis was downloaded from Our World in Data. CO2 and Greenhouse Gas Emissions Country Profiles, retrieved from https://ourworldindata.org/co2-and-greenhouse-gas-emissions, last visited August 31, 2023.

Among these four potential predictors of CO2 output per capita, GDP per capita emerges as the most significant predictor of CO2 output. The calculated Pearson Correlation Coefficient (PCC) between GDP per capita and CO2 per capita is 0.79, with a low P-value of 1.0037144160698617e-35. This outcome indicates a strong positive correlation between these two variables (see figure 1).

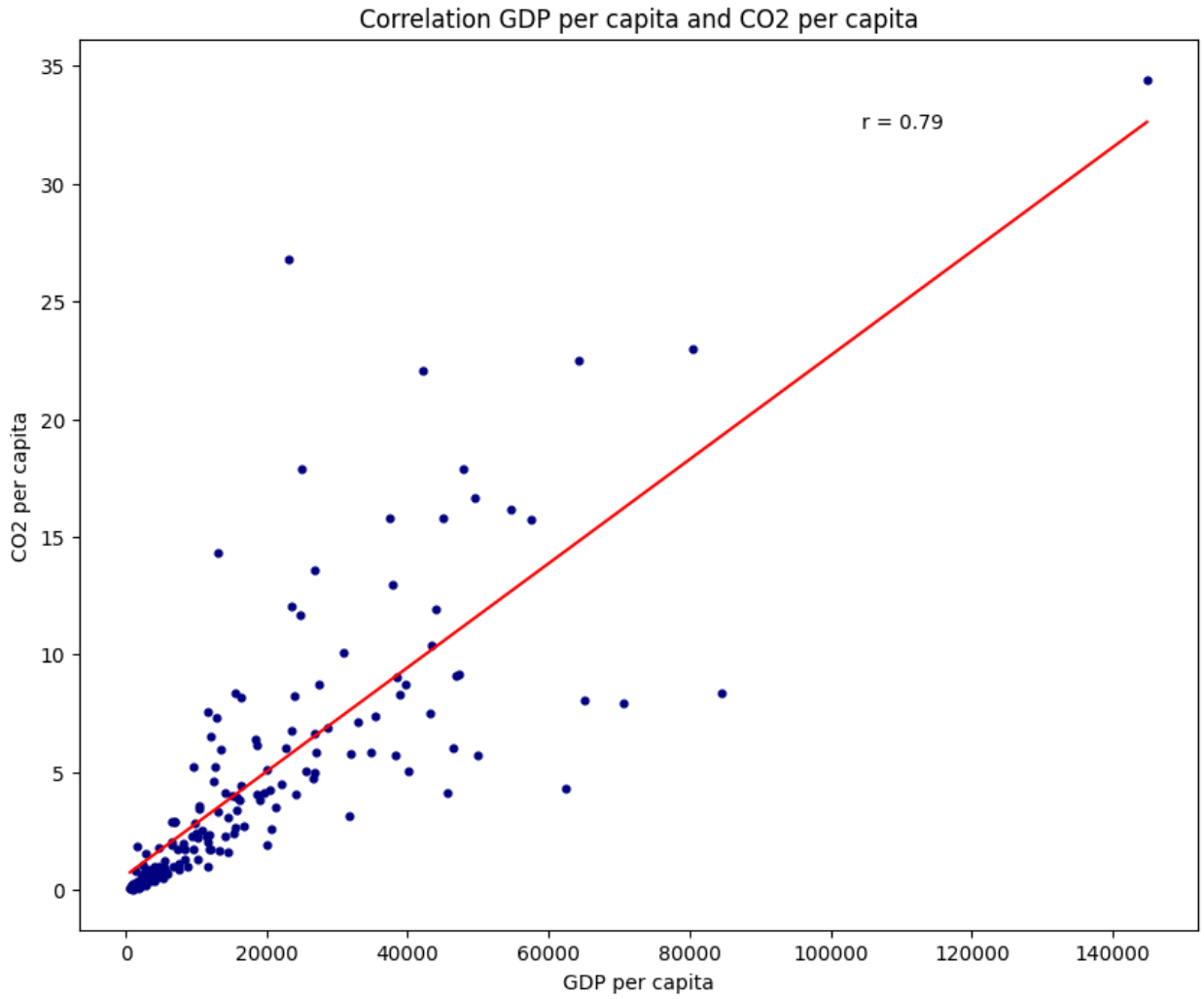


Figure 1: Correlation GDP per capita and CO2 per capita.

In addition, there is a strong correlation between energy consumption per capita[4] and CO2 per capita. The calculated PCC between energy consumption and CO2 is 0.72, with a P-value of 0.0, meaning the data is significant.

[4] The datasets used in this analysis were downloaded from Our World in Data. CO2 and Greenhouse Gas Emissions Country Profiles, retrieved from https://ourworldindata.org/co2-and-greenhouse-gas-emissions, last visited August 31, 2023, and 'Energy Use per Person, retrieved from https://ourworldindata.org/energy, last visited in August 31, 2023.

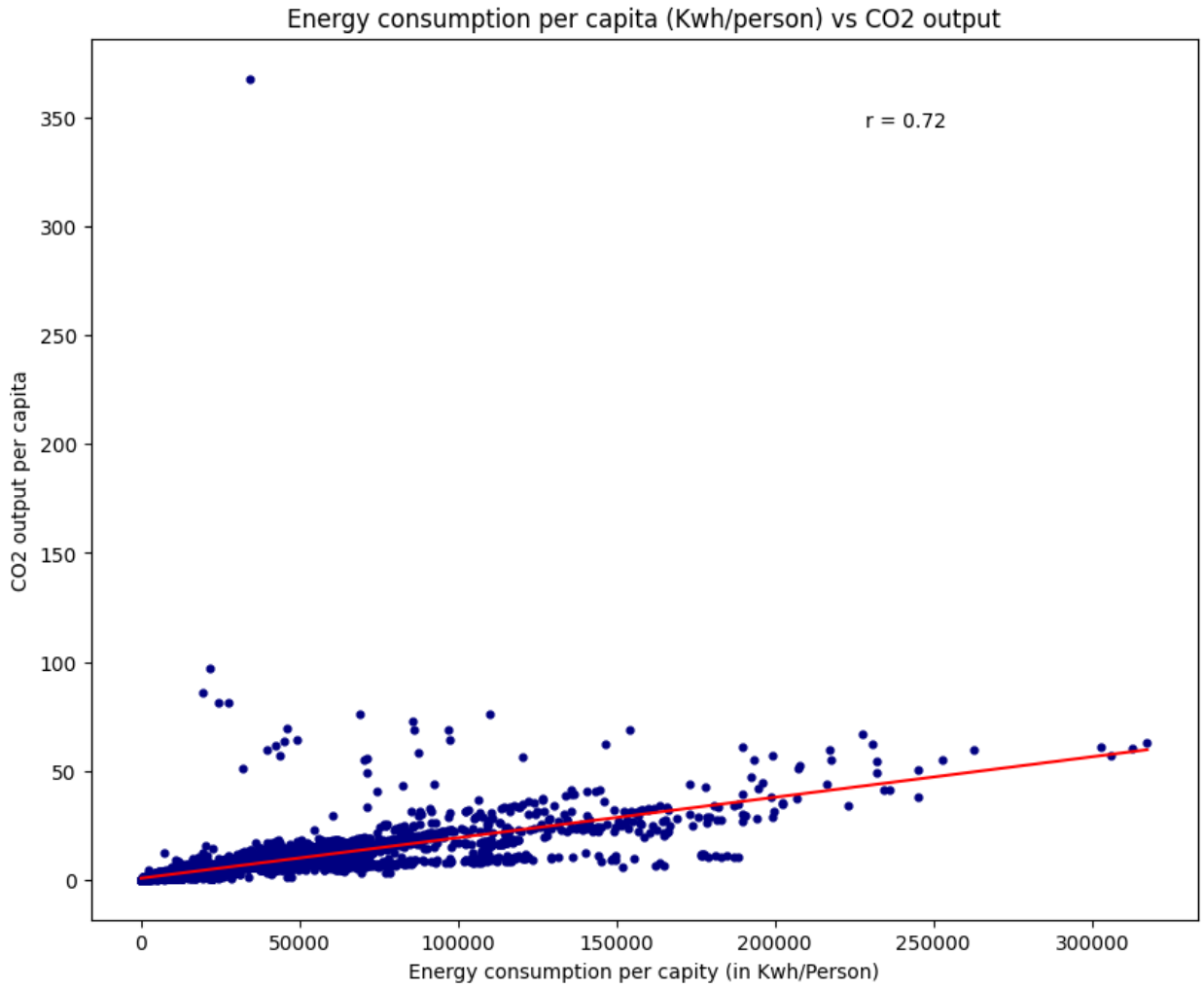


Figure 2: Energy consumption per capita in Kwh/person and CO2 output per capita

Furthermore, a correlation can be observed when examining the percentage of value added to GDP by specific sectors and CO2 outputs. Countries that exhibit higher CO2 emissions tend to have substantial industry sectors, accompanied by relatively smaller agriculture, forestry, and fishing sectors. In contrast, nations with lower CO2 emissions tend to have sizable agriculture, forestry, and fishing sectors while having smaller industry sectors (see figures 3 and 4).[5]

[5] Data sourced from Our World in Data. The following datasets were used: CO2 and Greenhouse Gas Emissions Country Profiles, retrieved from https://ourworldindata.org/co2-and-greenhouse-gas-emissions, last visited August 31, 2023, and World Bank Open Data, on Industry(https://data.worldbank.org/indicator/NV.IND.TOTL.CD?locations=1W, last accessed August 31, 2023), on Manufacturing (https://data.worldbank.org/indicator/NV.IND.MANF.ZS?locations=1W, last accessed August 31, 2023), on Agriculture, Forestry, Fishing (https://data.worldbank.org/indicator/NV.AGR.TOTL.ZS?locations=1W, last accessed August 31, 2023) and on Services (https://data.worldbank.org/indicator/NV.SRV.TOTL.ZS?locations=1W, last accessed August 31, 2023).

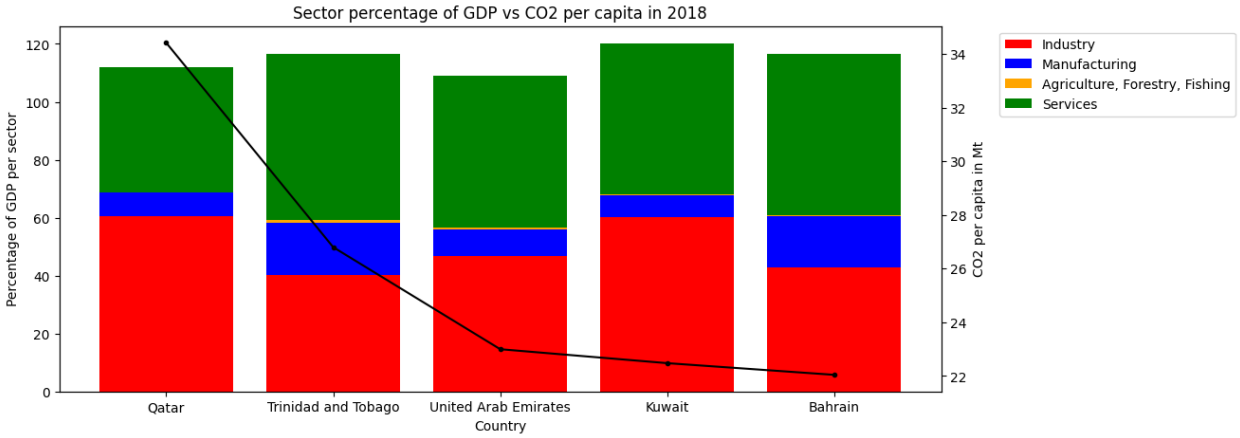


Figure 3: Sector percentage of GDP vs CO2 per capita in 2018 of top producers.[6]

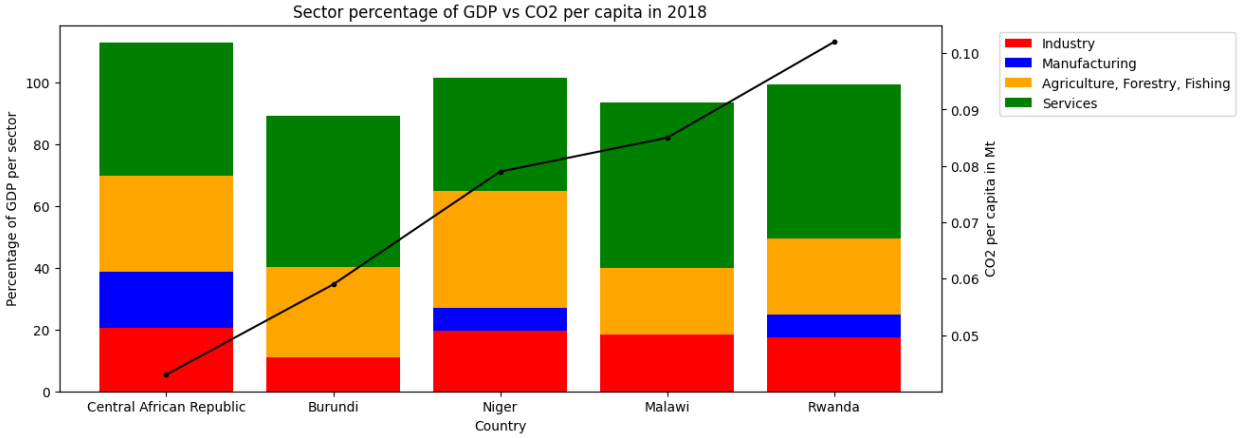


Figure 4: Percentage of GDP per sector and CO2 per capita in 2018 of lowest producers.

The calculated PCC between the percentage of added value to GDP of industry and CO2 per capita is 0.41, which suggest a moderately strong positive correlation, with a low P-value of 6.821714535337683e-08 (see figure 5).

[6] This data was sourced from Our World in Data, and merged different datasets. Underlying data adds up to more than 100 percent. The reason for this discrepancy is unknown, perhaps certain data points were included in multiple sectors.

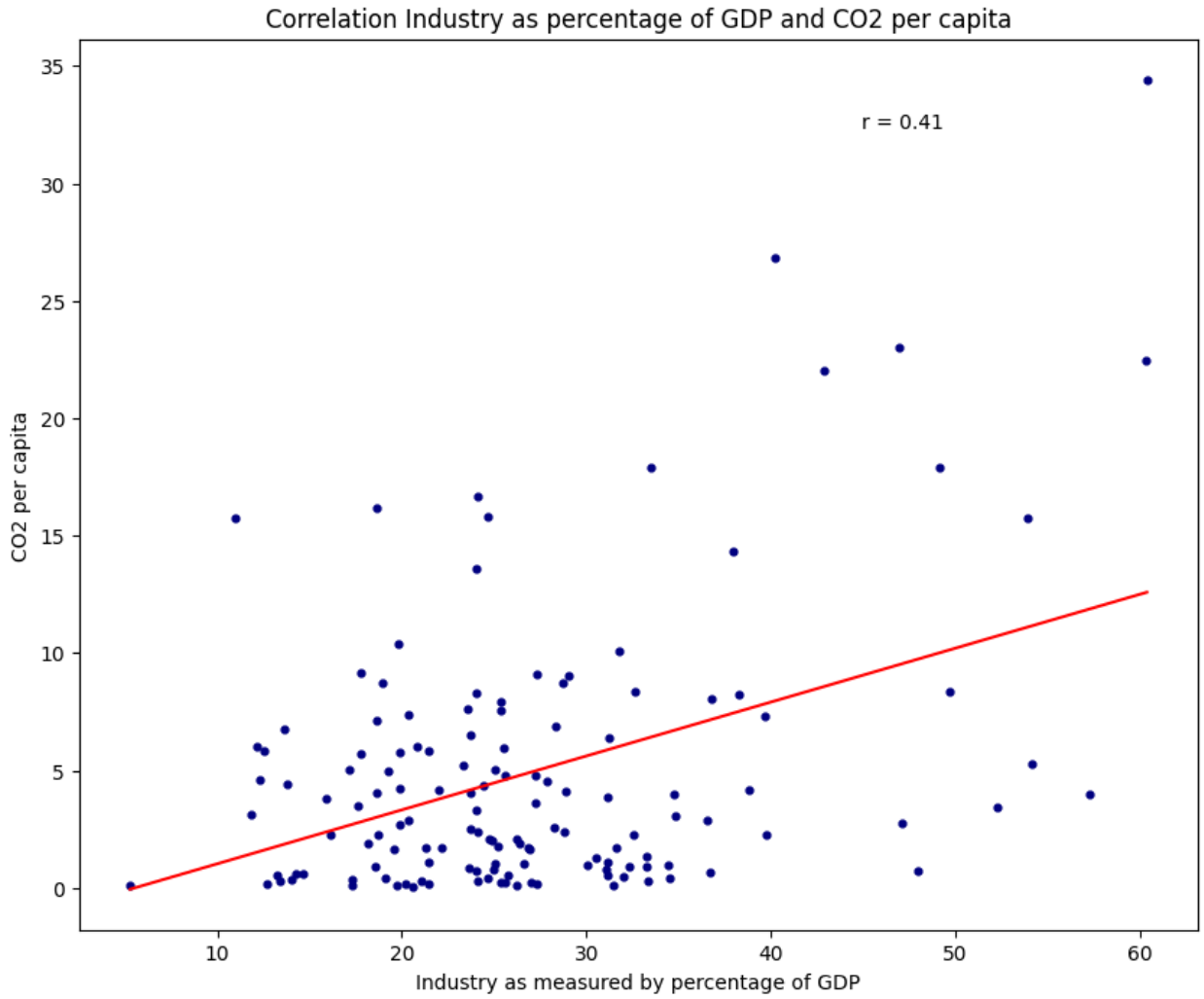


Figure 5: Percentage of worldwide added value of industry to GDP and CO2 per capita in 2018 correlated.

The calculated PCC for the agriculture, forestry and fishing sectors and CO2 per capita is -0.51, which suggests a moderately strong negative correlation between these sectors and CO2 per capita (see figure 6). The P-value for this correlation is 1.749988714295704e-10, which means the correlation is valid.

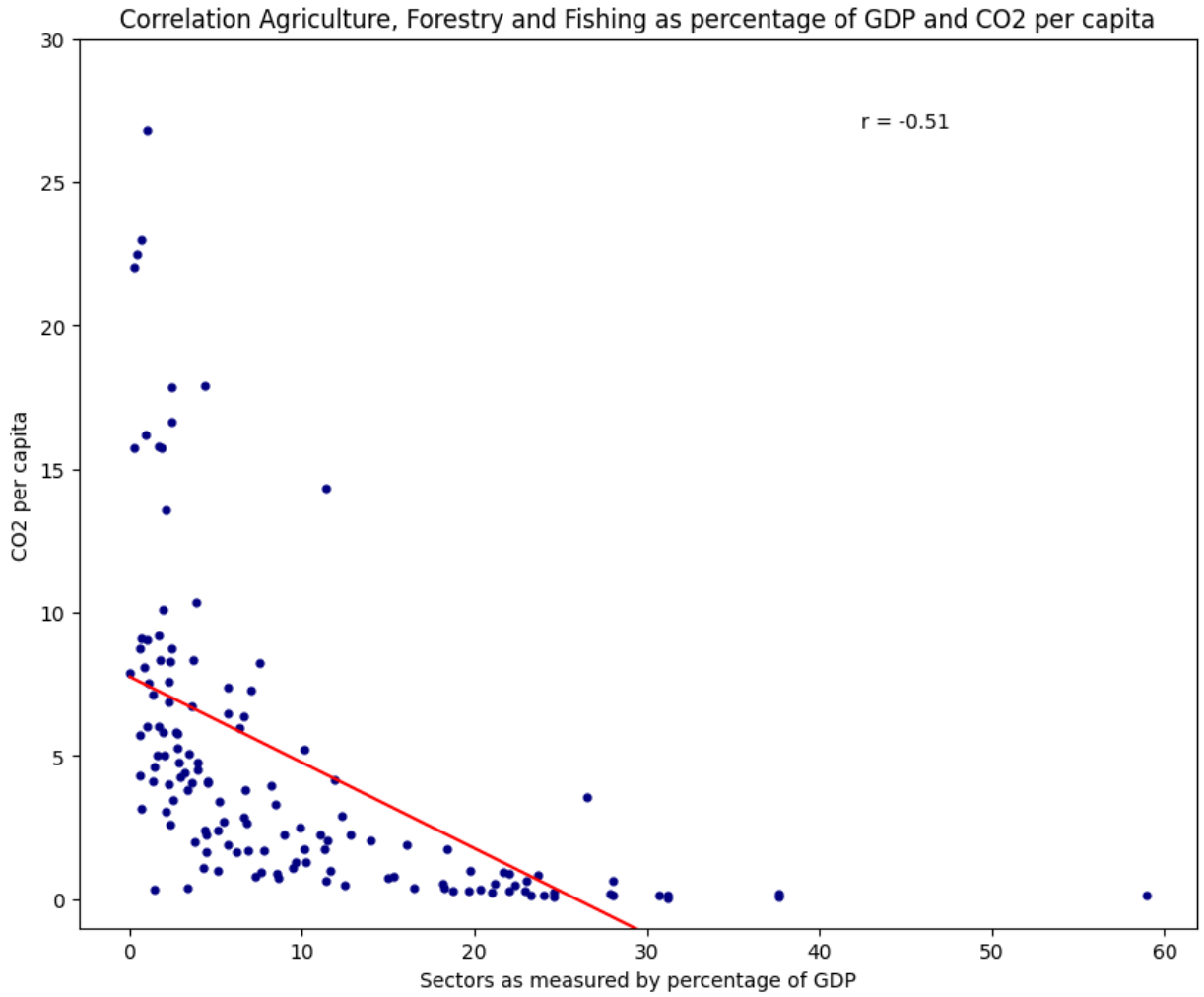


Figure 6: Percentage of worldwide added value of agriculture, forestry and fishing to GDP and CO2 per capita in 2018 correlated.

The data analysis did not reveal a discernible correlation between the percentage of renewables in the energy mix and overall CO2 emissions. Visualizing the proportion of renewables vs. non-renewables in the energy mix illustrates that global energy sources continue to predominantly consist of non-renewables (which includes nuclear energy in this representation). Despite an upward trend in the amount of renewables in the energy mix, the percentage remains too small to counteract worldwide CO2 emission increases over the years (see figure 7).

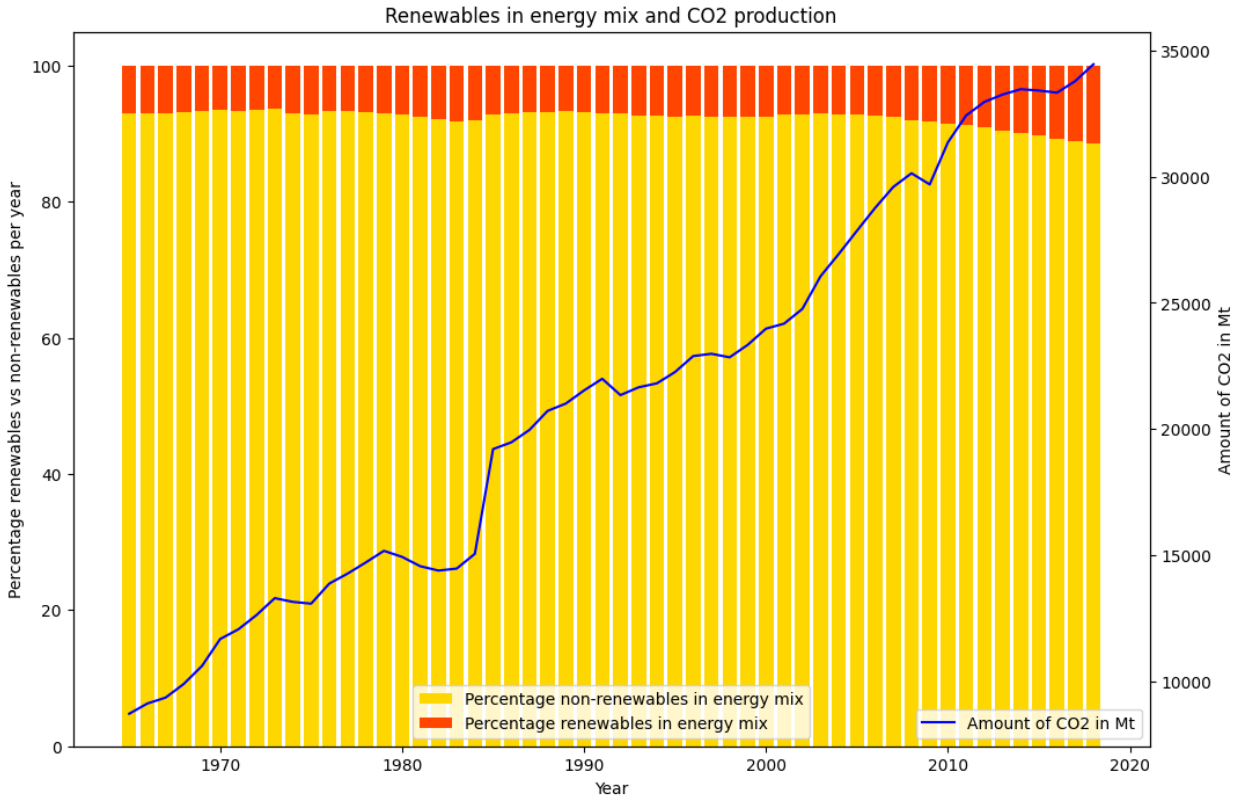


Figure 7: Percentage of renewables in energy mix and worldwide CO2 production in Mt.[7]

2.2. Countries with biggest strides in decreasing CO2 output

The Kyoto Protocol is a global treaty that seeks to combat climate change by establishing emissions reduction targets for participating nations. It was ratified in 2004 and entered into force in 2005. Although the protocol is not universally ratified, the treaty had a large impact in reducing worldwide CO2 emissions. This section therefore focuses on the timeframe from 2004 to 2021 and analyzes three year rolling averages to calculate the relative change in CO2 emissions of countries.

The analysis revealed that Aruba (-66.5%), Curacao (-63.0%), and Venezuela (-54.2%) exhibited the most substantial reductions in CO2 emissions.[8] Several other countries have also achieved significant progress in reducing their CO2 output, as evidenced by the top 10 performers showcased in figure 8.

[7] Dataset retrieved from 'Our World in Data', Energy Mix: https://ourworldindata.org/energy-mix, last accessed August 31, 2023.

[8] These large reduction can likely be attributed to the closing of oil refineries and socio-political reasons such as the US sanctions on Venezuela's oil industry. More research should be conducted to see how these nations were able to decrease their CO2 output.

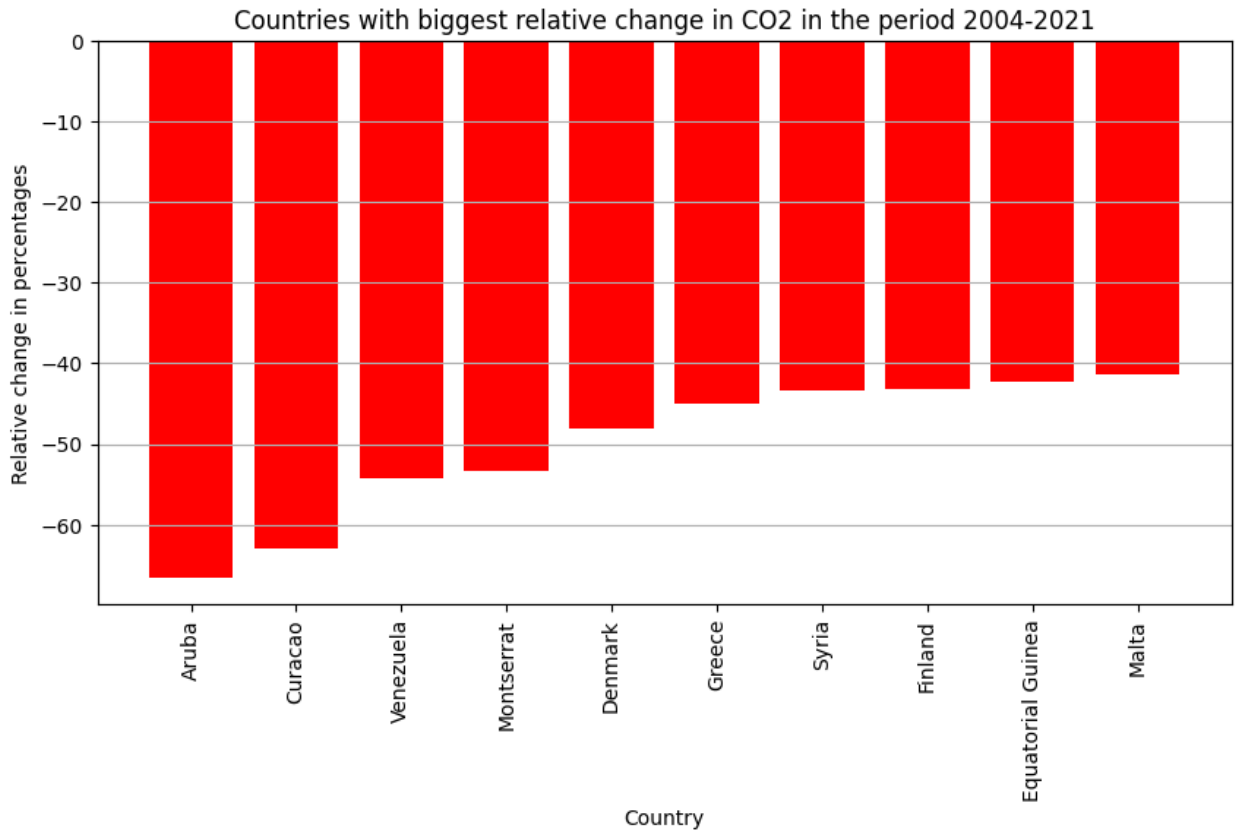


Figure 8: Countries with biggest relative change in CO output in the period 2004-2021.

2.3. Price forecasting non-fossil fuel energy technology

To forecast the prices of non-fossil fuel energy technologies between 2020 and 2030, the analysis utilized data on the worldwide levelized cost of energy per year for various technologies (see figure 9).[9] Linear regression was employed to forecast prices for bioenergy, geothermal, offshore, and hydropower. In contrast, exponential interpolation was found to be more suitable for forecasting the prices of solar photovoltaic, concentrated solar power, and onshore wind. This is because solar technologies rely heavily on semi-conductors. The semi-conductor industry exhibits a price pattern that is largely exponential, which is why it is expected that the price of solar technologies will also exhibit an exponential pattern. Furthermore, wind energy has become so popular that laws of scale start to be of significance, which is why an exponential price pattern is also expected here. It would therefore be incorrect to use linear regression on these technologies.

A note needs to be made on the use of linear regression and exponential fitting in this forecast. Logically, analyzing the data in this manner will give only a very rough estimate of what future prices

[9] Our World in Data, Levelized cost of energy. Data retrieved from: https://ourworldindata.org/grapher/levelized-cost-of-energy, last accessed August 31, 2023.

would look like, as it focuses solely on past prices to predict future pricing. It therefore leaves out external variables that may influence the price of these technologies.

The findings indicated a consistent trend of decreasing costs for all technologies over the examined period, with solar and onshore wind technologies showing the most substantial price reductions.

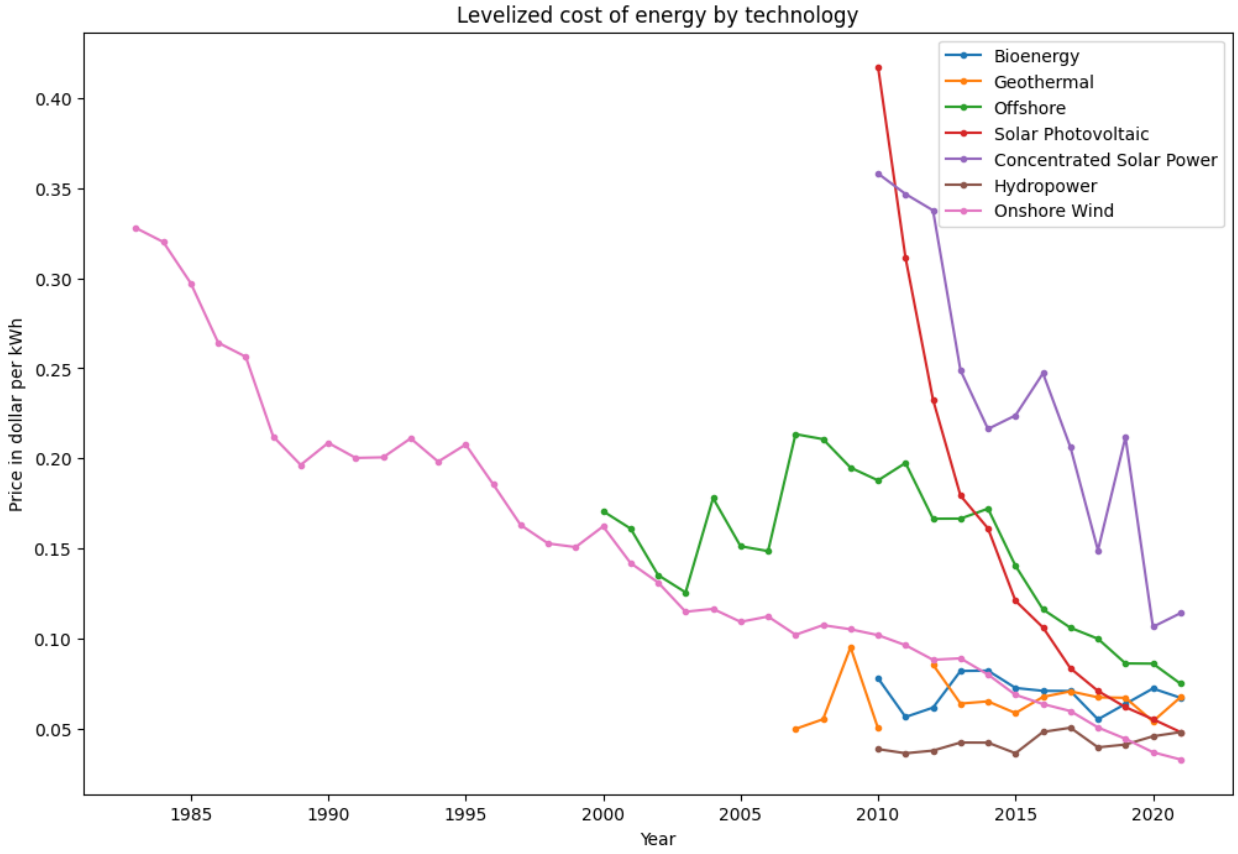


Figure 9: Levelized cost of energy by technology per year.

This trend is projected to persist in the period 2020-2030. Projections indicate that solar photovoltaic technologies are expected to have the lowest price in the future, followed by onshore wind and concentrated solar technologies (see figure 10).

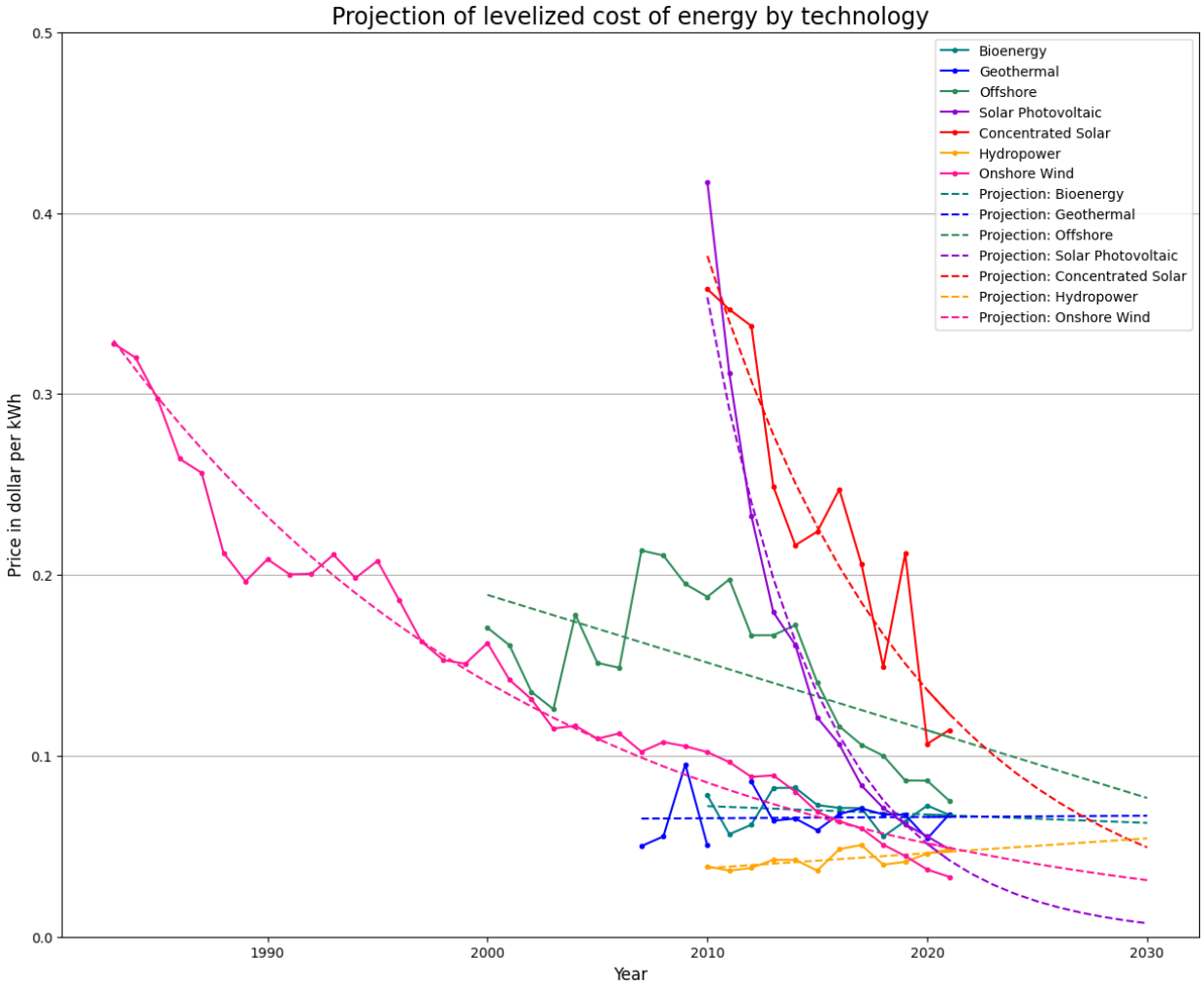


Figure 10: Projection for 2020-2030 of levelized cost of energy by technology.

3. Conclusions

This report provided insights in three key question:

1. What is the biggest predictor of a large CO2 output per capita of a country?
2. Which countries are making the biggest strides in decreasing CO2 output?
3. Which non-fossil fuel energy technology will have the best price in the future?

3.1. Conclusions predictors of large CO2 output per capita

The two largest predictors of CO2 output per capita of predictors analyzed in these report are GDP per capita of a country (PCC of 0.79) and energy consumption per capita (PCC of 0.72). Less strong correlations could be found for added value to GDP of industry and agriculture, forestry and fishing. The calculated PCC between added value to GDP of industry and CO2 per capita is 0.41, and -0.51 for agriculture, forestry and fishing, suggesting a moderate correlation.

3.2. Conclusions countries with biggest strides in decreasing CO2 output

The analysis looked at relative change in CO2 output over the period 2004-2021 and revealed that Aruba (-66.5%), Curacao (-63.0%), and Venezuela (-54.2%) made the largest strides in reducing CO2 emissions.

3.3. Conclusions price forecasting non-fossil fuel energy technology

To forecast the prices of non-fossil fuel energy technologies between 2020 and 2030, the analysis utilized data on the worldwide levelized cost of energy per year for various technologies. Linear regression was employed for bioenergy, geothermal, offshore, and hydropower technologies, whereas exponential curves were fitted to photovoltaic, concentrated solar power and onshore wind technologies. Findings indicated a consistent decrease in cost for all technologies researched, with solar and onshore wind technologies showing the largest price reduction. When forecasting prices for 2020-2030, this trend persists. Based on these projections, it is expected that solar photovoltaic technologies will have the lowest price in the future, followed by onshore wind and Concentrated Solar technologies.