QBUS 6860 Group Assignment

UID:

530323592

530699718

530324061

530554059

Table of contents:

Introduction

With increasing global concern about energy consumption patterns and environmental sustainability, the use of renewable energy has become a key factor in achieving Sustainable Development Goal 7 (Ensure access to affordable, reliable, sustainable, and modern energy for all). To significantly increase the share of renewable energy in the global energy mix, the present report aims to analyze sustainable energy indicators and other relevant factors for countries for the period from 2000 to 2020.

As a consulting firm, we use renewable energy, carbon emissions, and economic growth indicators to provide valuable insights and better decision-making. In addition, the economic crisis of 2008-2009 and COVID-19 in 2019 will have a significant impact on these indicators, which are discussed in this report.

Data Preparation

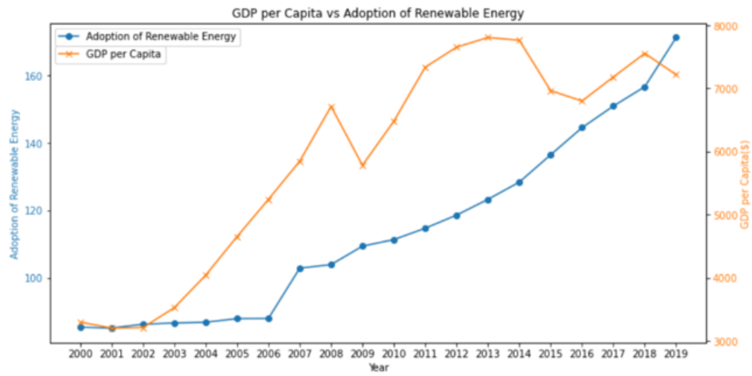
The data given for our task is the dataset of 'sustainable energy indicators and other relevant factors across various countries from 2000 to 2020.' Before we begin our data analysis, we must address all the missing values in our dataset to ensure the most coherent dataset. Firstly, we need to drop all the noisy data with major data missing problems, such as excluding the year 2020 for our analysis since there are many missing data, especially the missing data for our studied variables. Meanwhile, we dropped the countries that were established after 2000 since the time period for our studies is between 2000- 2019.

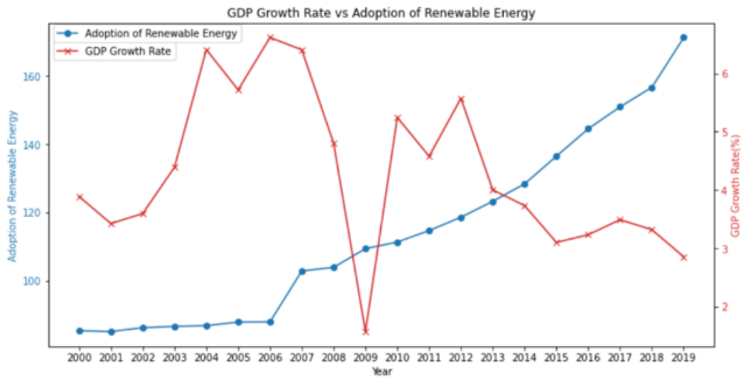
For the data cleaning part of our analysis, we find variables like Per Capita Renewable Electricity Capacity Nuclear Power Electricity (TWh), Fossil Fuel Electricity (TWh), Renewable Source Electricity (TWh); these variables encounter problems of several countries having entire data missed, we can simply drop all of these countries from the columns. For other variables like CO2 emissions, GDP per person, or economic growth, we observed countries having a different number of missing values from the year 2000 to the year 2019. Regarding this, we decided to remove the countries that have more than five missing values, for countries with fewer than five missing values, we compared these countries' data with others; we observed the countries that had missing values, these countries having low level of CO2 emissions, and Lower GDP per person and having high variabilities for Economic growth. Due to this, we decided to fill the missing values of CO2 Emissions and GDP per person of these countries with the 25 percentiles of the year, which the countries having a missing year or the 25 percentiles of the earliest year. Meanwhile, we replace the missing values for economic growth with the means of the year or the nearby year that the countries have missing values to reduce the bias.

In addition, we create a new column with the absolute values of the geographic latitude named abs_Latitude. Then, we categorized different countries based on the abs_latitudes, and create a new column named geographic zones which having nominal data like tropical, subtropical, temperate, subpolar, polar.

1.0 Relationship between the adoption of renewable energy and key economic indicators

To analyze this question, we first created two line plots to examine the trends over time for three variables: ‘Per Capita Renewable Electricity Capacity’, ‘GDP Per Person’, and ‘Economic Growth Rate’. The two plots show the trends between variables ‘Renewable Electricity Capacity’ and the other two key economic indicators respectively. The data points for each year represent the average value calculated from all countries for that year. We removed the year 2020 because in this year, there is an outlier in ‘Economic Growth Rate’ in , and an unusual low value in ‘GDP Per Person’. This is most likely due to Covid-19, which will be discussed later.





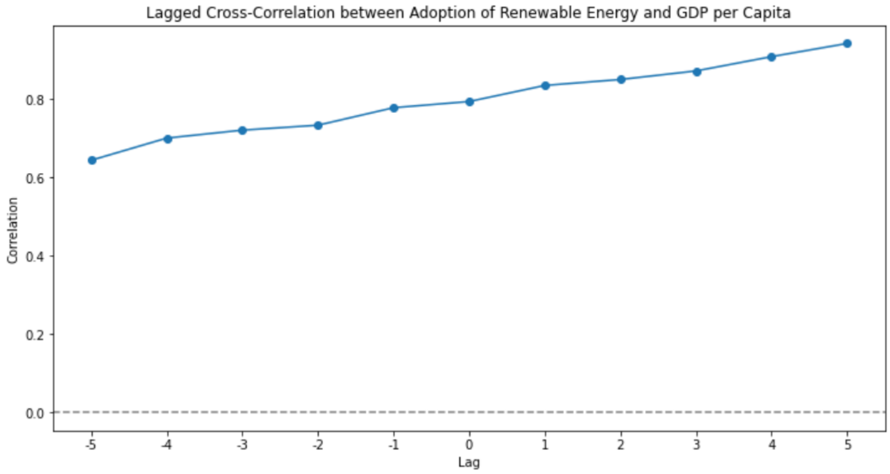
In the first plot, we can observe that the two variables have a similar trend from 2000 to 2019. When GDP per person increases, the adoption of renewable energy also grows. ‘GDP per person’ rises from $3000 to $7000 while ‘Per Capita Renewable Electricity Capacity’ rises from about 80 to 180. It can be clearly seen that there is a positive relationship between the two variables.

In the second plot, GDP growth rate has shown a fluctuating trend between 1% and 7% over the 20 years while the adoption of renewable energy is on a steady upward trend. We can draw a conclusion that the adoption of renewable energy has no correlation with GDP growth rate.

All above, the two line plots provide us with a preliminary conclusion about the correlation. To explore further relationship about the dominant factor and time lags, a lag plot is needed.

1.1 The lagged cross-correlation between the adoption of renewable energy and GDP per capita

The dataset covers a period from 2000 to 2019, which is 20 years in total. Therefore, we chose to investigate the correlation between the two variables over the past 5 years and the next 5 years, which is a relatively appropriate lag. To produce the plot, we calculated the lagged cross-correlation between the percentage change of the adoption of renewable energy and GDP per capita.

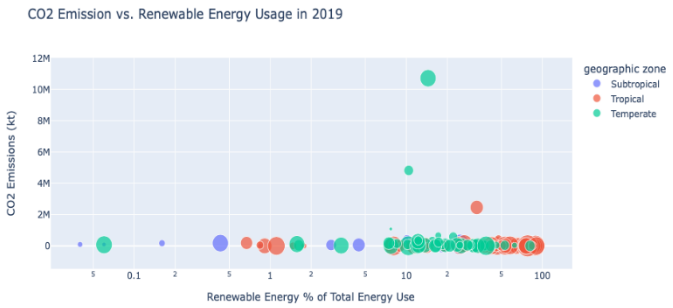


To analyze the time lag plot, we first need to explain its rationale. The horizontal axis in the graph represents lag values, while the vertical axis represents the correlation coefficients. A lag value of 0 indicates the correlation between the two variables of the same year. A positive value of y indicates a positive relationship between them, and vice versa. Positive lags suggest that the GDP per capita leads to the change of adoption of renewable energy, while negative lags suggest the opposite.

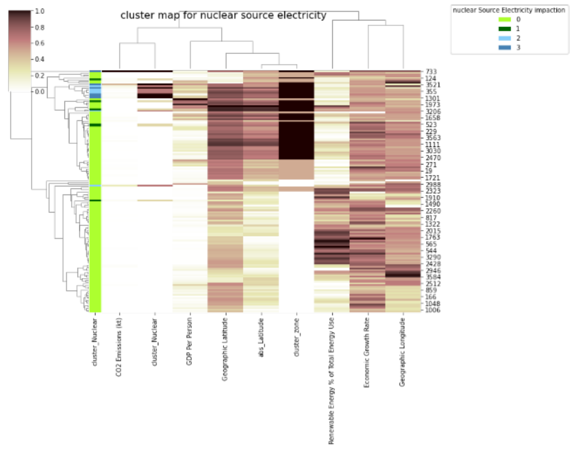
In the time lag plot, it can be observed that as the lag value varies from -5 to 5, the correlation coefficient gradually increases from 0.6 to close to 1.0. This suggests that the relationship between the adoption of renewable energy and GDP per capita strengthens as the lag increases. Since the correlation for positive lag values is higher than those for negative lag values, we can say that ‘GDP per Capita’ leads the relationship. The gradual increase of correlation coefficient also indicates that in real world, policymakers and investors are more likely to increase investment in renewable energy when GDP grows. This is also an important factor in achieving one of the SDG7 targets: Ensure universal access to affordable, reliable, and modern energy services.(United Nations)

2.0 Study of relation between CO2 emissions, renewable energy consumption, economic growth fact

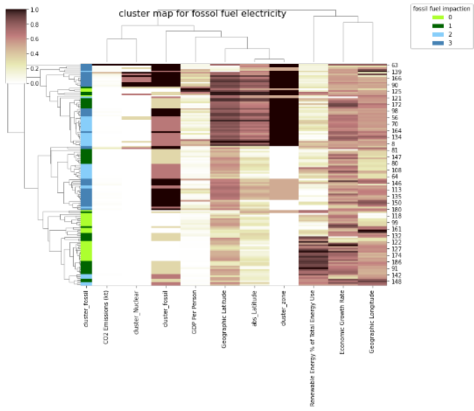
We will use cluster map to demonstrate the relationship between different variables via countries in different situations; in this cluster graph, we matched the countries with corresponding colors in the ordinal orders and listed them on the y_axis. The x_aixs for the cluster graph are the variables we selected to compare each other's correlation. From the cluster map, the audience can clearly see each country's correlation difference.



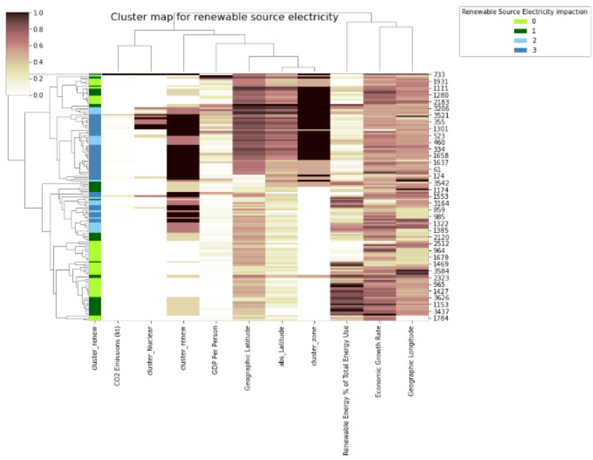
We use the bubble chart to show the relation between CO2 emissions, Renewable energy usage, Economic fact cross different geographic regions. The bubble chat consists of the y_axis, x_axis, bubble size, bubble colors, and timeline. We set the x_axis as the renewable energy % of the total energy use for targeted sample countries. We set the y_axis as the Co2 emissions for these countries. We use three colors that are in line with countries located in three geographic zones. In addition, the size of the bubble will determined by the country's economic growth rate. We set the timeline from 2000 to 2019; from the bubble chat, the audience can observe that the tropical bubbles having bigger sizes are closer to the right side of the X_axis, which indicates that for countries located in tropical zones, the countries' renewable energy usage is stronger related to the economic growth comparing with other regions.



The cluster map of nuclear source electricity compares the relationship between renewable energy consumption, CO2 emissions, and economic factors across countries with different levels of reliance on nuclear source. From the plot, there is a high variability correlation change between economics growth rate and renewable energy consumption for countries with low nuclear source usage. Hence, there is no strong correlation between economic growth and renewable energy usage for countries with higher nuclear source consumption.



The cluster map of fossil fuel electricity compares how the usage of fossil fuel electricity impacts the relationship between renewable energy consumption, CO2 emissions, and economic factors across countries. There is a significant difference of color between the countries with low fossil fuel electricity usage and countries with higher fossil fuel electricity usage, indicating that for countries that don't rely on fossil fuel-generated electricity, their economy will grow faster while they have higher renewable energy usage.

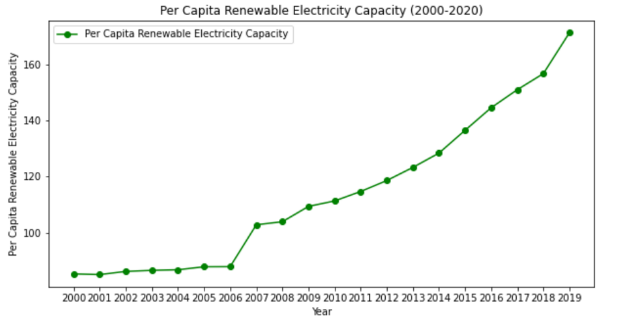


The cluster map for renewable source electricity compares how renewable energy consumption shapes the relations between renewable energy consumption, CO2 emissions, and economic factors; it demonstrates similar situations with the nuclear source consumption graph. Like some countries with low renewable source consumption, they have higher correlations between renewable energy usage and economic growth. However, some of these countries don't. Meanwhile, in countries with higher renewable energy usage, their economic growth is not correlated with renewable energy usage. In conclusion, rely on renewable source electricity didn't boost stronger correlations between renewable energy usage and economic growth.

Furthermore, none of the cluster maps plot strong correlations between CO2 emissions and the other two variables. Therefore, we concluded that CO2 is not relevant to impacting economic growth or renewable energy consumption.

All in all, from the above diagrams, we summarized that renewable source electricity consumption in countries in tropical zones is strongly related to the country's economic growth. Besides, countries that had strong relations between renewable source electricity consumption and economic growth are those countries that have weak reliance on electricity generates from fossil fuels.

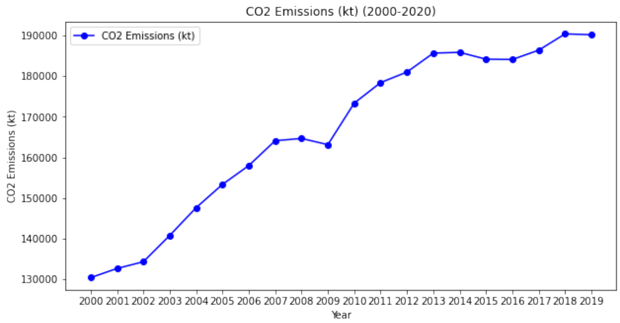
3.0 Impact of the Paris Agreement on renewable energy



The United Nations said that The Paris Agreement is a legally binding international treaty on climate change.

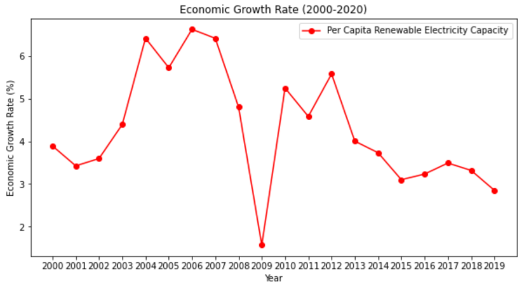
The agreement commits countries to take measures to limit the magnitude of global warming, giving further impetus to the development of renewable energy. As can be seen from the figure, Per Capita Renewable Electricity Capacity has largely fluctuated upwards between 2000 and 2013. This is because the Paris Agreement has prompted countries to increase investment and policy support for renewable energy in order to meet their emissions reduction targets. As a result, with the signing of the Paris Agreement pact on November 4, 2016, the use of clean energy has grown significantly faster from 2017 to 2019.

3.1 Impact of the Great Financial Crisis on Carbon Emissions



As can be seen from the line graph, carbon dioxide emissions grew slowly at the beginning of the twenty-first century. As the economy grew and energy consumption increased significantly, emissions increased significantly. During the financial crisis of 2008, the reduction in global economic activity and the slowdown in industrial production led to a decrease in carbon emissions, which were minimized in 2009.

3.2 The Great Financial Crisis and the Impact of Covid-19 on Economic Growth



From this line graph, we can observe the changes in economic growth rates between 2000 and 2020. There are two major global events that have had a significant impact on the growth of the economy: the financial crisis of 2007-2008 and the COVID-19 epidemic that began in late 2019.

The graph shows that since the economic growth rate reached its highest point in 2006, it then plummeted until 2009, when it even reached its lowest value since the twenty-first century. This coincides with the onset of the global financial crisis (2007-2009). The global recession triggered by the global financial crisis was characterized by a sharp decline in economic activity, a fall in output and a rise in unemployment. The banking crisis led to the collapse of several large financial institutions, requiring government intervention in the form of bailouts and recapitalization (Kaur, 2023). In addition, the financial crisis led to a collapse in global markets, a credit crunch, a decline in business investment and a sharp drop in consumer confidence, thus leading to a sharp contraction in economic activity.

In order to better explore the impact of Covid-19 on economic growth, I also followed the data from the beginning of the picture.

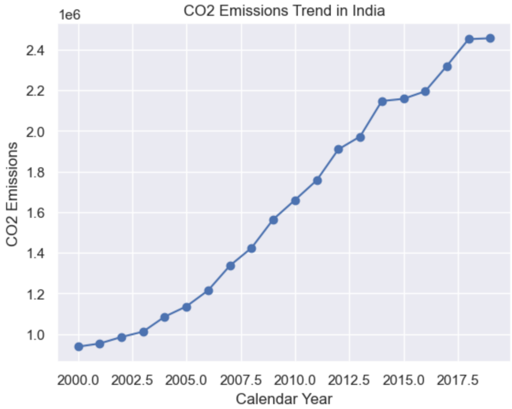
The global New Crown Pneumonia (COVID-19) coronavirus pandemic has had a severe negative impact on the world.In 2020, global gross domestic product (GDP) collectively declined by 3.4% (Einar, 2024). The chart also shows that from 2018 to 2019, the economic growth rate then begins to gradually decline. By 2020, there was a sharp decline in the economic growth rate and even negative economic growth for the first time. The outbreak led to embargoes and social isolation in various countries, many economic activities were forced to stop, businesses were closed, and supply chain disruptions led to the economic downturn.

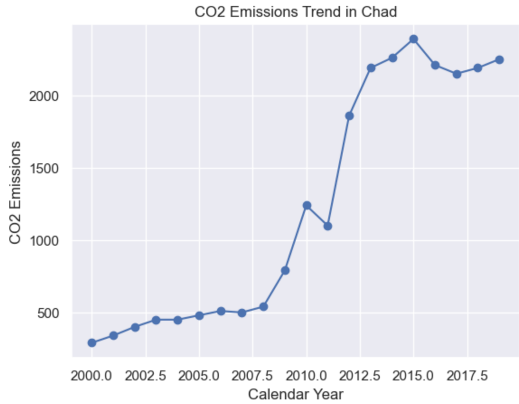
As mentioned in the previous section, we have divided the global geographic location of the countries according to the dimensions Tropical (0-23.5), Subtropical subtropical (23.5-35), Temperate temperate (35-66.5) and documented with bubble charts.

Upon investigation, it can be found that the high use of clean energy in the tropics is mainly due to its abundant solar energy. For carbon emissions, the values are higher in the temperate region, mainly because more developed or large countries are located there. The size of the bubble represents how fast or slow the economy is growing, with larger bubbles representing more rapid development. As can be seen from the figure, the relationship between economic growth rate and geographic location is not obvious, and there are both rapidly and slowly developing countries in different dimensions.

4.0 The insight for CO_2 emissions

As can be seen from the results of the previous parts of our report, overall, most countries are working towards achieving Sustainable Development Goal 7, and the use of clean energy is increasing significantly. But at the same time, we also found that economic factors have a significant impact on the development of clean energy and carbon emissions: after the outbreak of the financial crisis in 2008, global economic growth slowed sharply, and carbon emissions also fell. But among them, India and Chad are exceptions. As the heat map in the appendix 1 shows, India and Chad have been increasing their carbon emissions compared to other countries between 2000 and 2019.



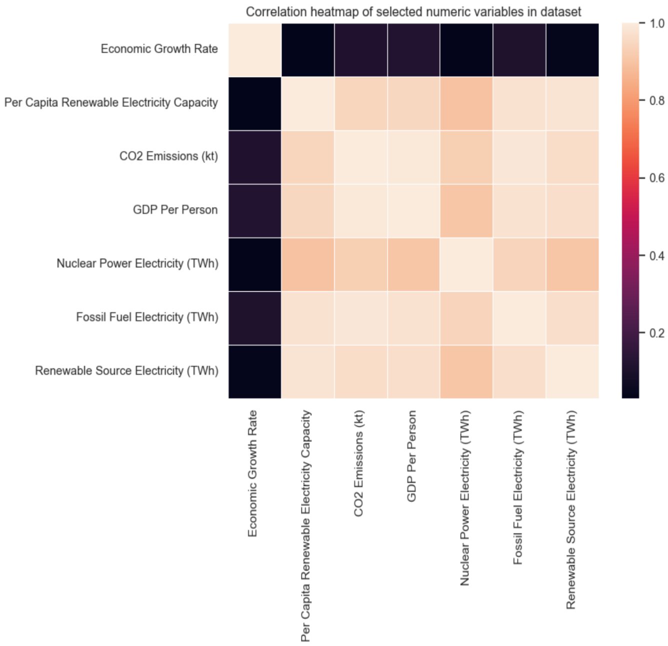


The two plots above show the change in carbon emissions of India and Chad over time, with the X-axis representing time, from 2000 to 2019. The Y-axis represents carbon emissions, which are measured in millions of kt on the left and kt on the right. It can be seen that although the overall carbon emissions of both countries showed an upward trend, Chad's data still showed a brief decline in 2010. India's carbon emissions, by contrast, have not been affected at all and have continued to rise steadily. So the question we were interested in was: What is the reason for India's carbon emissions not being affected by the financial crisis?

As we can see, India's carbon emissions have been growing at a steady speed. This shows that the financial crisis did not have a negative impact on it, and that other factors must have really caused the increase in carbon emissions. We assume that the biggest possible reason is that India's energy mix is dominated by coal, the fossil fuel with the highest carbon emissions. Even in the event of slower economic growth, carbon emissions are likely to continue to grow without a significant reduction in coal use. In addition, if India does not effectively promote renewable energy to replace traditional energy sources during this period, carbon emissions will naturally remain high or continue to rise.

4.1 The factors that influence the CO_2 emissions of India

In order to explore the reasons behind this phenomenon, we also took into account some other factors, such as GDP per capita and the use of various types of energy, and generated a heatmap relationship model (as shown in the figure below). Detailed data can be found in appendix 2.



The results show that there is little correlation between economic growth and carbon emissions in India. Instead, the two factors most closely related to carbon emissions are GDP per capita and fossil energy use. In addition, we found that the share of clean energy use in India declined significantly between 2000 and 2019, indicating a significant change in its energy mix. Thus, we believe that although the financial crisis around 2008 slowed down economic growth, resulting in lower energy consumption and reduced carbon emissions. But at the moment, India is also facing a major adjustment in the energy structure, and it is this shift from clean energy to fossil energy that has offset the negative impact of the financial crisis, so that carbon emissions have risen instead of falling.

Shortcoming

1.0 The shortcoming of data

Firstly, although we avoid using the variables with too many missing values, we are asked to use 'Per Capita Renewable Electricity Capacity' to measure the adoption of renewable energy in key business question 1. There are 903 missing values in this data, which are the values of 43 countries from 2000 to 2020, and many of the 43 countries are developed. Therefore, we finally removed all the missing values and investigate the relationship by using the data of rest countries. The data quality is low and will certainly limit our subsequent analysis. Another shortcoming is that in the variables that do not have too many missing values, we use the first quartile to impute null because most of the missing values are from small countries. However, this approach may introduce bias because the method does not consider the unique circumstances of the small countries, potentially affecting the reliability of the outcomes.

2.0 The shortcoming of analysis

During the process of analysis, we use the average value to represent the value of the columns for each year. However, average can cause biases. The countries in this dataset are composed of approximately 70% small/developing countries and 30%

large/developed countries. Economic sizes and population sizes differ significantly across countries, and using simple averages might obscure the varying contributions of larger and smaller nations to the global economy and energy consumption. Using more complex statistical methods, such as weighted averages, could provide a better analysis of the results. In addition, we believe that the popularization and development of renewable energy is not only related to economic indicators. Other non-economic indicators, such as the status of infrastructure, breakthroughs in new energy technologies, and global climate change agreements and international cooperation projects, are also important. However, it's hard to represent these factors numerically and include them in our analysis.

Conclusion

In summary, this report analyzes the relationship between renewable energy, carbon emissions and economic growth indicators for countries around the world from 2000 to 2020. In addition, we also take into account the impact of major global events such as Covid-19 and the financial crisis on these factors. The report finds that energy consumption patterns vary across countries and regions. Despite some missing data and few variables to study, we still find that energy consumption is not only related to economics, but there are more complex factors behind it. Therefore, in order to better explore energy consumption patterns and achieve the goals of SDG 7 at an early date, future studies should also consider the impact of economic structure, energy policies, and industrial and urbanization processes.

References

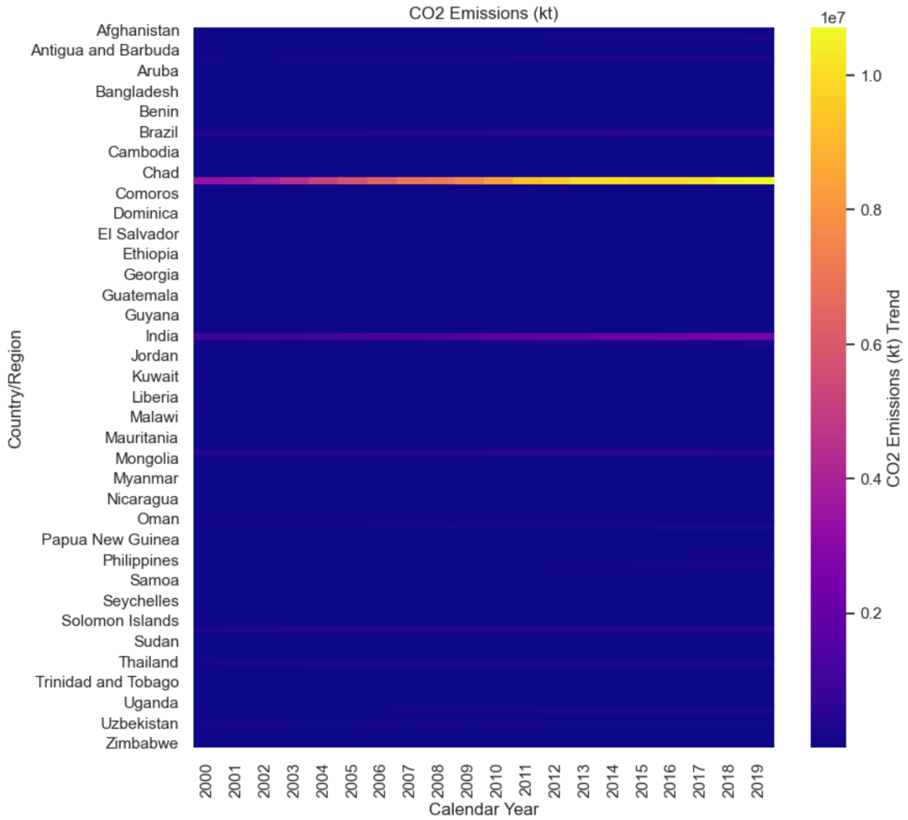
Dyvik, E. H. (2024). *Topic: Coronavirus: Impact on the global economy*. Statista. https://www.statista.com/topics/6139/covid-19-impact-on-the-global-economy/#topicOverview

Goal 7 | Department of Economic and Social Affairs. United Nations. (n.d.). https://sdgs.un.org/goals/goal7

Kaur, G. (2023, February 5). *What are the global financial crisis and its impact on the global economy?*. Cointelegraph. https://cointelegraph.com/news/what-is-the-global-financial-crisis-and-its-impact-on-the-global-economy

Unfccc.int. (n.d.). https://unfccc.int/process-and-meetings/the-paris-agreement

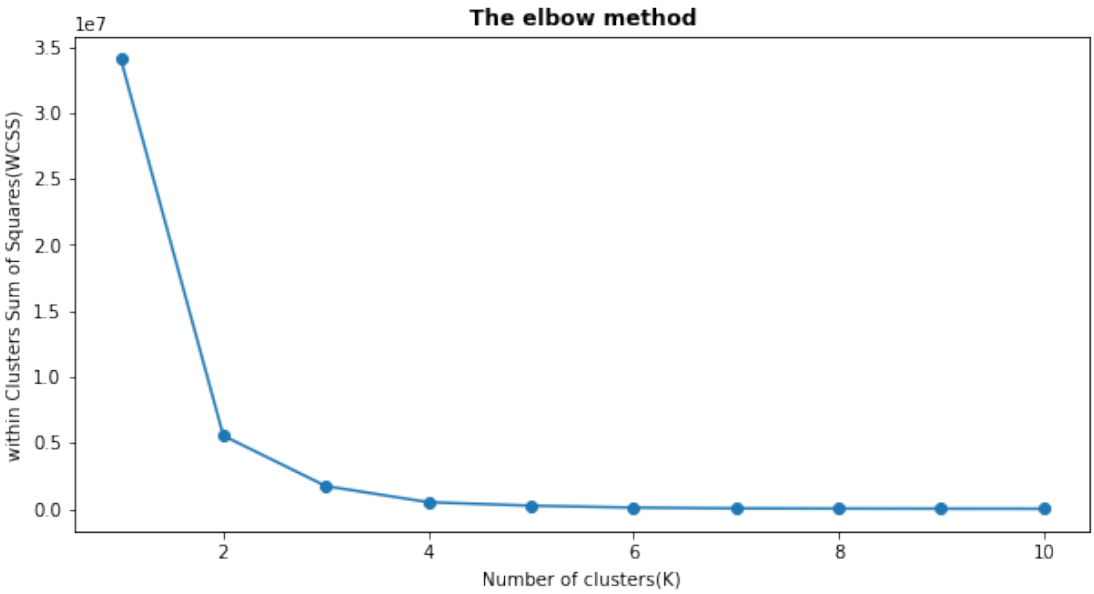
Appendix



Appendix 1

	Economic Growth Rate	Per Capita Renewable Electricity Capacity	CO2 Emissions (kt)	GDP Per Person	Nuclear Power Electricity (TWh)	Fossil Fuel Electricity (TWh)	Renewable Source Electricity (TWh)
Economic Growth Rate	1.000000	0.030076	0.113294	0.119672	0.035688	0.109030	0.040790
Per Capita Renewable Electricity Capacity	0.030076	1.000000	0.945458	0.950297	0.897156	0.973983	0.978259
CO2 Emissions (kt)	0.113294	0.945458	1.000000	0.988911	0.924783	0.988265	0.963218
GDP Per Person	0.119672	0.950297	0.988911	1.000000	0.902058	0.975641	0.969180
Nuclear Power Electricity (TWh)	0.035688	0.897156	0.924783	0.902058	1.000000	0.940067	0.903620
Fossil Fuel Electricity (TWh)	0.109030	0.973983	0.988265	0.975641	0.940067	1.000000	0.967422
Renewable Source Electricity (TWh)	0.040790	0.978259	0.963218	0.969180	0.903620	0.967422	1.000000

Appendix 2


The elbow method
1e7
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
within Clusters Sum of Squares(WCSS)
2
4
6
8
10
Number of clusters(K)

Appendix 3