THE UNIVERSITY OF SYDNEY

Assignment Coversheet – GROUP ASSIGNMENT

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Unit of Study Tutor		**Freya Singh**			
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What can we do about GHG/CO2 emissions?

COMP5048/4448 Assignment2

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I. Data Preprocessing

As requested, we are responsible for GHG emissions from Energy (total), GHG fugitive emissions (total) and GHG emissions from fuel combustion (Total, Coal, Oil, Gas), CO2 emissions from international (Marine bunkers, aviation bunkers), CO2 emissions/TES, CO2 emissions/GDP using exchange rates, CO2 emissions/GDP using purchasing power parities and CO2 emissions/population.

We wrote a program in Python that extracted the required columns from the original data set and neatly put them into a new Excel table. First, we import obtain data from the original data source and ensure the availability of data. Besides, we kept the feature of the original data set and treat the "-" in the raw data as 0, the ".." and "x" as NaN. And we filtered out regions and kept only countries. Then, we select related sheets from the original excel to form a new excel.

The structure of the new Excel table is clear: the first column contains the year information, the second contains the country name, and the third to last column contains numerical data for 12 attributes. This structure allows us to easily obtain attribute values for the same country in different years, and also to compare attribute values for different countries in the same year.

This process helps us to better analyze and compare attribute data across different countries and years, providing a useful data base for further research and decision-making.

II. Task1:Discovery of profile similarities through Visualisation

A. Visualisations

According to the requirements of task1, we will group countries according to GHG/CO2 emissions attributes (E attributes) and socioeconomic attributes (S attributes), thus helping us to set KGI and KPIS. The first three KPIs are visualizations related to E attributes, and the last KPI is visualizations related to S attributes.

The KGI is: How to describe greenhouse GHG/CO2 emissions and similar countries under various socioeconomic measures for the period 1971 to 2022 through 12 attributes. There are four KPIs, which are:

1. How to find countries with similar GHG/CO2 emissions between 1971 and 2022 through GHG Energy, GHG Fugi and GHG FC.

2. How to find countries with similar GHG/CO2 emissions between 1971 and 2022 through GHG FC-Coal, GHG FC-Gas and GHG FC-Oil.

3. How to find countries with similar GHG/CO2 emissions between 1971 and 2022 using CO2-TES, CO2 AVBUNK and CO2 MARBUNK.

4. How to find countries with similar socioeconomic measures between 1971 and 2022 through CO2-POP, CO2-GDP and CO2-GDP PPP.

Since the target(countries) is a discrete variable, and all 12 attributes are numerical variables, a scatter plot is used to show the distribution of discrete variables (countries) under different values. Each scatter plot studies three attributes, and uses the three visual variables of color, shape and size to complete a visual result. Orange indicates a low attribute value while blue indicates a high attribute value. Square indicates a low attribute value and circle indicates a high attribute value. Also, a large point indicates a low attribute value while a small point indicates a high attribute value.

We will generate two separate types of scatter plots, one to show the distribution of countries under the E attribute and the other to show the distribution of countries under the S attribute. These charts will help us visualize how countries are distributed across different attributes. For each attribute, if a country has a value greater than the median under that attribute, it is classified as a "high attribute", and vice versa as a "low attribute".

For the data from 1971 to 2022, we use the mean to calculate the values of different attributes for each country over this period. And for better visualization, more uniform data distribution, and greater difference in attribute values, we take the logarithm of all attribute values.

1) KPI1 - GHG Energy, GHG Fugi and GHG FC: The distribution of GHG Energy and two sub-attributes in different countries was studied(Fig.1.). The scatterplot is used for visualization. The horizontal axis represents the value of GHG Energy, and the vertical axis represents the value of GHG Fugi and GHG FC. The values of different countries under the three attributes can be displayed, so as to judge the value of their attributes. In order to complete the classification of countries under different attributes, the color represents the level of GHG Energy, the shape represents the level of GHG Fugi, and the size represents the level of GHG FC. These three visual variables help the discrete variable of countries to complete the classification.

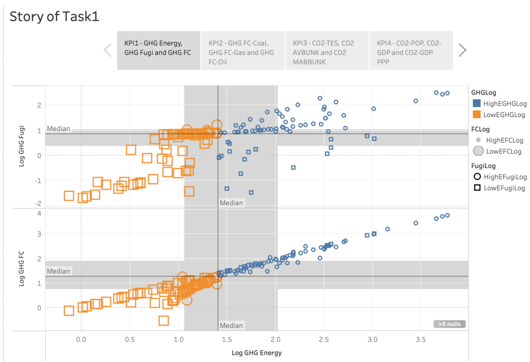

Fig. 1. Visualisation of KPI1

2) KPI2 - GHG FC-Coal, GHG FC-Gas and GHG FC-Oil: The distribution of GCoal, Gas and Oil properties in different countries is studied(Fig.2.). Scatter plot is used for visualization. The horizontal axis represents the value of GHG FC, and the vertical axis represents the value of GHG FC-Coal, GHG FC-GAS and GHG FC-oil. Through the values of the three vertical axes, the values of different countries under the attributes of the three vertical axes can be displayed, so as to determine the value of their attributes. In order to complete the classification of countries under different attributes, the color represents the level of GHG FC-Coal, the shape represents the level of GHG FC-Gas, and the size represents the level of GHG FC-Oil. These three visual variables help the country, a discrete variable, to complete the classification.

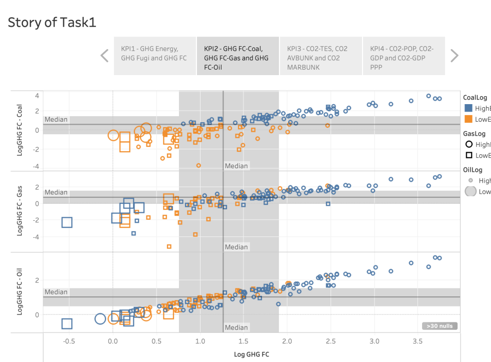

Fig. 2. Visualisation of KPI2

3) KPI3 - CO2-TES, CO2 AVBUNK and CO2 MARBUNK: Study the distribution of CO2-TES, CO2 AVBUNK and CO2 MARBUNK attributes in different countries(Fig.3.). Scatter plot is used for visualization. The horizontal axis represents the value of CO2-TES, and the vertical axis represents the value of CO2 AVBUNK and CO2 MARBUNK. The values of different countries under the three attributes can be displayed to judge the value of their attributes. To complete the classification of countries under different attributes, the color represents the level of CO2-TES, the shape represents the level of CO2 AVBUNK, and the size represents the level of CO2 MARBUNK. These three visual variables help the discrete variable of countries to complete the classification.

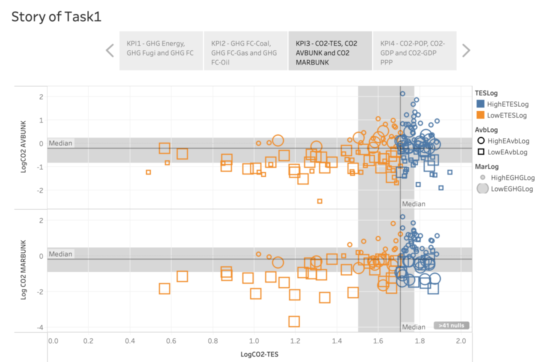

Fig. 3. Visualisation of KPI3

4) KPI4 - CO2-POP, CO2-GDP and CO2-GDP PPP: Study the distribution of different countries under CO2-POP, CO2-GDP and CO2-GDP PPP attributes(Fig.4.). Scatterplot is used for visualization. The horizontal axis represents the value of CO2-POP, and the vertical axis represents the value of CO2-GDP and CO2-GDP PPP, which can display the values of different countries under the three attributes, so as to judge the value of their attributes. In order to complete the classification of countries under different attributes, the color represents the level of CO2-POP, the shape represents the level of CO2-GDP, and the size represents the level of CO2-GDP PPP. These three visual variables help the discrete variable of countries to complete the classification.

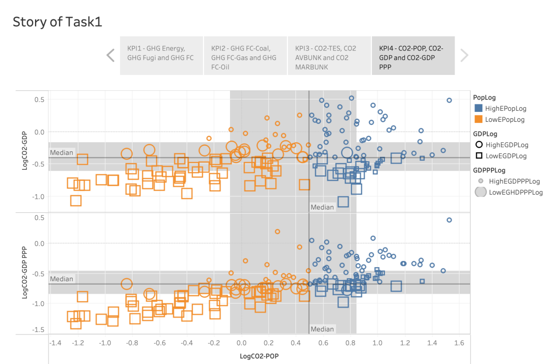

Fig. 4. Visualisation of KPI4

B. Evidence

In KPI1, it can be found that most countries have low GHG Energy values because most countries are orange (the color of low values), low GHG Fugi values because most countries have a low GHG Fugi shape, and a similar number of countries with high GHG FC values because the number of countries with large shapes and the number density of countries with small shapes look similar.

In KPI2, it can be found that most countries have high GHG FC-Coal values because most countries are blue (the color of high values), the number of countries with high GHG FC-Gas values is equal because the number of countries with different shapes looks similar, and the number of GHG FC-Oil values is similar because the number of countries with large shapes looks similar to the number of countries with small shapes.

In KPI3, it is found that most countries have an equal number of high and low CO2-TES values because the two colours look the same, an equal number of high and low CO2 AVBUNK values because the number of different shapes looks the same, and a similar number of CO2 MARBUNK values because the number of large and small shapes looks the same.

In KPI4, it can be found that most countries have the same number of high and low CO2-POP values, because the number of two colors looks the same, the number of countries with high and low CO2-GDP values is the same, because the number of countries with different shapes looks the same, and the CO2-GDP PPP value is similar, because the number of countries with large shapes and the number density of countries with small shapes looks similar.

C. Grouping

Through the above four visualizations, countries are grouped using their E and S attributes.

Each attribute under all E attributes is judged to get the total situation of the high and low of each attribute in the country. If the number of E attributes with high Emission is greater than or equal to 5 (more than half, there are 9 E attributes), the country is defined as a high emission country (that is, a high E country), and vice versa, a low E country.

The height determination method of S attribute is as follows: If the CO2-POP value is less than the median CO2-POP, and the number of the remaining two S attributes is greater than or equal to one of the high attributes, then the country is a Low socioeconomic country, otherwise consider whether it is a low E country, if it is a low E country, then the country is a low socioeconomic country Otherwise, it is a Mid socioeconomic country. If the CO2-POP value of a country is greater than or equal to the CO2-POP median, the CO2-GDP and CO2-GDP PPP are judged. If the number of high attributes is greater than or equal to one, then the country is a middle socioeconomic country, otherwise it is a high socioeconomic country

The auxiliary diagram of the above logic is shown below :

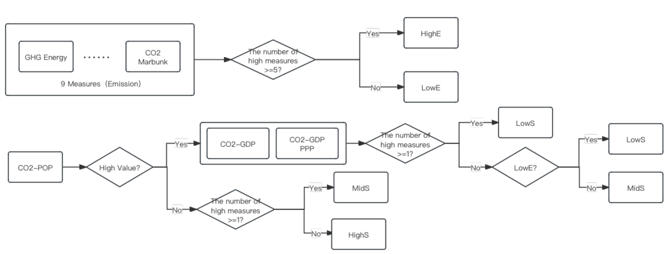

Fig. 5. Logic Line

By combining the visual results of the E and S attributes, the final grouping result is: There are six categories of countries, namely, high Emission and high socioeconomic countries, high Emission and low socioeconomic countries, high Emission and high socioeconomic countries. Low Emission and low socioeconomic countries, low Emission and low socioeconomic countries. Here is the result:

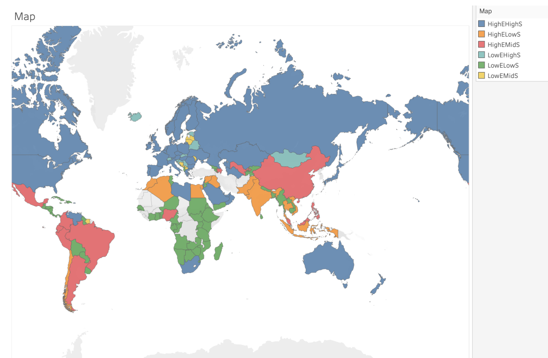

Fig. 6. Similar Groups

III. TASK2:TREND ANALYSIS THROUGH VISUALISATION

A. Visualisation

Question 2 requires an analysis of the country based on the trend of sudden emissions changes with socioeconomic indicators. We use three columns of data: CO2-GDP, CO2-GDP PPP and CO2-POP as wage indicators for changes in sudden emissions with economic population. We use them as the vertical axis and year as the horizontal axis to observe how these three indicators change over time. We use a line chart to visualize the overall trend, because line charts are usually used to represent analysis about ”trends”. At the same time, we add filter and color by country in the line chart. Through this setting, we can observe the changing trends of all countries and specific countries at the same time.

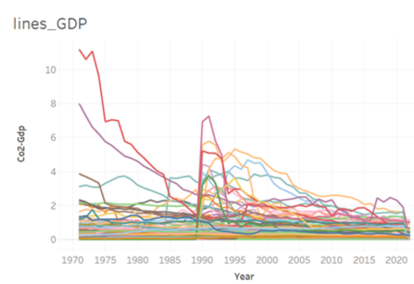

Fig. 7. Trends of CO2-GDP

First of all, according to the Figure 8,9 and 10, it can be seen that the change trends of the three indicators in various countries are generally similar. At the same time, since the calculation methods of CO2-GDP and CO2-GDP PPP are similar, the curves of the two are often very consistent. In subsequent analysis, they can be placed in one chart to analyze the trend of carbon dioxide emissions in different countries with economic changes. It can also be observed in the figure that there are strong similarities in the line charts changes in many countries. However, we found through discussion

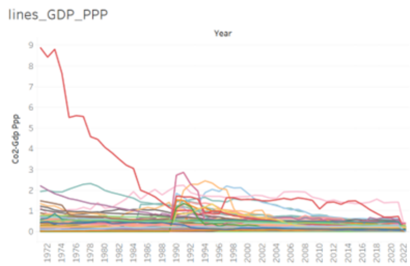

Fig. 8. Trends of CO2-GDP PPP

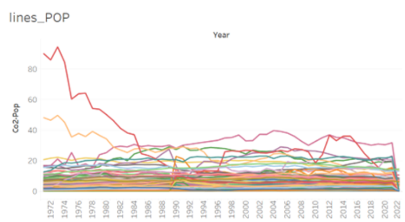

Fig. 9. Trends of CO2-POP

that the above line chart cannot clearly classify and display countries with similar trends. Therefore, we further improved the line chart, grouped countries with similar trends, and used the line chart to display the grouping results.

Fig. 10. Trends of One Country

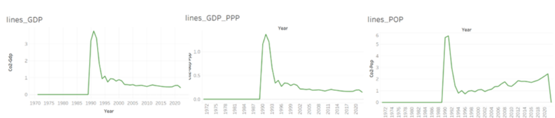

Fig. 11. Trends of Another Country

In order to observe the changing trends of each country, through interactive visualization, that is, by clicking on the line chart showing the changes of the three indicators of each country over time, it can be seen that the changing trends of the countries in the data set can be roughly divided into the following categories .(Figure 11 and 12) The three indicators of some countries, such as France and Germany, which are common in developed countries, continue to fall. The three indicators of some countries, such as Haiti and Honduras, continue to rise. The indicators of some countries, such as Nigeria and Laos, show peak fluctuations. In some countries, such as Sudan, the three indicators continue to rise. There are also some countries, such as the former Soviet Union and the former Yugoslavia, whose data have experienced cliff-like changes due to historical reasons. In addition, there are countries such as Argentina where the changes in indicators are relatively stable and do not fluctuate drastically over time. In addition to the above-mentioned countries, there are also some countries, such as China, which are more special. The changes in their three indicators are quite different from each other.

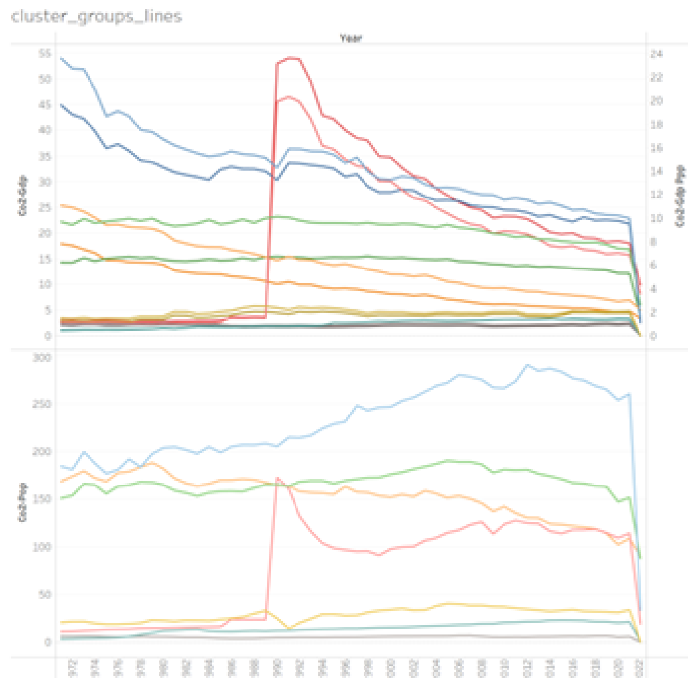

Fig. 12. Cluster Results

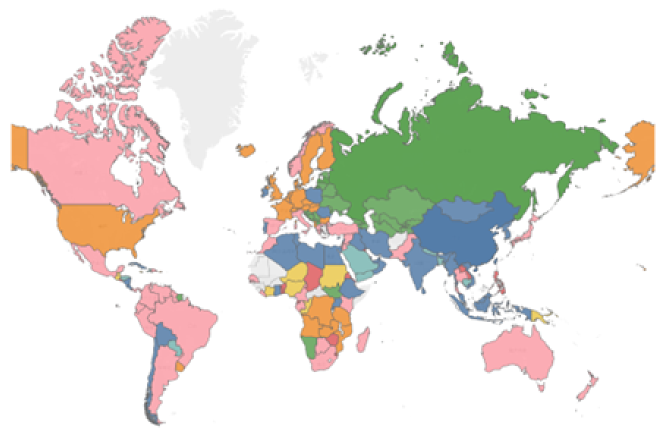

Fig. 13. Cluster Results on Map

To sum up, the countries in the data set are roughly divided into 8 categories according to changing trends, as shown in the figure 13 and 14. We have added a map as a visualization method to more intuitively display the specific countries included in each category, and through interactive visualization, click on the labels of different categories to highlight the positions of the map and line chart at the same time.

B. Explanation

Conduct a detailed analysis of the above eight categories of countries and explain the reasons for the fluctuations in the line charts:

- Cluster1: Most of these countries are populous countries, and some are developing countries with rapid economic development. Compared with other countries, these countries are developing their economies while balancing their population structure. Therefore, the carbon dioxide emissions of these countries usually show a more complex relationship with the trends of GDP and POP.
- Cluster2: The overall indicators of these countries show a downward trend year by year. The countries in this category are mainly developed countries. These countries have relatively strong economic strength and strong environmental awareness. They began to implement environmental protection policies and develop environmental protection-related science and technology, so their related measures show a downward trend year over year.
- Cluster3: The overall indicators of these countries are relatively stable and remain at low levels all year round. Some common developed countries in this category have developed to a relatively high economic level, and their population structure and carbon dioxide emission levels have also been relatively stable.
- Cluster4: The measures for countries in this category show a clear peak shape over the years. Most of these countries are developing countries with poor overall economic levels. Their economies only began to develop rapidly around 2000, so their various indicators first surged year by year, and then fell back as these countries paid more attention to environmental protection issues.
- Cluster5: Most of the countries in this category are still in the stage of economic development and have not yet implemented large-scale measures to control carbon dioxide emissions. Therefore, carbon dioxide emissions increase year by year with changes in various socioeconomic indicators.
- Cluster6: Countries in this category mainly include countries that were newly independent in the 1990s. These countries are mainly from the former Soviet Union, the former Yugoslavia, but also include Suriname and Namibia. These countries only have data records starting in 1990, and most of them experienced some political turmoil after independence. Therefore, their overall economic indicators and carbon dioxide emission trends are similar.
- Cluster7: The overall indicators of these countries have obvious changes in the middle depression over time. In most of these countries, due to social unrest or changes in socioeconomic structure, carbon dioxide emissions decreased significantly in a period of time with changes in economic indicators, and then slowly increased in a subsequent period of time.

Problems with this visualization: Although the changing trends of various countries are similar, due to the different data dimensions of each country, the changing trends of these countries may be obscured in the overall display.

Visualization improvements: We originally used scatter plots to observe trends, but because scatter plots serve more of a ”classification” and ”correlation” role, and because there are so many countries, it is not easy to observe the similarity of trends. Therefore, we changed to a line chart. After visualization, we found that the line chart can more appropriately show the differences in trends in different countries.

IV. Task3: Prediction through Visualisation

A. Find year1 and year2 in US

We choose the United States for analysis because the United States is one of the countries with higher greenhouse gas emissions in the world, so it is necessary to make effective plans for its emission reduction. Reducing U.S. emissions has important implications for global greenhouse gas reduction goals. Its emissions reduction experience and measures can provide important education and inspiration to other countries, especially those facing pressure to reduce emissions. Because it is necessary to find the years with the lowest and highest GHG/CO2 emissions, the bar chart can use vertical or horizontal columns to represent the values between different categories or groups, by analyzing the stacked bar chart, you can clearly see the changing trend of greenhouse gas emissions over time. This visualization makes comparisons between data very intuitive. So we drew a stacked column chart from 1971 to 2022 to compare emissions. Because GHGENRGY= GHGFCOMB+GHGFUGITI, we made a stacked bar chart of GHG Fugi and GHG FC and determined that the year with the lowest GHG/CO2 emissions was 1983(Fig.15.). The year with the highest GHG/CO2 emissions was 2000. The horizontal axis is the year and the vertical axis is the emissions. By observing the height of the bar chart, you can easily identify in which years the emissions reached the highest or lowest level, which can be used to visualize and analyze the time series data of emissions [1].

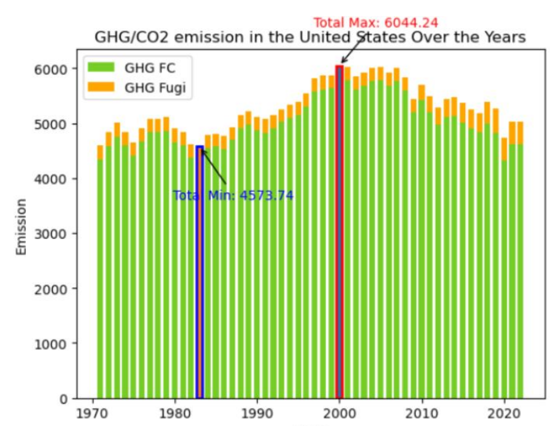

Fig. 14. GHG/CO2 Emission in The United States Over the Years

Then we drew a line chart of the changes in the twelve attributes of the United States over the years and marked 1983 and 2000(Fig.16.). We found that in 1983, GHG Energy and GHG Fugi were the lowest, GHG FC-Oil, GHG FC-Gas and GHG Fugi is also at a relatively low level, GHG FC-Coal is at an average level, and the values of CO2 MARBUNK and CO2 AVBUNK are relatively small, which has a small overall impact. Therefore, 1983 is more reasonable as the year with the lowest emissions. In 2020, GHG Energy, GHG Fugi and GHG FC-Coal are all at the highest, and GHG FC-Oil and GHG FC-Gas are all at relatively high levels in recent years, so we regard 2000 as the year with the highest emissions.

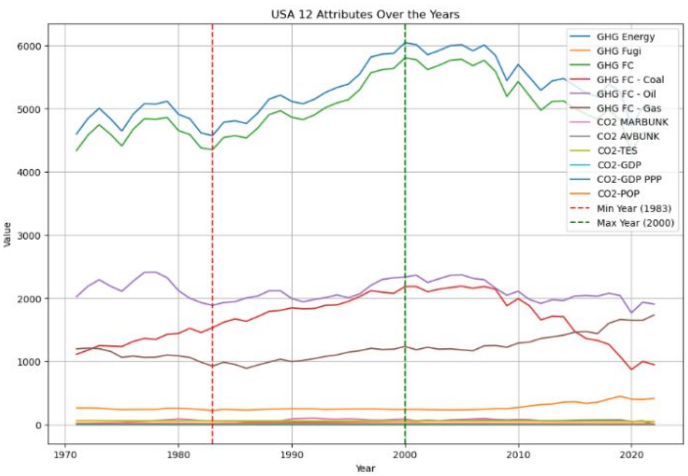

Fig. 15. USA 12 Attributes Over the Years

B. Make a plan

We calculated the difference between the twelve attributes in 2000 and 1983. The abscissa is the difference and the ordinate is the twelve attributes(Fig.17.). It is reasonable to arrange the differences as the abscissa because it enables a visual comparison of changes in different attributes between 2000 and 1983. Attributes with larger differences will be more visible on the histogram, which helps to quickly identify which attributes have changed the most. It is appropriate to use the height of the histogram to represent the difference in attributes because the height can represent the magnitude of the value.

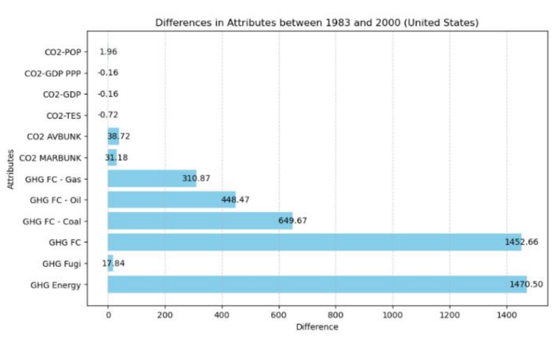

Fig. 16. Difference in Attributes between 1983 and 2000(United States)

Then we calculate the difference between the twelve attributes in 2000 and 1983 and divide it by the highest decline rate of the twelve attributes to get the years required for the twelve attributes to drop from the data in 2000 to the data in 1983(Fig.18.). Then select the year with the largest required attribute as the year required by our plan. This approach takes into account the different reductions for each attribute to ensure the plan is comprehensive and feasible while prioritizing the most challenging attributes to ensure the overall abatement plan is implemented effectively.

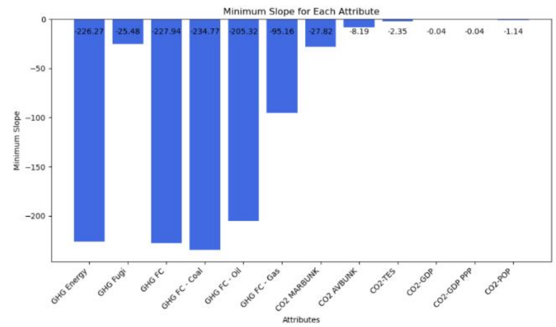

Fig. 17. Minimum Slope for Each Attribute

We calculated the annual changes in twelve attributes in the United States and displayed the highest value of each attribute's decline in a bar chart. Since the 2019 epidemic[2] and the 2008 economic crisis[3] affected GHG/CO2 emissions, resulting in a larger decrease in the data in 2020 and 2009 compared to the previous year, we excluded the period from 2019 to 2020. year and data from 2008 to 2009. The abscissa of the bar chart arranges the attributes, the ordinate represents the maximum decrease of each attribute, and the data label displays the specific value. This visual presentation method helps the audience clearly compare the decreasing trend of each attribute and determine which attributes perform best in terms of reduction, providing important information for the focus of emission reduction plans.

We then divide the difference of each attribute by the highest value of each attribute drop to get the minimum time required for each attribute and then select the longest time required among the twelve attributes to determine our planning time.

GHG Energy: 1470.50 / 226.27 = 6.50 GHG Fugi: 17.84 / 25.48 = 0.70 GHG FC: 1452.66 / 227.94 = 6.37 GHG FC - Coal: 649.67 / 234.77 = 2.77 GHG FC - Oil: 448.47 / 205.32 = 2.18 GHG FC - Gas: 310.87 / 95.16 = 3.27 CO2 MARBUNK: 31.18 / 27.82 = 1.12 CO2 AVBUNK: 38.72 / 8.19 = 4.72 CO2-TES: 0.72 / 2.35 = 0.31 CO2-GDP: 0.16 / 0.04 = 4.00 CO2-GDP PPP: 0.16 / 0.04 = 4.00 CO2-POP: 1.96 / 1.14 = 1.72

It can be seen from the calculation results that the longest time required by GHG Energy is 6.5 years. In order to allow enough time for the plan to proceed smoothly, we rounded up and made a 7-year plan.

After obtaining the planning year, we drew the change trend chart of the twelve attributes during the planning period

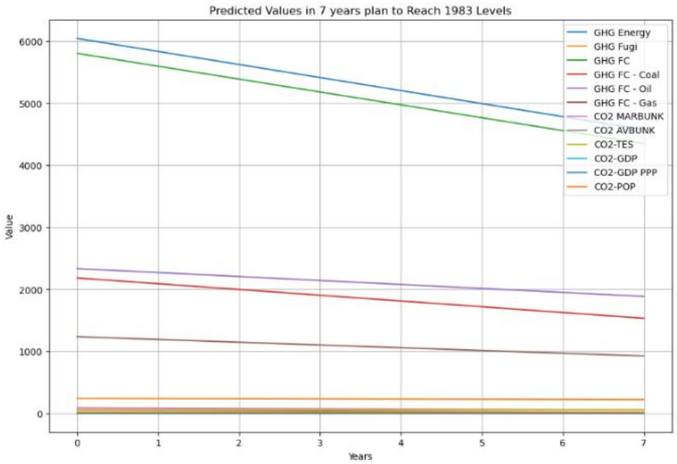

Fig. 18. Predicted Valies in 7 Years Plan to Reach 1983 Levels

based on the twelve attribute values in 2000 and 1983 and the planned 7 years, showing how the twelve attributes were determined by the data in 2000. The process of changing from year to year to the data of 1983. The abscissa is the year and the ordinate is the value. Line charts are great for showing trends over time. The color of the polyline can be used to distinguish different attributes, allowing the viewer to visually identify changes in each attribute. Through this arrangement, visual variables and interactions, the changing trends of the twelve attributes can be clearly presented. We can see the data changes of each attribute from 2000 data to 1983, and understand how they approach the 1983 level year by year to meet the planned 7-year period. This visualization helps viewers better understand property changes and provides an intuitive way to present program progress.

Year 1: A key task in the first year is to embark on initial energy transition measures to reduce carbon emissions. We will promote clean energy policies, including solar and wind power, and develop supporting policies to encourage the adoption of clean energy. At the same time, we will carry out energy efficiency projects focusing on improvements to buildings and industrial facilities to reduce energy consumption. We are specifically focusing on lowering the 'GHG Energy' and 'CO2-TES' indicators to reduce energy-related carbon emissions.

Year 2: In Year 2, we will begin the early stages of transportation reform. Our goal is to improve transportation systems and reduce carbon emissions in the transportation sector. This year, we will strengthen the public transport system, improve service quality and reduce fares to encourage more people to use public transport. At the same time, we will promote electric vehicles and build electric vehicle charging stations to reduce the 'CO2-POP' indicator.

Year 3: In the third year, we will focus on reforms in the industrial and production sectors to reduce industrial carbon emissions. We will introduce industrial carbon emission standards and encourage companies to adopt cleaner production technologies to reduce 'GHG FC - Coal' and 'GHG FC - Oil' indicators. In addition, we will support circular economy projects to reduce waste and lower the 'CO2 MARBUNK' indicator.

Year 4: In the fourth year, we will introduce a carbon emissions pricing policy to incentivize companies to take measures to reduce carbon emissions. We will implement a carbon emissions trading system and start pricing carbon emissions. This will encourage companies to reduce carbon emissions, especially the 'GHG FC - Gas' and 'GHG Fugi' indicators.

Year 5: In Year 5, we will optimize urban planning to reduce carbon emissions in the urban environment. We will build cycling and walking paths and reduce urban traffic congestion to lower 'CO2-GDP' and 'GHG FC' indicators. At the same time, we will promote urban greening projects and increase urban greening rates to improve urban air quality.

Year 6: In the sixth year, we will strengthen regulations and policies to ensure the implementation of environmental regulations. We will develop policies to encourage carbon neutral and renewable energy projects to drive improvements in the 'CO2-GDP PPP' and 'GHG Energy'. We will strengthen the legal framework to ensure the effective implementation of environmental policies.

Year 7: In the final year, we will strengthen climate change education and international cooperation to achieve greater emissions reductions. We will strengthen climate change education, raise public awareness of environmental protection, and encourage sustainable lifestyles. At the same time, we will actively participate in international climate negotiations, promote global cooperation, and share clean technologies to achieve the goals of environmentally sustainable development, especially the improvement of 'CO2-TES' and 'CO2 AVBUNK' indicators. This plan will consider 12 attribute indicators to gradually improve the United States environmental profile from the state in 2000 to the state in 1983.

V. Evaluation of Visualisation

Based on the questionnaire survey we made the following changes

The iterative process of creating a stacked bar chart of U.S. greenhouse gas emissions involves the following steps: Initial stacked bar chart: First we created a stacked bar chart representing annual U.S. greenhouse gas emissions by source. This chart includes the emissions of "GHG Fugi" and "GHG FC". Visual Challenge: After generating the initial stacked bar chart, it became apparent that visually identifying the years with the highest and lowest emissions was challenging. Interactive enhancements: To address this challenge and make the charts more user-friendly, interactive features were added. Interactive features enable the chart to highlight and mark the years with the highest and lowest emissions. Highlight Maximum and Minimum Years: When interacting with the chart, users can easily identify the years with the highest greenhouse gas emissions (maximum years) and the years with the lowest greenhouse gas emissions (minimum years). These highlighted points provide a clear visual representation of the

TABLE I
QUESTIONNAIRE SURVEY

Question	Feedback
1. How easy is it to determine a country's qualification for classification from the displayed scatter plot?	1 2 3 **4** 5
2. Can you discern the changing trend of a country's carbon dioxide emissions concerning socioeconomic indicators based on the scatter plot?	1 2 **3** 4 5
3. How well can you observe the changing trend of incremental emissions in different categories of countries with socioeconomic factors based on the displayed line chart?	1 2 **3** 4 5
4. How effectively does the bar graph display the factors influencing GHG/CO2 emissions in the United States?	1 **2** 3 4 5
5. Do you think there are other points where this visualization could be improved?	The highest and lowest years of emissions are difficult to distinguish visually. The lowest slope plots of the twelve attributes are repeated and can be optimized.

data, helping viewers quickly grasp the important years in terms of emissions[4]. By incorporating this interactive feature to highlight the years of maximum and minimum emissions, the visualization becomes even more effective in conveying key information about U.S. greenhouse gas emissions. This iterative process improves the chart's usability and its ability to facilitate data interpretation for stakeholders and general audiences [1]. Find histogram iteration with a minimum slope Initial calculations and visualization: The process begins by

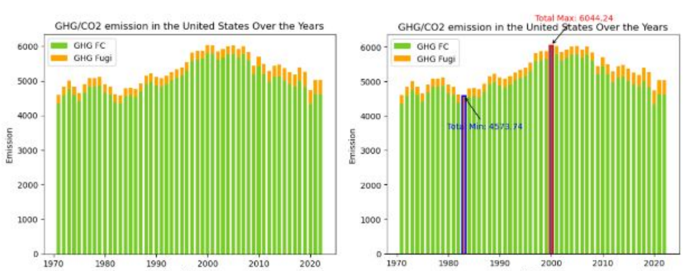

Fig. 19. Before Optimization vs After Optimization

calculating annual changes in twelve attributes across the United States. This produced twelve separate graphs, one for each property, showing changes over the years. Each graph is annotated with labels to highlight the years with the largest reduction (smallest slope) for the corresponding attribute. Visual Challenge: While the original method allowed for identifying years with the largest reductions in individual attributes, it was not an efficient way to observe and filter the data to find the largest overall decrease (minimum slope) for all attributes. Revised Visualization Method: To overcome this challenge, a new visualization method was implemented. A single bar chart is created instead of twelve separate charts. The bar graph depicts the highest reductions over the years for all twelve properties. The iterative process leads to a more efficient visualization that provides a unified view of the maximum reduction for all attributes. This new approach helps identify the most substantial improvements in greenhouse gas emissions, filter out short-term anomalies and provide a clearer picture of long-term trends in emissions reductions.

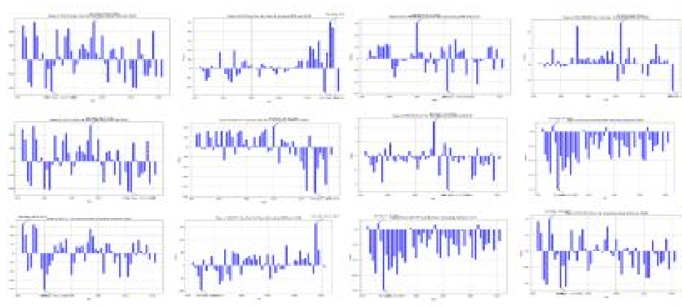

Fig. 20. Before Optimization

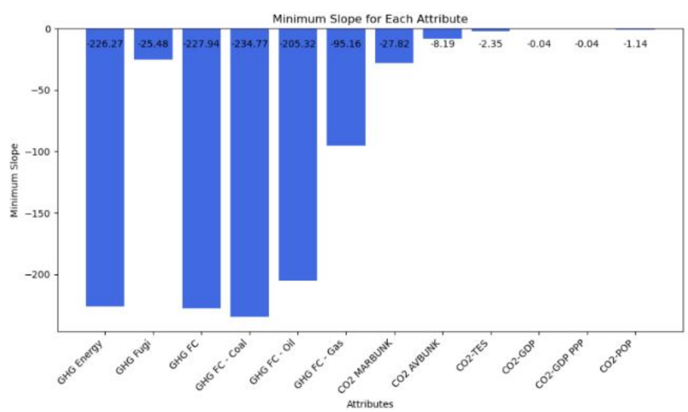

Fig. 21. After Optimization

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