Global warming Visualized through Temperature, Energy Consumption, and Carbon Emissions of The World During 1965 - 2013

Introduction:

In this modern age, along with the advances like industrialisation and technological revolution the world also is being affected adversely by the side effects of these developments. Global warming being one of the side effects every living being on the earth. The past few decades have seen adverse climate changes and the situation is only to get worse with the amount of damage we are doing on earth. Global warming is being studied by many climate researchers and scientists and by environment enthusiast. There are many reasons for global warming which is mainly caused by the carbon emissions in the earth's atmosphere which trap the heat from the sun's rays in the earth's atmosphere thus increasing the temperatures which in turn cause the polar caps to melt and e sea levels to rise. The situation has got worse in the past decade. It was interesting to find that there are very few comprehensive tools for the researchers to view the past data in order to see the trends of a few recent years. The climate data is complex as it involves multiple dimensions i.e geospatial, temporal and climate data being interdependent on other factors.

Data and Visualization views:

We have chosen the indicators of Energy consumption and Carbon emissions to study the advent of global warming through temperature changes in the world. The temperature data is spanned across last 50 years for all the countries (calculated as average per year in degree celsius). However the energy consumption calculated in Kg Oil equivalent per capita and carbon emissions calculated as metric ton per capita for the time period of 1965-2015 for all the countries in the world.

To accommodate the multiple dimensions we have broken our visualisation into three parts.

1) **Geospatial Overview:** We individually visualized the Temperature, Energy consumption through choropleths, across the different countries of the world from 1965-2013. In the same view we also visualise the carbon emissions through bubbles on the world map. This views helps us compare the difference in the indicators across different countries, helps us observe the change in the trend of energy consumption in the entire world in the past 50 years who are the great consumers and which countries are being affected the most. *{Developer: Aditi Mallavarapu}*
2) **Temporal view:** In the geospatial view, it was difficult to compare the changes of a particular country from year to year. Eg. Temperature in 1978 vs Temperature in 1980 or Temperature in 2000 vs Carbon emissions in years prior to 2000. The temporal view is designed to facilitate such comparison for a country. This view enables the user to compare the different indicator changes for a country simultaneously for the past 5 decades. *{Developer: Aryadip Sarkar}*
3) **Interactive Storyboard view:** The interactive storyboard view display comparisons for the top 10 countries who consumed the most energy or emitted the most carbon dioxide each year. It also helps the user understand the inter-relations between energy consumption, carbon emissions, temperature. This view is more focused to cause awareness and of how the different factors have a direct bond towards global warming and its ill effects and how increment/decrement of one factor proportionately affects other factors . *{Developer: Hai Tran}*

Literature:

Designing intuitive and meaningful visual representations in climate context faces a variety of challenges[5]. There are some sophisticated visualisations on the temperature data for the past 50 years. In Jei et al [3] authors designed a tool to analyse the temperature changes in the past 5 decades in China. This tool is very efficient to identify overall state of climate change and provide users with a compact view for analysing spatial and temporal data. As climate data visualization faces heterogeneous user groups, including users with different skills, qualification grades, interests, and from different disciplines, who are confronted with numerous tasks [5] we wanted to make the tool easy to use and adaptable by all. Although our tool does not encompass all the principles and guidelines laid by this tool, we have tried to break the different functionalities from one view to multiple views. We found it much less complicated to navigate through the different dimensions, rather than view all the temporal and geospatial and indicator data in one view.

Our temporal views has been inspired from the survey paper by Ruchikachorn and Mueller [2] , common to the survey paper and our data we had a temporal dimension for the data. (Figure 1).Our views are a modification on the view shown below, instead of the spiral visual we adopted the donut like visual so that it was easier to view the data intuitively.

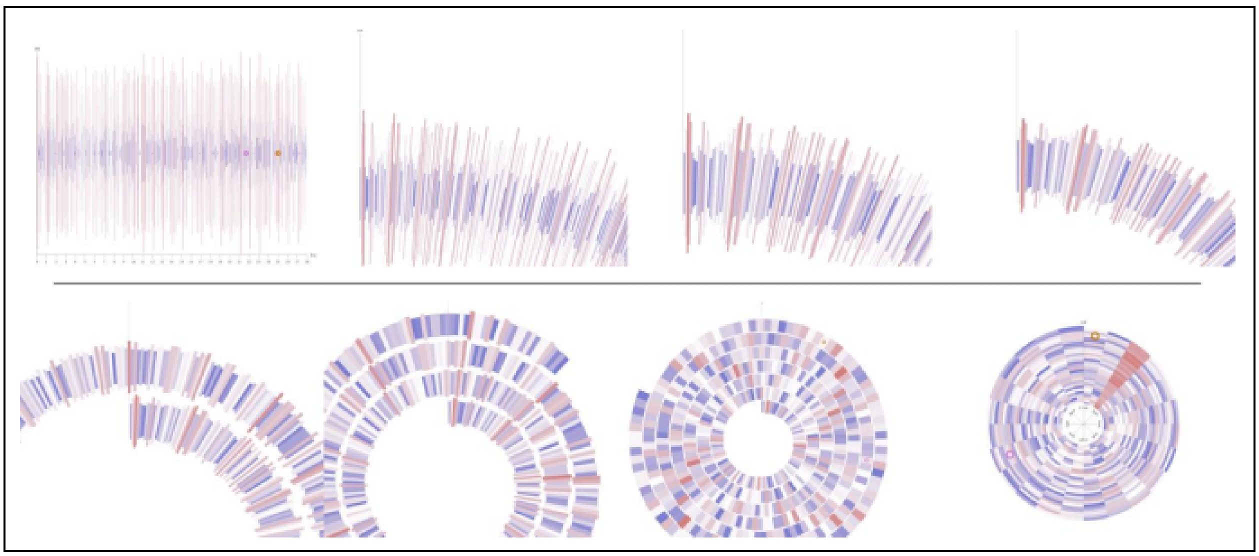

Figure 1. Ruchikachorn and Mueller's [2] spiral chart

Our data has a temporal aspect represented by the years and we wanted to notice if the data was also periodic over the years (if the trend of increase or decrease in the temperatures, consumption or emissions is recurring). A broad literature survey by Carlis and Joseph [1] pointed us to the use of spiral time series visualizations. The paper scrutinizes the existing methods to visualize serial, periodic data and find the spiral data layouts to be efficient in portraying the data dimensions of time and periodicity. They make use of Archimedes spiral which moves away from the origin at a constant rate to visualize variety of serial periodic data points like chimpanzee feeding patterns and movie release patterns etc.

Weber et. al. [3] emphasize spiral charts to be capable of showing nominal and quantitative data depending upon the channel used to visualize the data. The spiral charts have been found to be scalable of huge amounts of data

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As our data is serial in nature and we wish to notice the periodicity we choose this method of visualization with a minor change. [1] consider the spiral layout with a user-defined indent to avoid crowding of the data points at the center of the spiral. We visualize time or years along the path so rather than indenting the starting point of the spiral, we will modify the spiral path in the form of concentric circles. Each circle circumference represents 10 years, and each year temperature data can be compared to the temperature data before 10 years and after 10 years along with the immediate preceding and succeeding years (Figure 2). This small modification helps us compare the trend every decade intuitively rather than in a spiral where we would need to locate the year and compare the data. We will color code the sectors representing each year depending on the value of the indicator recorded that year (average over 12 months for each country). High temperature is represented with warm color (red for example) and relatively low temperature by white.

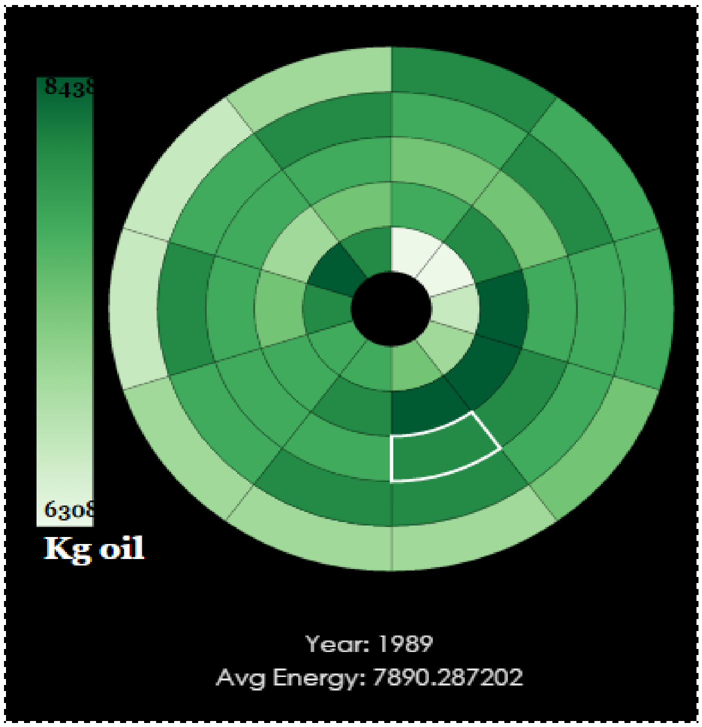

Figure 2: Temporal Visualisation: Energy Consumption in past 50 years
(highlighted sector piece(shown) representing year, color representing change)

This technique is scalable to the number of features we add in as it would enable us to not only visualize the temperature data but would also help us accommodate the carbon emission and the energy consumption data to see the effect of one on the other. As climate data is reoccurring and does not cease, the visualization would be able to accommodate more data just by increasing the number of years on each circle (eg. 2 decades from a decade in a circle). Also, the same visualization would also accommodate specific country's change in temperature over the years to narrow down our analysis.

Visualisation tasks:

1. **Actions**

   a. **Analyze**

      i. ***Discover:*** Our geospatial view encourages user to explore the change of an indicator from year to year among country. From there, the user can discover the trend and generate hypotheses of global warming, pollution, and energy usage (e.g. do these problems impact the entire world or just a few areas? Are neighboring countries affected? etc.)
      The temporal view also contributes to discover task, one could compare the trends of the three indicators for a country to see how one affects the other. The major inspiration of this view was to notice if carbon emission and energy consumption in a particular year have an immediate effect on the temperature or does it ripple along in subsequent years.

      ii. ***Present:*** Our reason of having three visualizations, in the order of overview-details-relationship, is to set-up a storyline for the audience to follow. The first two visualizations (geospatial and temporal views) introduce the context and main characters of the story before showing the audience how the characters in this environment interact with each other in the third viz (Interactive storyboard view). The third viz links all the discrete details given in the previous two and approach these pieces of information from another perspective (how the indicators impact each other) to suggest some potential factors that may invoke audiences' further thoughts: could global warming possibly affect sea level and air quality? Which countries are using too much energy or producing too much polluted chemicals? If they could control such factors, would the world's average temperature go down?

      iii. ***Enjoy:*** Since it is interactive, the third viz motivates user to play with it instead of just to take a glance at it. Every details of this viz is crafted carefully to stimulate the audience's curiosity and excitement: sky color, sea level, and especially the bubbles which indicate pollution.

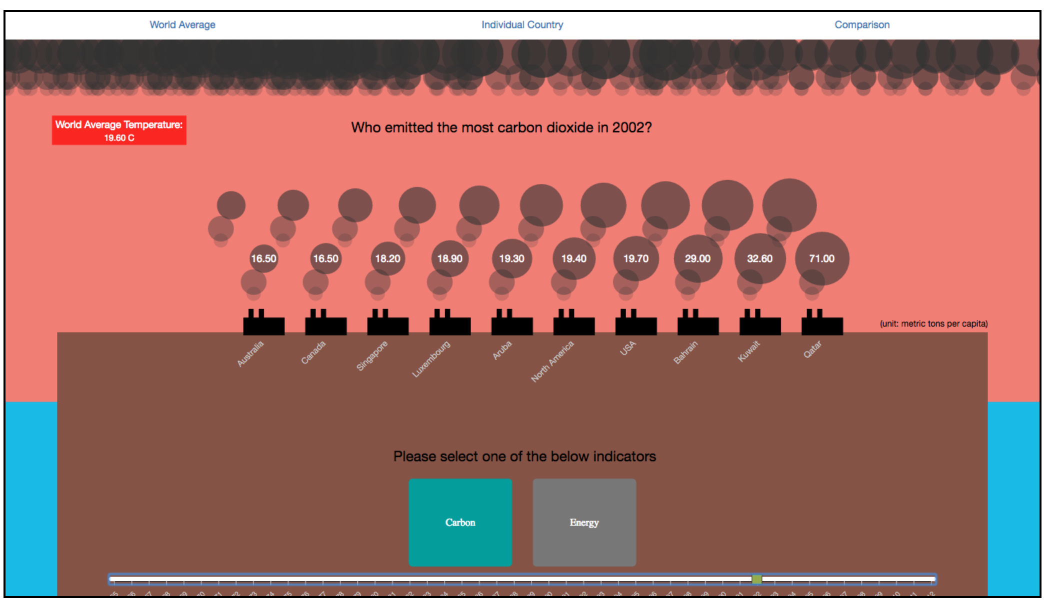

Figure 3: Our third visualization (Interactive storyboard view)

b. **Search**

i. ***Lookup:*** Our temporal view has a search bar with autocompletion to help user find a country more quickly.

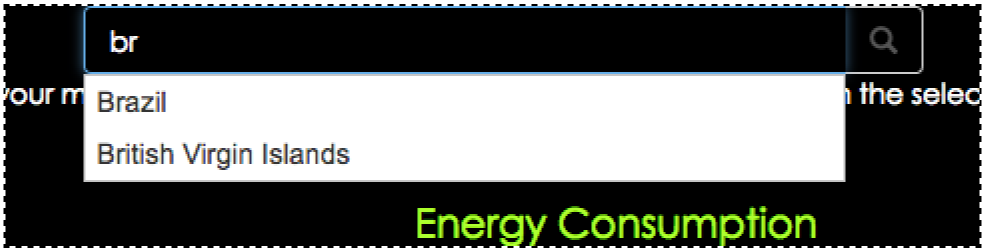

Figure 4: Autocompletion in our temporal view

ii. ***Locate & Browse:*** Besides geolocation in the first visualization, we provide different visual elements for user to quickly identify a specific data entry by indicators (using buttons or drop-down list) or by year (slider).

c. **Query**

i. ***Compare:*** Colors and sizes are used heavily in all of our visualizations either to make comparisons or to give user a signal that one or more indicators have changed. The bubble map in our geospatial view is an example -- the size of the bubbles help user quickly compare the amount of carbon dioxide emitted among the countries.

ii. ***Identify:*** The color saturations are used in the temperature and energy (geospatial view) and the temporal view for all three indicators to identify the most affected country in terms of temperature, most energy consuming country and country with more carbon emissions.

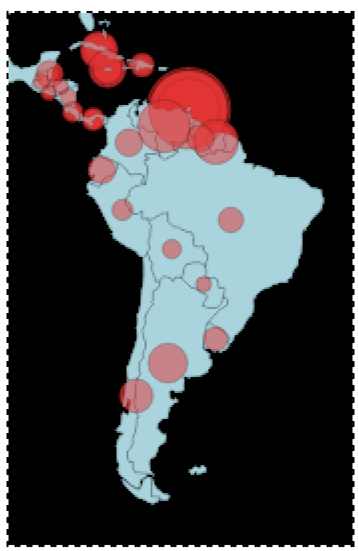

Figure 5: Carbon dioxide emission rate of South African countries in 1995

2. **Targets**

   a. **Data**

   We collected the data from the repository maintained by world bank [6] in json format. The 3 files which holds our data are:

   1. **Carbon Emission of every country per year** : This JSON file holds the information of the emission of carbon (metric tons per capita) of major countries (approximately 250+) in the world, for each year starting from 1965 to 2015
   2. **Energy consumption of every country per year** : This JSON file holds the information of the energy consumption (Kg of Oil Equivalent per capita) of major countries (approximately 250) in the world , for each year starting from 1965 to 2014
   3. **Average temperature of every country per year** : This JSON file holds the information of the average temperature (degree celsius) of major countries (approximately 250+) in the world , for each year starting from 1965 to 2012
   4. **The JSON file which holds the coordinates of the countries** in the world for designing the choropleth.

   b. **Attributes**

   1) The "Carbon Emission of every country per year" JSON file has a specific format. The file is sort of array of objects in which each object has specific attributes which is defined below:

   a) *Country* : This attributes shows the name of the country
   b) *Year* : This attribute shows the specific year
   c) *Carbon*: The attribute shows the carbon emission of that specific country for that specific year in metric tons per capita.

Example: `{"Country": "Finland",  "Year": 2013,  "Carbon": 10.63715919}`

The above object holds the information of the Carbon emission of Finland in the year 2013.This means that in the year 2013, the carbon emission of Finland was 10.63715919 metric tons per capita.

2) The "Energy Consumption of every country per year" JSON file has a specific format. The file is sort of array of objects in which each object has specific attributes which is defined below:

   a) *Country* : This attributes shows the name of the country
   b) *Year* : This attribute shows the specific year
   c) *Energy:* The attribute shows the energy consumption of that specific country for that specific year in Kg of Oil Equivalent per capita.

Example: `{  "Country": "Finland",  "Year": 2013,  "Energy": 6074.749787}`

The above object holds the information of the Energy consumption of Finland in the year 2013.This means that in the year 2013, the carbon emission of Finland was 6074.749787 Kg of Oil Equivalent per capita

3) The "Average Temperature of every country per year" JSON file has a specific format. The file is sort of array of objects in which each object has specific attributes which is defined below:

d) Country : This attributes shows the name of the country

e) Year : This attribute shows the specific year

f) Temperature: The attribute shows the average temperature of that specific country for that specific year in degree celsius.

Example:
```
{"Country":"Finland","Temperature":1.9072499999999994,"Year":2012}
```

The above object holds the information of the average temperature of Finland in the year 2013. This means that in the year 2013, the average temperature of Finland was 1.90724 degree celsius

Patterns in Data Set:

a) Temperature changes in Poland:

1) Geospatial View: Temperature: The temperature in parts of europe has drastically changed and become warmer in the three decades between 1965- 1995.

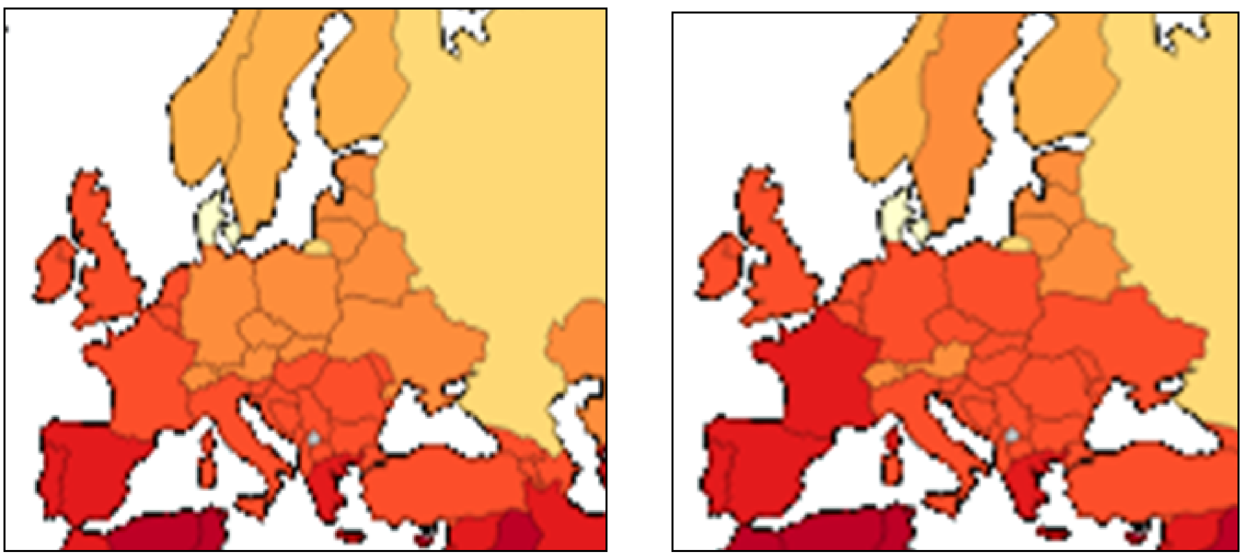

Figure 6: Germany , Poland and Ukraine, the temperature in 1995 doubled compared to the temperature in 1965

2) Temporal View: Poland temperature increase was also evident in the temporal view, but the energy and the carbon emission rings show that Poland was consuming comparatively more energy from 1975- 1989 and the carbon emissions also agree with the consumption but the temperature rise effect is seen in the years subsequent to those years showing that the indicators have a ripple effect which is also long lasting (in this case 5 years) on the temperature. The reduction in energy consumption and the carbon emissions in the subsequent years may take a longer time make a positive mark.

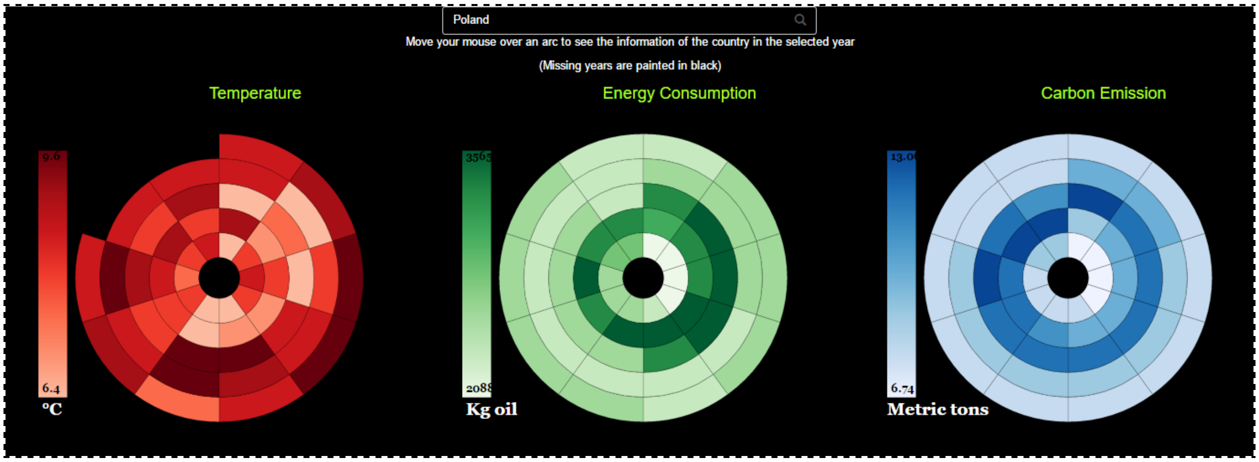

Figure 7: Temperature, Energy and Carbon emissions in Poland showing the energy consumption from 1975 to 1989 to be increased and carbon emissions gradually increasing from 1975- 1985 and similar effects for temperature from but no gradual reduction in temperatures as seen in carbon emissions.

b) Energy Consumption in Saudi arabia, Luxembourg and Iceland:

The energy consumption has been mapped according to the per capita, one would imagine that countries like China and USA would be the massive consumers, but the countries Saudi arabia, Luxembourg and Iceland in the recent years. However Luxembourg has maintained the trend since 1965.

c) The middle eastern countries and Europe:

In 1965 the middle eastern countries had number of passive carbon emitting countries and only Luxembourg and Kuwait dominating the field. But after few decades, the area has major contributors to carbon emissions.

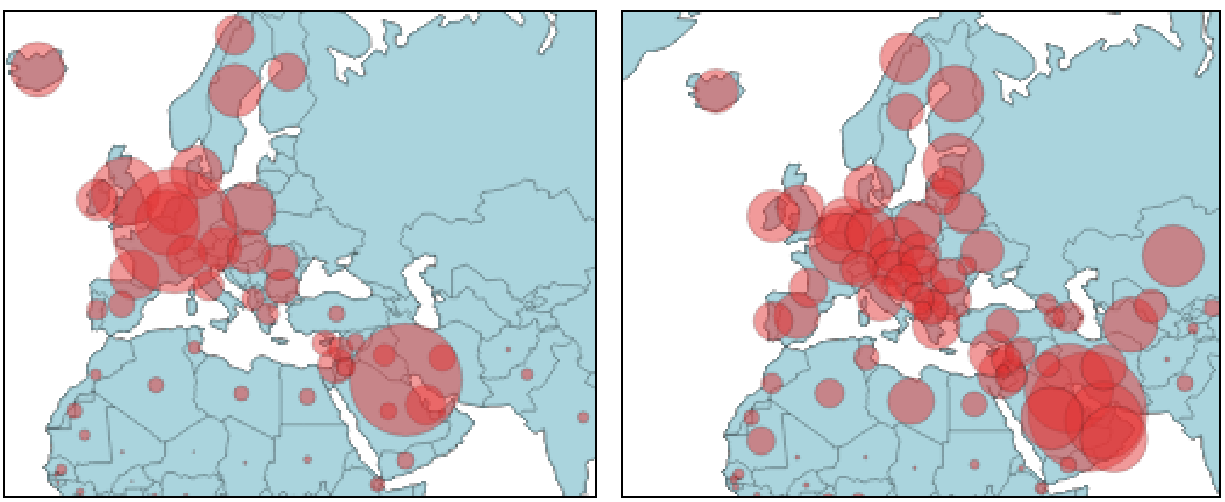

Figure 8: (Left) Luxembourg and Kuwait having more carbon emission in 1965. (Right) All the middle eastern countries and European countries have major carbon emissions in 2012.

References

[1] Carlis, John V., and Joseph A. Konstan. "Interactive visualization of serial periodic data." *Proceedings of the 11th annual ACM symposium on User interface software and technology.* ACM, 1998.

[2] Ruchikachorn, Puripant, and Klaus Mueller. "Learning visualizations by analogy: Promoting visual literacy through visualization morphing." *IEEE transactions on visualization and computer graphics* 21, no. 9 (2015): 1028-1044.

[3] Li, Jie, Kang Zhang, and Zhao-Peng Meng. "Vismate: interactive visual analysis of station-based observation data on climate changes." *Visual Analytics Science and Technology (VAST), 2014 IEEE Conference on*. IEEE, 2014.

[4] Weber, Marc, Marc Alexa, and Wolfgang Müller. "Visualizing Time-Series on Spirals." Infovis. Vol. 1. 2001.

[5] Nocke, Thomas, et al. "Visualization of climate and climate change data: An overview." *Digital earth summit on geoinformatics* (2008): 226-232.

[6] World bank data repository http://data.worldbank.org/indicator?tab=all