**Global Emissions Explorer with d3.js**

**Udacity Data Analysis P6**

(Note: The final version folder contains the complete working visualization. Versions 1 and 2 are in the associated folders. The old data folder contains the initial dataset and different stages of the data that were used along with the Jupyter Notebook used to wrangle the data with Python.)

**Summary**

The Global Emissions Explorer is a web application designed to allow readers to understand and contextualize carbon dioxide emissions data. The exploration tool consists of two parts: a world map allows readers to visualize emissions of all countries at once, with circles on each country sized according to the CO2 emissions for that country in a given year, and a chart allows readers to see how the emissions levels from the top 15 emitting countries have changed since 1850. All of the data in the visualization is available from the Climate Analysis Indicators Tool created by the World Resources Institute, but the data in its raw form can be difficult to interpret. It is my hope that this visualization will allow readers to observe the extent to which emissions have risen since 1850 as well as make comparisons between countries to determine which nations have the most progress to make towards developing a sustainable society.

**Design**

The primary design objectives I always had in mind were to allow for quick comparisons both between countries and over the years and to keep the charts relatively clutter-free to allow for rapid comprehension. Initially, for Version 1 of the project, I created only the world map, but I decided to add the chart after receiving feedback asking for an easier method to compare countries across the years. The line graph allows readers to see multiple countries at once, and observe how the countries have changed both in terms of absolute carbon dioxide emissions, and relative to one another. Version 2 of the project added in the chart with full functionality, but limited styling. At first, I added in every single country (about 160 were in the data) to the line graph, but after receiving feedback that most of the countries were not major contributors to global CO2 emissions, I decided that only showing the top 15 countries from 2013 would be appropriate. My choice of 2013 was because that was the most recent year in the dataset and indicates which countries have the most work to do in terms of reducing emissions. Examining the data as part of my preliminary observations, I found it interesting how the top 15 countries now have changed over the years (notably China and the United States) and therefore decided to only show these countries. One of the toughest design decisions was the scale for the y-axis of the chart. I initially had all the countries available to plot, as well as the world total. However, the world total dwarfed all but the top 2 countries, and changing to a log scale elicited comments that the chart was now difficult to understand. I realize that a log scale might have been the appropriate solution, but the general public often does not intuitively understand the implications of a non-linear scale. Subsequently, I decided to remove the world total and change the scale to a simple linear one. Even though most of the countries are still dwarfed by the US and China, I believe that this was the design decision that best communicated the trends in the data I was trying to underscore. I also initially thought about sizing the countries themselves on the world map by emissions, but I decided that simply putting circles on the countries and then having the circles dynamically change was the best way to emphasize the increase in emissions since 1850.

After the first project submission, I changed the scale on the chart to dynamically update based on the highest emission value for any country graphed. This allowed me to add in the world total emissions and allows for more detailed comparisons between countries.

The interactive elements that I included were dictated primarily by feedback asking to be able to make comparisons and for finer detail. I opted against including a radius scale on the map in favor of tooltips that appear when a reader mouses over a countries’ circle. The tooltip includes the actual emissions number, the country (in case readers are not up to date on their geography), and the global rank. I personally find Millions of Metric Tons of carbon dioxide a difficult measure to understand, which is why I wanted to size circles to allow for relative comparisons both temporally and globally. I included the option to animate over the decades because I wanted to show how much emissions have increased from 1850 to 2010. I also allow users to select any specific year if they want more details. By showing both the overall trend and allowing for finer examination of the details, I think my visualization will satisfy readers with widely varying levels of interest. For the line graph, I added interactivity in the form of selecting countries. As explained, I only allowed the user to select from among the top 15 carbon dioxide emitting countries in order to limit clutter and because those countries contribute an overwhelming share to the global total. I also included tooltips for every decade (and 2013) on the chart in case users want a higher level of detail.

The revisions made after the first project submission on the map were mainly aesthetic. I colored countries by their global emissions rank for the given year and added a legend to allow readers to quickly identify the scale of the emissions data as well as interpret the meaning of the colors and I believe these changes improve the usability of the visual.

Styling has never been my strong point, and my objective for this project was to not let styling get in the way of the displays. I wanted to try and stick to simple colors and not distract with too many aesthetic elements. For the initial welcome page and the about page, I included background images which have received mixed comments. On this aspect, I am willing to concede and if I become a professional data analyst, I hope that I will be working for a company with skilled designers!

**Feedback**

The initial feedback I received when discussing my idea was to keep the visuals simple and do not overload them with information. I had been planning to design a comprehensive tool that incorporated socioeconomic data, but most people I talked to said that would detract from the main stated goal of my project, which was to allow readers to observing changing carbon dioxide emissions. Additional data could be helpful in some contexts, but curious readers would have plenty of other sources to learn more about each country and I was told to keep my focus on the emissions. After these discussions, I decided the most sensible course was to concentrate on clearly displaying the emissions data. I settled on the concept of creating a world map with circles sized by the CO2 emissions of each country. Version 1 was the implementation of this idea and could stand on its own as a useful tool for grasping the overall emission trends (the large picture). However, I received constructive criticism telling me that comparing countries for a given year based solely on the map was difficult because the size of the circles could not be differentiated. Other feedback for Version 1 regarded the styling of the map, and the misplaced location of some of the country circles which was due to the path.centroid method I was using to calculated the best location for the country data. There were also some minor functionality issues that would make the tool easier to use that I needed to correct for subsequent versions. I was asked about including a scale for the radius of the bubbles, but decided against it because users could mouse over the country bubble and see the exact quantity of CO2 emitted (in millions of metric tons). Based on the feedback for Version 1, I decided to create the chart that showed the emissions over the span of time as a line graph.

I made the graph with basic functionally for Version 2 and asked for additional feedback. The second time through the feedback and improvement process, the criticism mainly focused on aesthetics. I am not the most adept designer, and I expected that I would receive plenty of constructive criticism regarding style choices. Most of the changes were minor, but they made a large difference not only in appearance, but in the clarity of the visualizations. The most significant change I implemented based on feedback for Version 2 was to limit the number of countries that I included in the chart. I had initially displayed all 160 countries, but changed the display after hearing that most of the countries were not major contributors and including all of the countries as options cluttered the appearance of the graph. I had also originally included the world total CO2 emissions, but this required readjusting the scale and the majority of countries did not even register with the y-axis scaled based on the maximum world total. I experimented with using a logarithmic y-axis, but again, feedback changed my mind as people said that a log axis can be difficult to interpret. For the final version of the chart, I included only the top 15 emitting countries in 2013 and settled on a linear scale. Considering the line graph, I must agree with all the feedback that these changes resulted in a cleaner and more usable visual.

The final visualization has attracted plenty of feedback that I will look to incorporate in a future upgrade. Some people do indeed want to see socioeconomic data included, while others think it should remain separate. Perhaps the best option would be to have a selection panel that would allow readers to see the socioeconomic data they want. I would have to make sure that it is non-intrusive but I do think that it can add a lot of needed context to the visuals (for example, seeing how as a country gets wealthier, the emissions of that country increase, or how emissions fell for some countries in the global recession of 2008). I have also received comments regarding the number of countries I choose to include in the chart, and maybe a dynamically scaled y-axis would be the proper choice, or I could have the default scale as linear, but allow users to select logarithmic if they are comfortable interpreting a log scale. Moreover, based on the responses from users, I think it might be helpful to have a table available for those who want to view all the data in detail. It would not be as quick to understand as the visuals, but for those who were interested in learning more, a table would allow for a thorough examination of all the carbon dioxide emissions data. Finally, I received many comments about the styling, and on that issue, I agree that I could benefit from hiring a designer, but most readers said that the styling was appropriate for the displays and did not distract from the data.

I made substantial changes to both the chart and the map after the first Udacity submission. All pages received additional navigation features that expand page access beyond only the home page. The titles on the graphs were updated to reflect a more explanatory data analysis approach as opposed to an exploratory visualization. I want readers to observe the worldwide and country by country increase in emissions from 1850-2013, and subsequently I altered the titles to reflect that objective. For the map, I changed the styling, colored the country dots on an ordinal scale assigned by emission rank, and added a legend for rapid interpretation of the size and color of the emission circles. I appreciate the recommendations as I think these changes improve the functionality of the world map graphic considerably. The map now more accurately conveys the underlying data and expresses my goal of demonstrating the extent of worldwide emissions increases. Additional work was also done to the chart based on the Udacity review. The most crucial aspect was adjusting the y-axis to scale dynamically. It now adjusts based on the highest emission level out of the countries selected, allowing for better comparisons between countries. I also added the world total in as one of the options to graph. Finally, I added the note to the graph with some simple instructions that appear when no countries are selected. These changes also certainly improve the appearance and functionality of the visual. I appreciate the thoughtful review from everyone who looked over my work and the Udacity reviewer who took the time to analysis my visualization and provide constructive recommendations.

**Resources**

The data itself is from <http://www.wri.org/resources/data-sets/cait-historical-emissions-data-countries-us-states-unfccc>

The chart display was adapted from an example in the book *Getting Started with D3* by Mike Dewar that is available for at <http://shop.oreilly.com/product/0636920025429.do>

The rest of the links presented below form a nearly comprehensive list of resources that I utilized over the course of this project. There are many additional Stack Overflow questions that were of vital assistance to me over the course of this project but that I did not have the chance to bookmark. I hope these anonymous contributors to Stack Overflow and other online mediums know the positive impact of their contributions for data science and for all developers!

<https://bl.ocks.org/mbostock/29cddc0006f8b98eff12e60dd08f59a7>

<http://www.wri.org/resources/data-sets/cait-historical-emissions-data-countries-us-states-unfccc>

<http://bl.ocks.org/abenrob/c4ac3d581a7b16ff5f2f>

<http://www.wri.org/blog/2017/04/interactive-chart-explains-worlds-top-10-emitters-and-how-theyve-changed>

<http://stackoverflow.com/questions/7346827/how-to-find-the-array-index-with-a-value>

<http://stackoverflow.com/questions/1069666/sorting-javascript-object-by-property-value>

<http://bl.ocks.org/d3noob/10633704>

<https://classroom.udacity.com/nanodegrees/nd002/parts/00213454010/modules/318423863275461/lessons/3184238632239847/concepts/31814787270923>

<http://jsonviewer.stack.hu/>

<http://www.d3noob.org/2013/02/update-d3js-data-dynamically.html>

<http://stackoverflow.com/questions/11832914/round-to-at-most-2-decimal-places-only-if-necessary>

<http://stackoverflow.com/questions/5767325/how-to-remove-a-particular-element-from-an-array-in-javascript>

<http://www.yourhtmlsource.com/stylesheets/csslayout.html>

<https://www.w3schools.com/css/css_font.asp>

<http://www.quackit.com/css/css_color_codes.cfm>

<http://examples.oreilly.com/0636920025429/mikedewar-getting_started_with_d3-bdfc34e/visualisations/subway_wait_assessment_UI.html>

<https://bl.ocks.org/d3noob/c506ac45617cf9ed39337f99f8511218>

<https://jsfiddle.net/wb8u02kL/2/>

<http://shop.oreilly.com/product/0636920025429.do>

<http://stackoverflow.com/questions/4810927/how-to-go-up-a-level-in-the-src-path-of-a-url-in-html>