Global CO2 and Energy Usage

CS171 Process Book

Anna Zhong and Rachael Smith

Table of Contents

Project Proposal & Research Objectives

Background & Motivation

Global warming is a reality of the world we live in. Multiple lines of scientific evidence show that sea levels and temperatures are rising and, as a result, making environments uninhabitable for an increasing number of the world's organisms. Global warming also impacts humans by loss of habitat from inundation and by threatening food security by decreasing crop yields. While there is skepticism over the human contribution to global warming, with some believing the current situation of global warming to be a part of natural historical changes of climate, the Intergovernmental Panel on Climate Change (IPCC) reported in 2014 that s**cientists were more than 95% certain that most of global warming is caused by increasing concentrations of greenhouse gases and other human activities**. To that end, we decided to explore the correlations between human activities and the volume of global CO2 emissions over the years.

We intend to span over various indicators, such as population, GDP, energy usage (fossil fuels and alternative), energy production and deforestation (by forest area), in order to **seek a comprehensive understanding of the various human factors contributing to carbon emissions** that in turn might contribute to global warming. We want to clarify that this project is not about the scientific aspect of climate change—we will not be comparing temperature, sea level or ocean acidification data. We also do not claim that any correlations shown in the visualization necessarily point to direct causal relationships. We are more interested in **exploring how humans might have contributed to global warming, as well as visualizing the pace and scale with which we have done so**. As such, we are expecting to visualize some interesting, if not alarming, data, and we hope that this will educate viewers on the current global carbon emissions situation.

Project Objectives

Ideally, our visualization will consist of three "chapters". We consider it essential that we implement the first "chapter," we are hopeful that we will implement the second "chapter" and it would be outstanding if we could accomplish the third.

The first chapter tells the story of the history of global carbon emissions. Our hope is to educate users on how emissions have changed over time, and how these changes have correlated with economic growth, population growth and deforestation. In this chapter, we are mainly interested in seeing exponential growth in all of these factors within the past twenty – thirty years, although we are aware that this doesn't necessarily prove any causation between the factors.

The second chapter tells the story of global carbon emissions today. Here, we hope to answer questions about how the income of each country, as well as its geographical region, affects its current emissions. We intend to look at the relative amounts of total emissions per country, as well as per capita emissions. Users will be able to visualize both the geographic distribution of emissions today, as well as the economic distribution of emissions.

The third chapter will tell story of carbon emissions in the USA today. For instance, we think it would be interesting to visualize the breakdown of emissions by industry. More research will be necessary to determine the precise nature of this chapter, as this will depend on what (if any) relevant data is available.

The ideology is that each chapter will progress to an increasingly more specific set of data to visualize. Each previous chapter serves to contextualize the restricted focus of the subsequent chapters.

Research Questions

Since we are interested in exploring how humans might have contributed to global warming, questions that we want to explore include:

- At what rate did our population growth, or deforestation, or use of oil and other fossil fuels translate to growing amounts of CO2 in the atmosphere? To visualize the pace and scale with which some of these factors are growing, we will be using colors, circles and a timescale.
- What does this look like today, and in looking at today's situation, how do we expect the data to look in the near future?
- What are some factors affecting the rate of CO2 emissions in the atmosphere, other than GDP and population? Are there correlations between the amount of renewable energy being used and a slowing of the growth of CO2 emissions? For this question, it would be useful to visualize not only the total volume of CO2 emissions every year, but also the rate of change from the previous.
- How might one country compare to another country (perhaps its neighbor, or major trade partner, or a country in the same income group)? To answer this, we could allow for two countries to be selected and compare their details next to each other.

Hopefully, by trying to answer these questions, we visualize some interesting findings other than the expected upwards trend.

Data

Sets and Sources

We are using data from the **World Bank**, which can be found at the links listed below. Note that most data sets have data for 248 countries from 1960 – 2012, as well as metadata including each country's geographical region and income group.

For the first chapter, we will use the following data sets. Refer to "Visualization" for how we will use them:

- CO2 Emissions (kt): http://data.worldbank.org/indicator/EN.ATM.CO2E.KT
- Forest Area (% of land area): http://data.worldbank.org/indicator/AG.LND.FRST.ZS
- Energy Use (kt of oil equivalent): http://data.worldbank.org/indicator/EG.USE.COMM.KT.OE
- Alternative and Nuclear Energy (% of total energy use): http://data.worldbank.org/indicator/EG.USE.COMM.CL.ZS

- Population, total: http://data.worldbank.org/indicator/SP.POP.TOTL
  - Here, we may make use of additional data sets from the World Bank which list population in rural and urban areas.
- GDP (current $US): http://data.worldbank.org/indicator/NY.GDP.MKTP.CD

For the second chapter, we will use the following data sets:

- CO2 Emissions (kt): http://data.worldbank.org/indicator/EN.ATM.CO2E.KT
- CO2 Emissions (metric tons per capita): http://data.worldbank.org/indicator/EN.ATM.CO2E.PC

For the third chapter, the World Bank provides separate data sets for a number of contributing factors to carbon emissions. These include electricity and heat production, gaseous fuel consumption, liquid fuel consumption, manufacturing industries and construction, residential buildings and commercial and public services, solid fuel consumption, transport and "other". To specifically visualize which industries or contributing factors the United States' carbon emissions are coming from, we will just scrape data for the United States from each of these data sets.

We are also interested in researching relevant data regarding relationships between countries (such as the trade relationships in homework 2), because we like the circular layout with links, and the use of hierarchical bundling. However, this is proving quite challenging in the context of global carbon emissions since there is no reasonable "link" to make between the emissions or energy usage of individual countries. Any suggestions for other relevant correlations are welcome in the feedback for this proposal.

Refinement & Structures

We hope to keep this step simple, and we are fortunate that the World Bank provides all of its global indicators in separate data sets, such that in order for us to include the data for any indicator, we would only need to load that corresponding data set. The data sets we are using generally only provide the information for the indicator in question, so we do not have to clean out much of the data. However, the data is only available in Excel, CSV or XML formats. While it won't be difficult to load an XML file using Javascript and transfer and reorganize all of its information into Javascript variables within our code, we might want to consider whether this will slow down the visualization.

If we have time during implementation and if we are finding that our visualization is too slow, we could write a Python program to convert the XML data and write it into a JSON file of our desired format, which we would just load straight into our visualization. Either way, we will have to parse the XML data into custom objects, which gives us a lot of freedom in how we want to organize the information. In particular, it would be helpful if we compiled all of the indicators together under their corresponding countries and years, since all data sets have the same 248 countries and span the same years (1960 – 2012). The metadata for each country is also the same for all data sets, which is convenient. An example of this would be:

```
{
```

```
      "country": "Australia",
      "income": "high"
      "geographical region": "Pacific"
      "years": [
            "1960": [
                  "CO2_total": 1923844709
                  "CO2_per_capita": 273
                  "forest": 60
                  "energy": 17283019201191
      "alternative_energy": 17
                  ...
            ]
      ]
}
```


Using such a format would make it easy for us to visualize changes of multiple indicators together over time, i.e. for any given year and country, we could easily access all of its information. However, if we were visualizing a certain topic, such as forest area over all countries and all years, then it would be easier to keep the data in separate variables according to topic.

Potential Visualization Features (Description)

As we have mentioned, our visualization will break down into 1-3 different chapters, each of which tells a different story about Carbon Emissions. At the core of the first chapter will be a map-based visualization which can represent discrepancies between countries in GDP, Population, and Forest Area. There will be an animated slider component that will show each country's emissions per year through circles that will "pop up" on the map to emulate carbon emissions. The amount of carbon emissions will be represented by the size of the circle and the frequency of the circles appearing. Users will also have the ability to click on a country on the map to view country-specific energy usage stats on a line chart to the right of the map. These include data for total energy usage over time, with a percentage of that colored for total alternative energy usage. *(See Sketches Fig 1)*

Our second chapter will represent countries as nodes in a force diagram rather than as a map. The size of the nodes will represent either 2014 emissions or 2014 emissions per-capita, depending on the user's selection. Nodes can either be grouped geographically or grouped by economic class (via rankings provided by the metadata in our World Bank CO_2 dataset). Users will be able to toggle between chapters via buttons at the bottom left hand of the page. *(See Sketches Fig 2)*

Potential Visualization Features (Priority Ranking)

Must Have Features

- Animated geographic visualization of global carbon emissions through time.

- **Yearly carbon emissions per country** are represented by the size of circles which 'pop' up and fade out over time. These circles are overlaid on a map.
- A slider will represent the **year** (from 1960-present).
- Button above the map will allow users to toggle between **GDP, Population,** or **% Forest Area** for each country. This will be encoded by the gradient of the color of the country.
- **Total yearly carbon emissions** will be represented in a scatterplot above the slider.

- <u>Country specific energy usage data</u> will be represented by an area chart to the right of the global visualization
  - Users can click on a country in the global visualization to see country-specific data isolated in a second view.
  - The chart will plot **energy usage** and **alternative/nuclear energy usage** from 1960 to present.

Optional Features

(These are listed from highest priority to lowest priority).

- Second Chapter: Force diagram representing <u>2014 global carbon emissions</u>
  - Each node represents one country. Users will be able to toggle between two options for node size: representing **total emissions** or representing **per capita emissions.**
  - Users will be able to select between groupings of nodes by **geographic location** or by **economic class.**
  - Users will be able to mouse-over nodes to view more specific data regarding each country (rate of population growth, rate of GDP growth, % change in emissions from previous year).
- Third Chapter: US-specific emission visualization
  - Pie Chart will represent Carbon Emissions by industry in the US.
  - Slider will allow Users to interact with the pie chart to see changes in this data over time.
  - Line chart will show relative size of each industry in the US over time.

Sketches

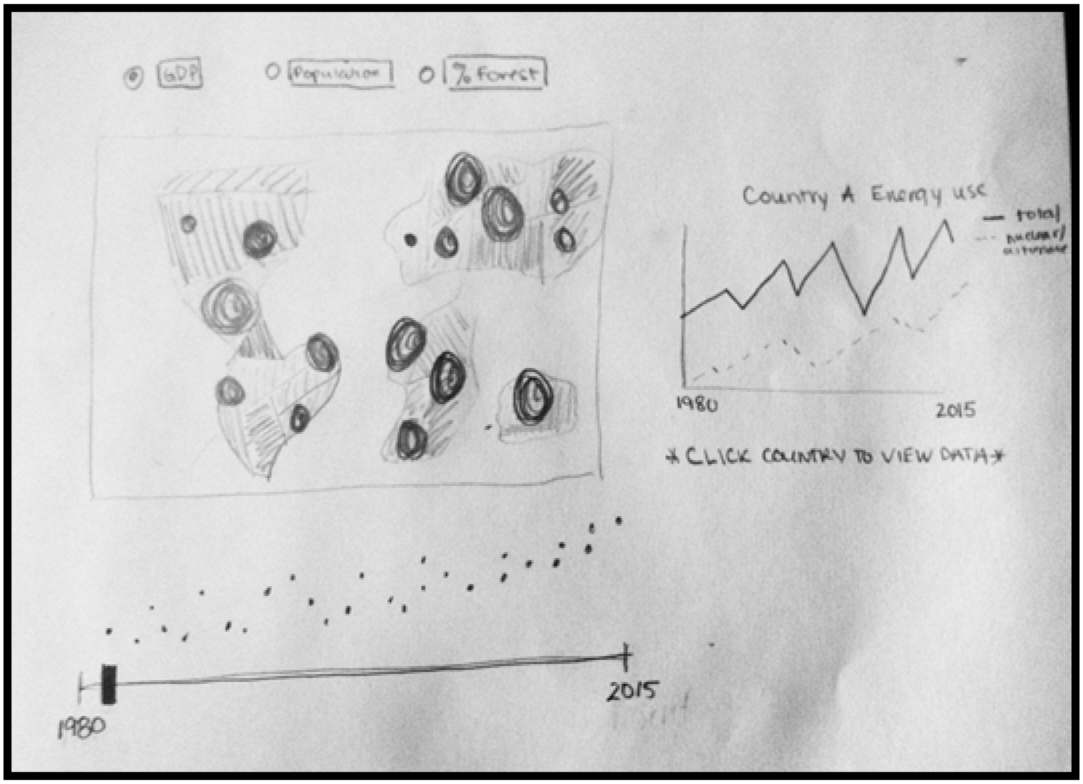


Figure 1: Chapter One- Initial Sketches

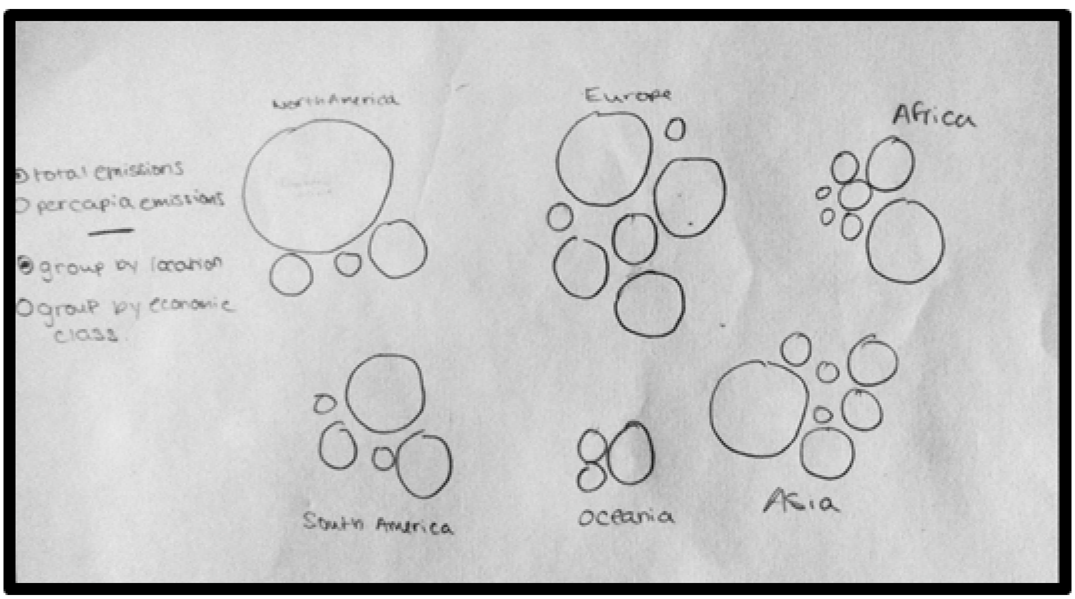


Figure 2: Chapter Two - Initial Sketches

Timeline

April 3-10: Main map structure for the first chapter: incorporating total CO2 emissions as circles that "pop up" and GDP, population and forest area as color gradients on a map of the world. Update process book.

April 11 – 17: Animate the first chapter and include interactivity for clicking on certain countries on the map and viewing line graph visualizations of total energy consumption and percentage of alternative energy consumption on the side. Update process book.

April 17: Submit Milestone. We aim to have a decent version of our first chapter done by the milestone.

April 18-25: Finish first chapter implementation and fix bugs (this might take longer than we expect).

April 25-May 1: Build the second chapter. It will be an interactive force diagram with mouse-over tooltip data. If time permits, build the third chapter, honing in on carbon emission for the United States using a pie chart or other circular data visualization. Update process book.

May 1-May 5: Clean up the storyline, boost up the graphic design and aesthetic elements, add seamless animations and make the video. Update process book.

May 5: Submit! Prepare to be blown away by our visualization**.**

Project Implementation Journal

Data Collection and Refinement

Overview

As we planned in our project proposal, we got much of our data from the World Bank. Their enormous dataset can be accessed at http://data.worldbank.org/ , and it provides free data about developing countries across the globe. For our project we made use of several sets which together provided GDP, Population, CO2 emissions, %Forest Area, Total Energy Use, % Alternative and Nuclear energy, and % Renewable Combustibles for most countries for the years 1960-2014. For latitude and longitude data we used a separate dataset accessible here.

For our second chapter we also used data from the U.S. Energy and Information Administration (EIA). Their data, which can be accessed at http://www.eia.gov/totalenergy/data/annual/ , provides detailed information about energy useage in the United States. We used their data which broke down US Primary Energy Usage by source and by economic sector, as well as their dataset which breaks down US Carbon Dioxide by source sector.

Our raw data sets from the World Bank are stored in the **data** subfolder. Our manually created data set from the EIA is contained in **sector_data.json** within the **data** subfolder.

Chapter One: World Vis

Conversion:

The world bank data sets were available as xml files. Due to our familiarity with using json files with d3, our first step in the datascraping process was to use a free online service to convert the xml files to json. A mistake we made early on in our project was to assume that because our files would be in json format data cleanup would be a rather straightforward, reasonably quick process. It was not. Although data cleanup was somewhat of a tear-wrenching struggle, we *were* fortunate that once we figured out a method to cleanup one dataset it was VERY easy to do the rest, as all of the World Bank datasets were structurally isometric.

Clean-up

For each dataset we began by reformatting the raw json file from the xml source. The raw JSON file contained one object for each country, for each year, and the first step in processing was to extract the relevant information from each object. Next, we condensed the datasets. We combined GDP, Population, CO2 emissions, Latitude and Longitude, and Economic Group information into one dataset. The condensing step was a significant challenge as it involved iterating through our *very* large raw large dataset several times, and it was challenging to find a method efficient enough that it did not 'brick' our browser.

A second difficulty we encountered was a horrific bug-- we had *all* of the population, gdp, and co2 arrays in our CO2 dataset pointing to the *same* ‘physical’ array, without realizing it. It took us over an hour to diagnose this bug, and it left us feeling dejected and as if we deserved to re-take cs50. However, we persevered, and we came out of the Great Data Bug Fiasco of 2015, stronger and better.

Ultimately, set was structured as an array containing one object for each country, with values for the country name, three letter identifier, latitude and longitude, as well as arrays containing values for GDP, Population, and CO2 emissions for each year 1960-2012. For years in which we did not have a value for a particular indicator we inserted a -1 into the array index. Ultimately, each object in our data array was structured as follows:

```
{
      “name”: “Australia”,
      “country_id”: “AUS”
      “gdp”: [...]
      “years”: [...]
      “pop”: [...]
                 ...
}
```

Here “years” refers to emissions values. Later, we added an array for %Forest Area values and country metadata including Economic Group and Region.

All of the data was processed in visualization.html, and it occurs as the page is loading.

Chapter One: Country Vis

Since the World Bank Datasets are structurally isometric, our data processing for Country Vis was nearly the same as for World Vis. Here we grouped together Total Energy Use, % Nuclear Energy Use, and % Renewable Combustible energy use for each country for years 1960-2012 into a dataset which was structurally very similar to the one used in World Vis. The reason that we did not combine them into a single dataset is that the scope of the Energy Use dataset is slightly smaller- it covers fewer countries.

Chapter Two

For chapter Two we were not planning on doing any additional data collection and refining. However, as our design plans changed (See Visualization: Chapter Two) we realized we would need to locate more data regarding the relationship between energy use and carbon emissions. The data we located at the EIA was available as CSV and XML, however the percent of the data we needed was relatively small, so we manually constructed and formatted a json file. For the sankey visualization we used, we arranged the data into an array of nodes and an array of weighted links between nodes like so:

```
{
      “links”: [
            {“source”: “NODE1”, “target”: “NODE2”, value: “10”},
                  ...
      ]
      “nodes”: [
            {“name”: “NODE1”}
                  ...
       ]
}
```

Eventually we needed to add a second element link element to the json file containing normalized values for the links.

Visualization: Chapter One

Initial Layout Structure

Our first chapter is the most complicated of our visualizations. We borrowed from CS171’s HW3 to establish a basic structure for coordinating our different views in this chapter (See Fig 3). Our largest portion of the screen (blue) would be dedicated to our WorldVis view, with two smaller boxes on the left dedicated to the two CountryVis views. Above, we would have buttons to allow users to toggle between heatmaps in the WorldVis view. The worldVis view is a vis object that is defined in the file **worldvis.js**, while the two countryVis views are defined in **countryvis_usage.js** and **countryvis_compare.js**.

WorldVis view would contain a world map visualization, a slider to toggle between years, and a line chart above the slider indicating the world co2 emissions totals for each year.

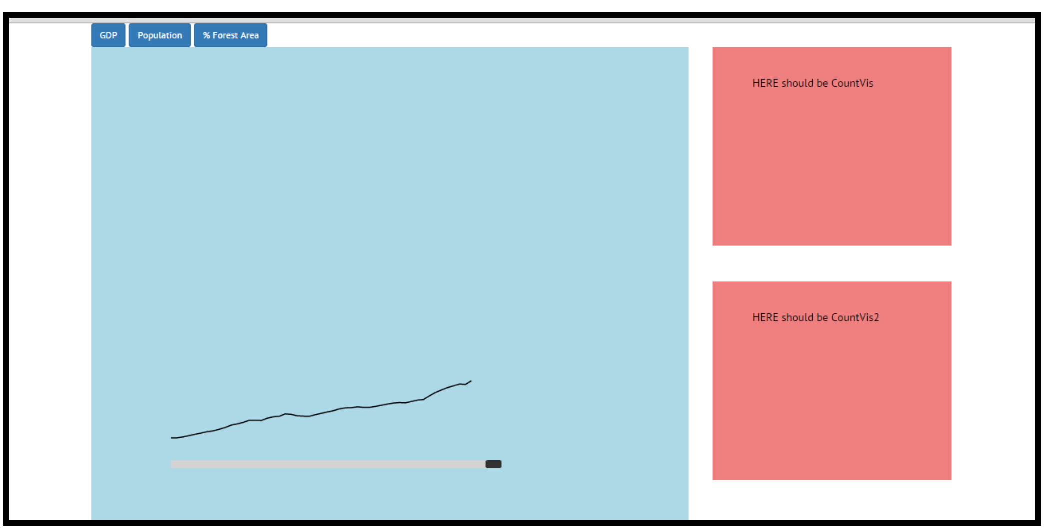


Fig 3 *Basic Layout of Ch 1*

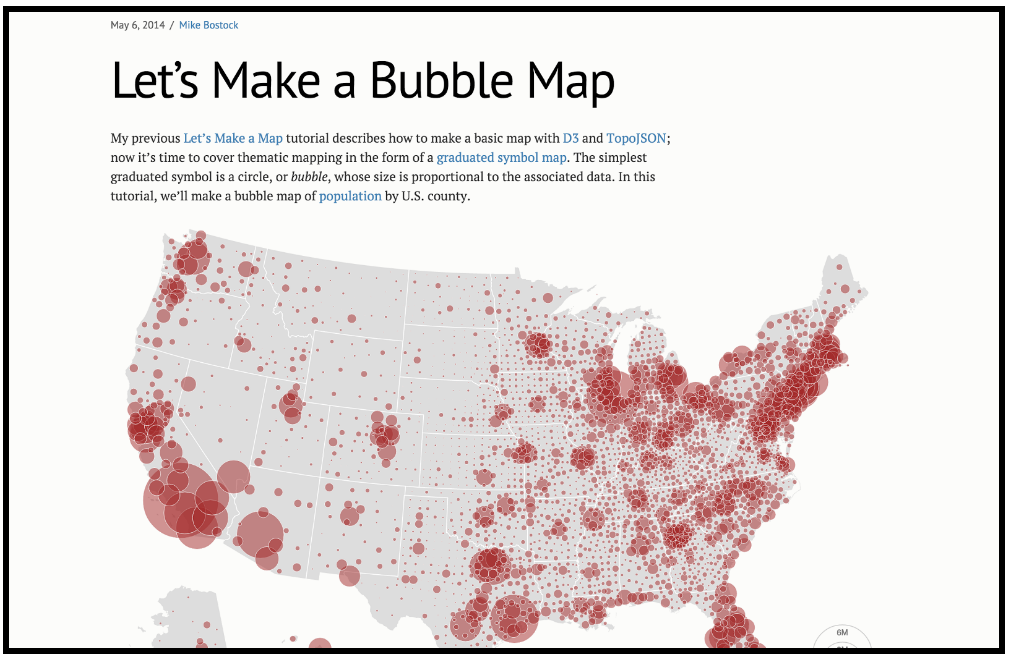
Layout Development

As we began to implement the World Vis and Country Vis features, the Chapter 1 Layout changed dramatically. We had to move the countryVis views to beneath the WorldVis views to ensure that the map was large enough. We added a third countryVis "box" beneath worldVis to provide users with additional data about the selected country. Finally, we added storytelling elements to the left of worldVis (See Storytelling: Chapter 1) The final layout can be seen at the end of this chapter.

WorldVis

Design Inspiration

WorldVis is a visualization of the CO_2 emissions per country. We took inspiration from Mike Bostock's work on "bubble maps" (See Fig. 4). We thought that the bubbles were especially fitting for our visualization because we the circular symbol can be seen as analogous to a cloud of CO_2 gas rising from a country. These bubbles will also change in size depending on the year selected by the slider and the emissions value for that year.

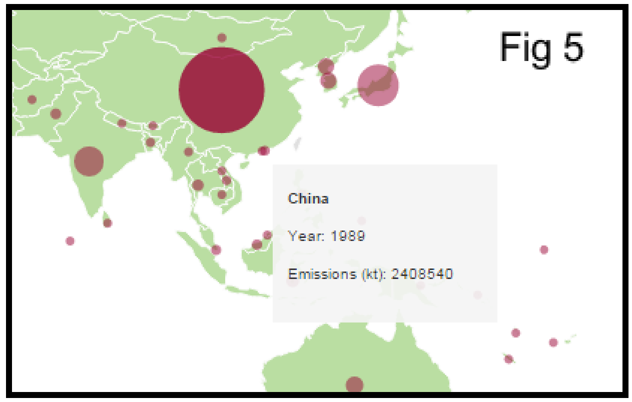


(Fig 4)

Datamaps

Next step was to actually create the main map view. To facilitate this, we are using a Javascript library built with d3 called datamaps. It allows us to generate chloropleth maps and bubbles, which is exactly what we need. Having said that, it took a lot of manipulation of our numerous data sets (see Chapter One: World Vis) to get it working correctly.

Figure 6 below shows our visualization after we have our bubbles working, with the slider currently at 2012. Already, we have a sense that the visualization might encounter problems with a couple of countries dominating the data set, namely the United States and China, as we saw in the node visualizations of our second homework.



Later we added **tooltips** to the bubbles show the country, emissions value, and current year. (See figure 5 to the right). As you can see, the bubble opacity rises upon mouseover.

The final touch was to implement **animation**. We added a play/pause button to the left of the CO2 total's chart (see Fig 9). When animation is on, the slider moves across the screen, through each of the years of data. The bubbles grow (or shrink) according to changes in emissions values for a given country over time, and the heat maps update according to changes through time.

Unfortunately, we couldn't find a good library for javascript animation, so we had to build our own animation function. We did this by storing the state of the play button as a boolean and creating an animation loop function which would call itself recursively only if that boolean was set to 'true' and if the slider had not already reached it's endpoint. The animation loop calls functions to update the position of the slider, the bubbles and choropleths, and tooltips, if they are in view.

A major difficulty we encountered with animation is that the Datamaps library is set such that each time the data for a bubble is updated the bubble is erased and redrawn. This had the unfortunate effect of making it look like our bubbles were shrinking to nothing then popping back up throughout the visualization. We attempted to fix this by manually overriding the code in the library. Ultimately we found that we had to adjust the but found that we had to modify the **handleBubbles** function in the **datamaps.world.js** library in order to remove this effect.

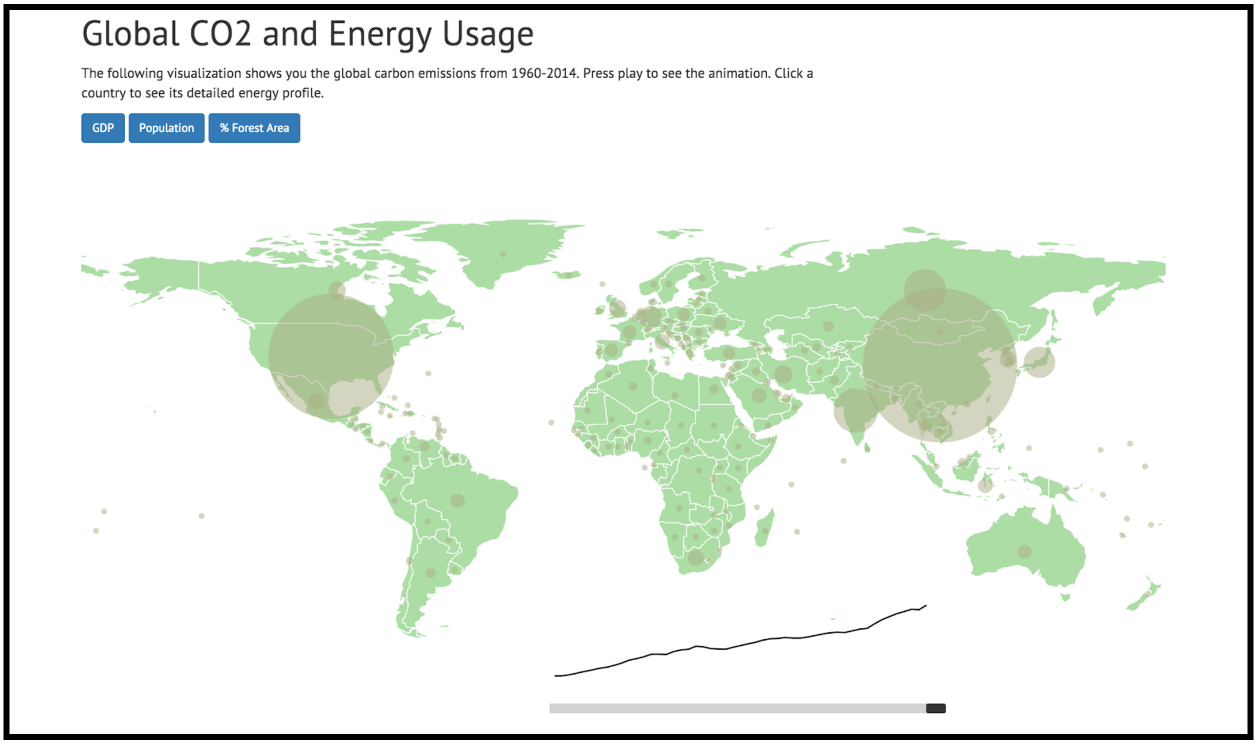


Fig 6

Heat Maps

Next we added Heat Maps using Datamaps choropleth feature. Show below in Fig 7 is the ellow-orange-coral color scheme we initially chose for GDP. Fig 8 shows the blue-purple color scheme we chose for population. Later, we added a % Forest Area heat map. For % Forest Area our data only covers 1990-2012, so our visualization for this indicator is more limited. Users are able to toggle between heat maps by selecting a button in the worldVis screen. To the left of the visualization we added legends to give the users a more concrete grasp on the range of the data across countries.

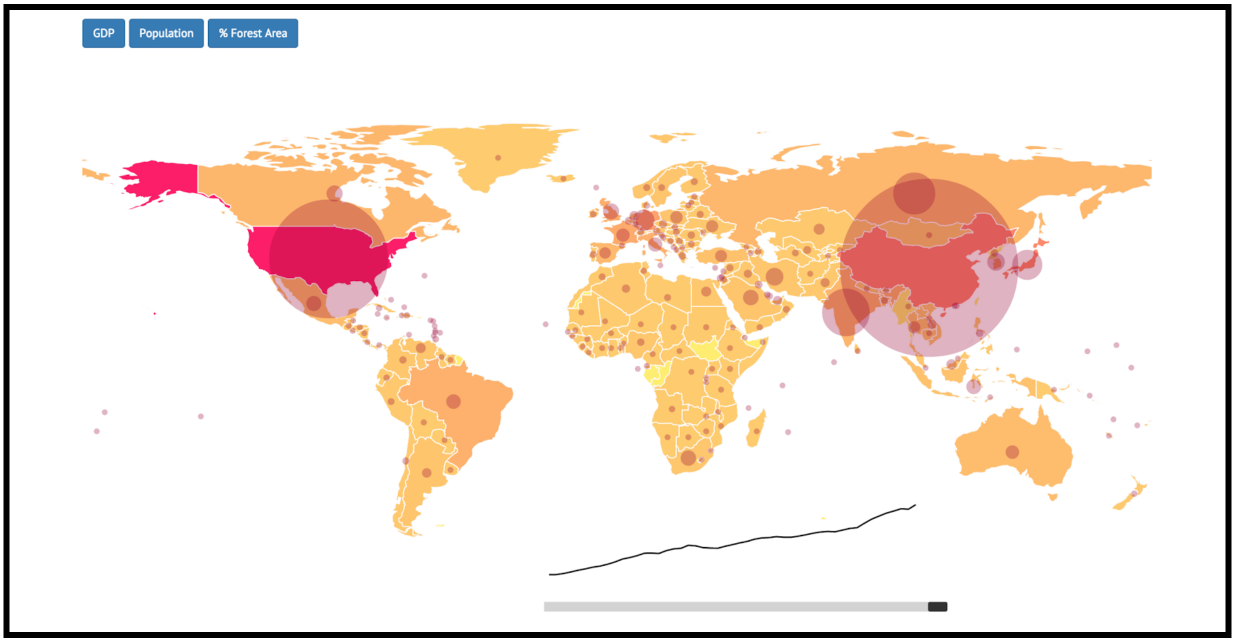


Fig 7

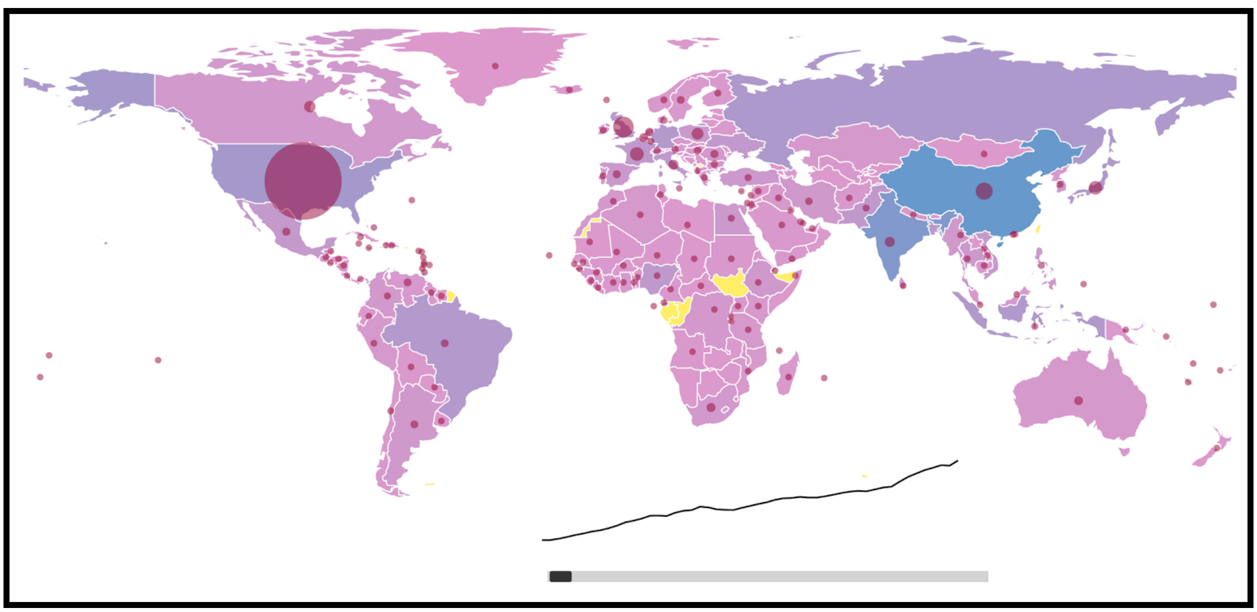


Fig 8

CO2 Emissions Chart

In world vis, we wanted a way to visualize the world's total emissions values over time. Intially we considered visualizing it as a line chart (See Fig 3, 6, 7,8). Ultimately, we decided to change this to a bar chart. This was for two reasons. Aesthetically, the line chart left a lot of white space in the middle of our visualization, which was off putting. Practically, we felt that the bar chart was a better way of representing our *discrete* data. (See Fig 9)

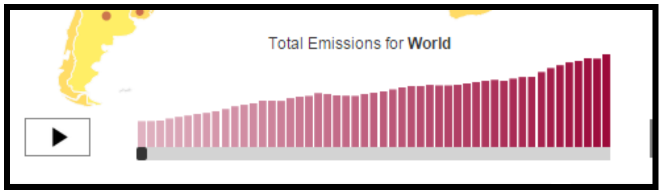


Fig 9

Later on, we modified this chart such that when a country is selected it updates to show the total CO2 emissions, over time for that particular country, rather than for the whole world.

Country Vis: Energy Useage

Our two country visualizations allow users to hone in on data specific to a country when they click on a country. The first one we implemented visualizes energy use data in a stacked area chart. The entire area represents total energy consumption (in kt oil equivalent) along the y axis, while the x axis shows how energy consumption has changed over time. The top section (blue in Fig 10) represents the percentage of energy derived from fossil fuels, the second (green in Fig 10) shows the percentage from Alternative and Nuclear Energy, and the third (pink in Fig 10) shows the percentage from Combustible renewables.

Once we had the functionality down, we modified the graph to add a y-axis label, a legend, and grid lines to enhance user experience. We also adjusted to a more neutral color scheme (See Fig 11)

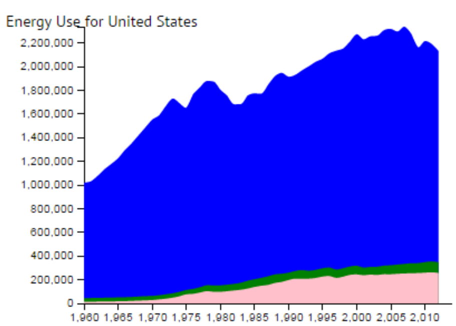


Fig 10

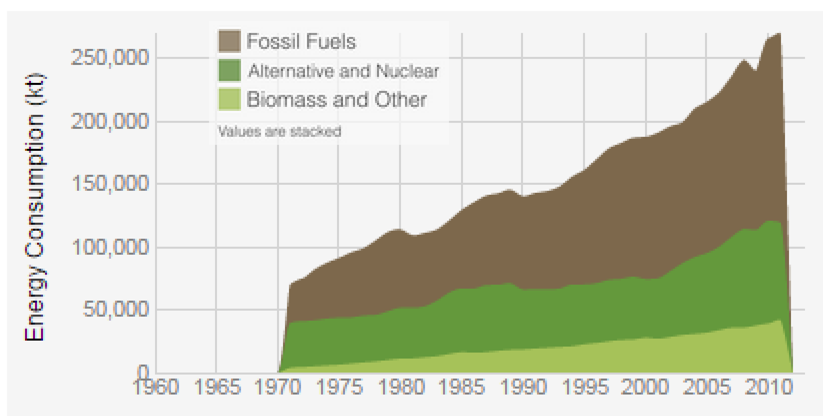


Fig 11

Country Vis- Comparison

For our second Country Specific Visualization we wanted to visualize how changes in a given country's gdp and population over time relate to changes in CO2 emissions. It took us two tries to come up with a visualization design we were satisfied with.

First Iteration

Our first idea was to create a line chart. There were three lines, the first represented a given countries GDP divided by the world total GDP, that is, the percentage of the global GDP which that country accounted for. The subsequent lines represented the same value but for the population and CO2 indicators. This chart can be seen in Fig 12 below, containing data for Argentina. The brown line represents % Global GDP, the yellow represents %Global Emissions, and the green is %Global population.

Second Iteration

Ultimately, we decided to revamp this view. We felt that a more simpler, more tangible way to understand the relationship between changes in emissions over time and changes in Population or GDP would be through one line for per capita emissions and one line for emissions per USD GDP. The finalized version of this view can be seen below in Fig 13.

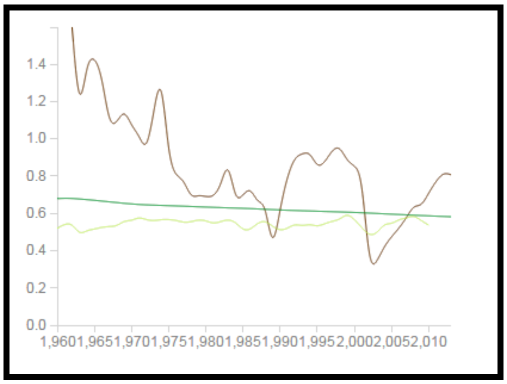


Fig 12

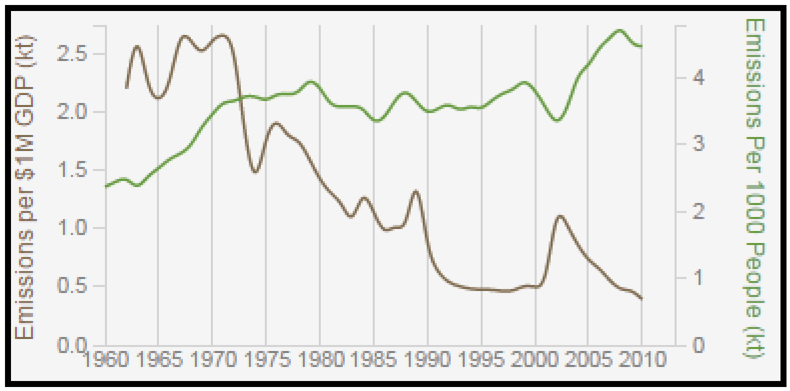
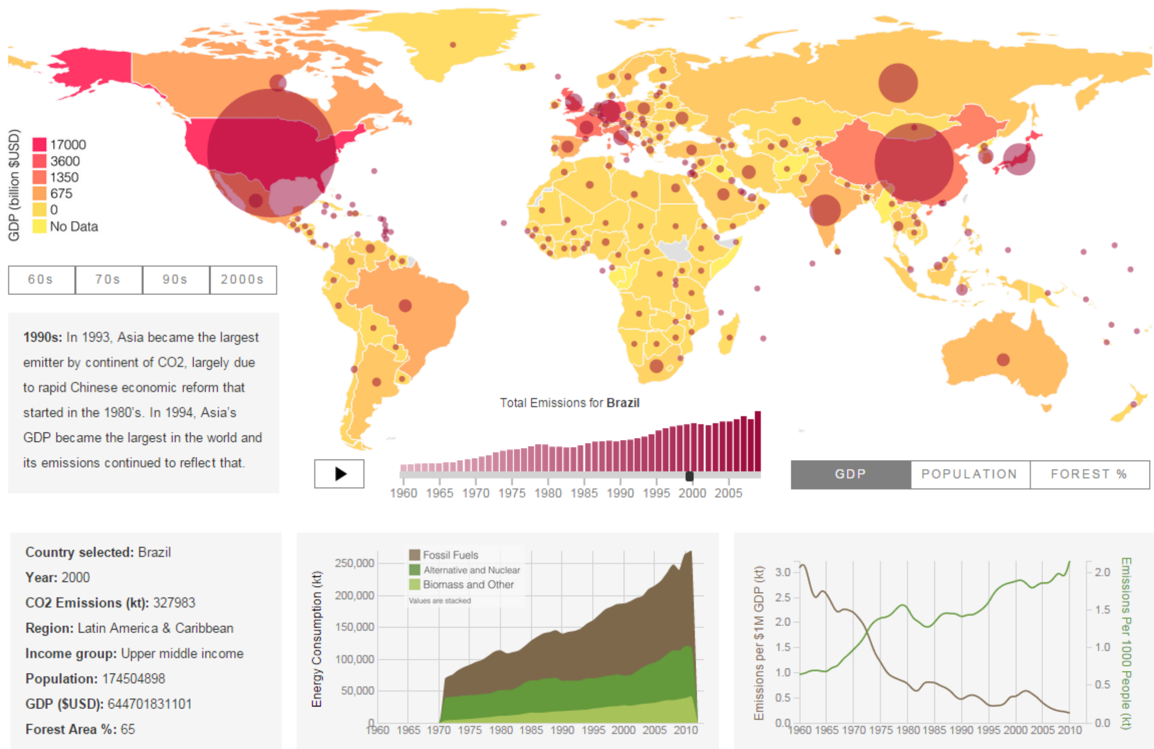


Fig 13

Chapter One Final Layout



Visualization: Chapter Two

Overview

For our Chapter Two visualization we wanted to focus on emissions data for the present day, with the hopes that we could do a third chapter honing in on data in the US specifically. As we began implementing the design we put forth in our project proposal, we realized that it would be overlapping with a lot of the data we were already providing in chapter 1 (See First Iteration: Force Diagram). Around the same time, we realized that we likely would not have time to implement 3 chapters. For this reason, we decided to scrap the force diagram we had intended for chapter 2, and start out on a new visualization. For our *new* Chapter 2we decided to hone in on the US, which we were intending to save for a 3rd chapter. We wanted to explore in greater detail the relationship between energy use and carbon emissions in our own country. We found an excellent data set from the EIA (see Data: Chapter Two) which broke down US energy Useage by energy source and economic sector and another data set which broke down Emissions by Economic Sector. We chose this data because it allowed us to explore this relationship through an economic lens. Instead of using a force diagram for this visualization, we decided on a Sankey Diagram. For more information on the design development of this chapter see Second Iteration: Sankey Diagram.

First Iteration: Force Diagram

Design Inspiration

For our second chapter we were inspired by an infographic from The Guardian (See Fig 14). We wanted to use a Force Diagram in which countries would be circular nodes, just as in this infographic. However, unlike this static example, we wanted to allow users to interact with the visualization in three key ways. First, users would be able to toggle between the node size representing (1) a country's total emissions and (2) a country's per capita emissions. Second, users would be able to mouseover the nodes to access tool tips with more information about the countries. Third, users would be able to group nodes either by geographic location or by economic group.

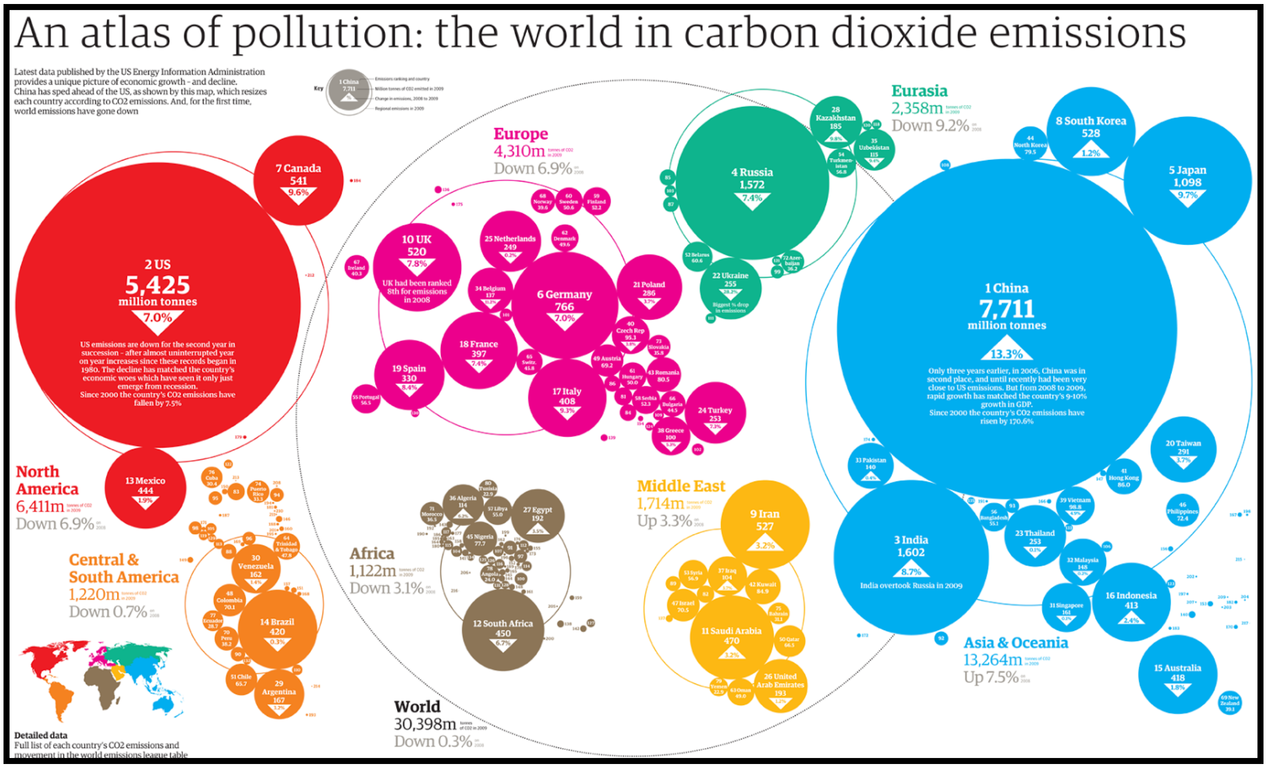


Fig 14

Initial Implementation & Reasons For Discard

We began implementing our second chapter by creating a second vis object, housed in **circlevis.js**. We created a force diagram with each country represented by a node, and we added buttons to allow users to interact in the ways outlined above (See Fig 15). However, once we got to this point, we noticed a couple things about this second visualization:

- When set to "Total CO2", and "geographic location" the nodes would encode essentially the same data as Ch1 when the slider is pulled all the way to the right.
- A small subset of the countries have nodes which are significantly larger than the majority of countries. To make our visualization more interesting, and less cluttered we would be better off to exclude those smaller nodes, focusing our visualization on a small subset of those small players.

The first issue made us realized we had to rethink our chapter 2 visualization, so that it could offer users a look at the data that was more significantly different than the view offered in chapter 1. Furthermore, as we considered the second point we decided that if we were going to restrict the scope of our visualization to a small subset of countries, we may as well restrict it to a single country, and explore it's emissions data in greater detail or through a new lens. It was back to the drawing board for us!

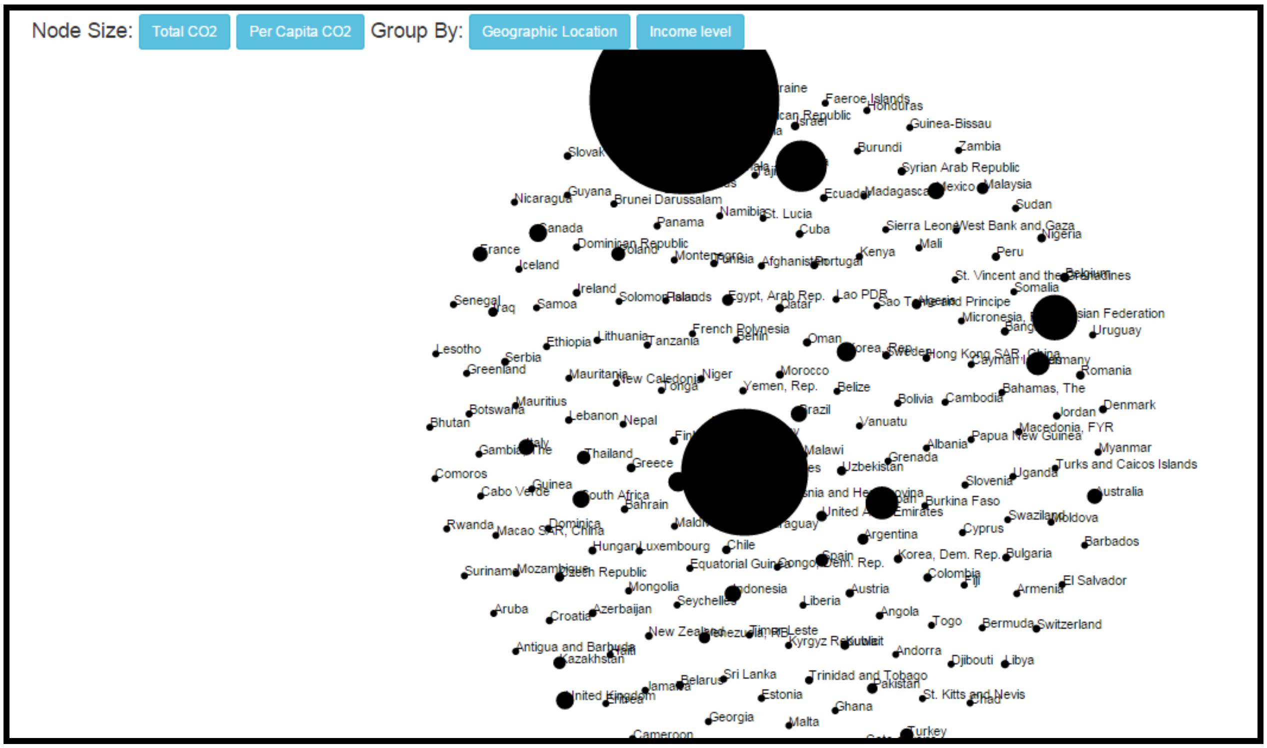


Fig 15

Second Iteration: Sankey Diagram

Design Inspiration

We were inspired by Mike Bostock's [Sankey Diagram Visualization](#) (See Fig 16). For his visualization he made use of a d3 sankey plugin. We intended to use this plugin as well, however we found it easier to use the [Google API](#) as a resource to create our Sankey Diagram. We particularly liked the applicability of this style of chart to the representation of flow. We were interested in examining in more detail the two main components of CH1: country co2 emissions and country energy useage, and we thought that a flow diagram would be a great method of visualizing how exactly energy use gets transformed into carbon emissions.

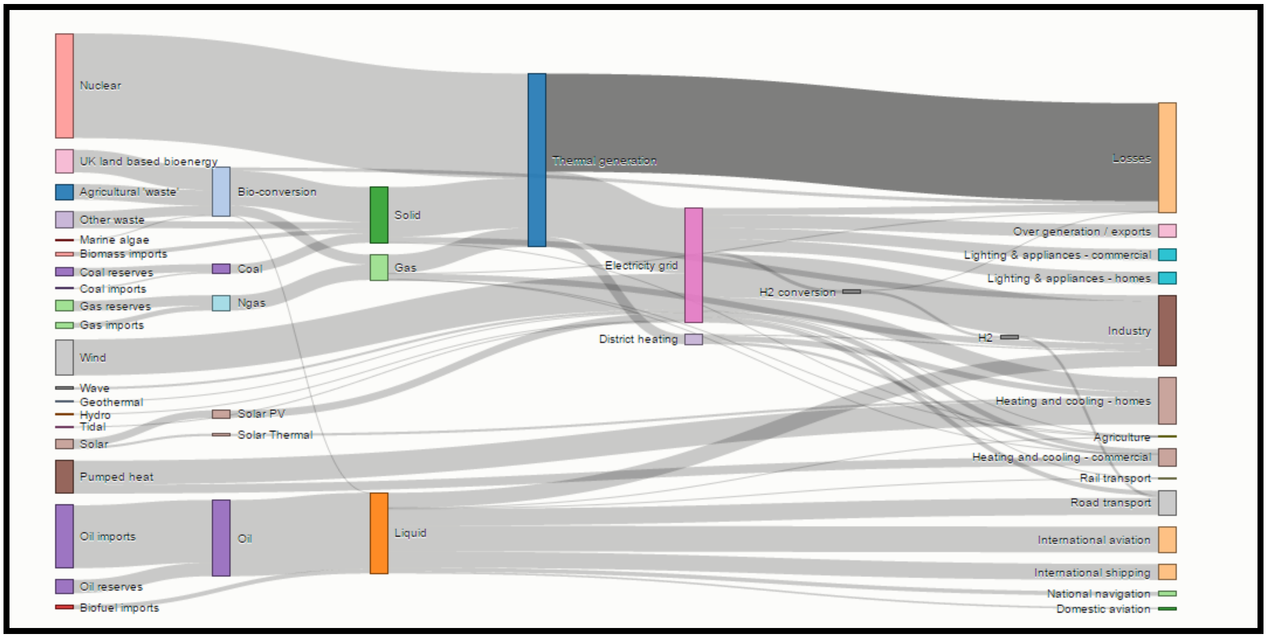


Fig 16

Implementation

As we mentioned, we implemented our Sankey Diagram using the Google API, after first attempting to make use of the d3 plugin. The Google API was relatively straightforward to figure out and, luckily we did not have to deal with many bugs. The major issue we encountered was in how we structured our data. Initially, we had set all the link weights to be percentages. However this resulted in a skewed diagram (see Fig 17). We had to normalize the weights so that the links were not just absolute percentages, but that they represented a percentage relative to the total Primary Energy use. (For instance, if 70% of energy from coal went to Electric Power then the node weight was not 70, but rather 70 * (the percentage coal makes up of Primary Energy Use). Once we corrected this, the chart was looking great! Another pro of using the Google API implementation is it essentially does the tooltips for you. So, when the user mouses over a link, a tool tip will inform the user of the source and target nodes, as well as the percentage of primary energy flow represented by the link. Pretty Cool! (See Fig 18 to see for yourself)

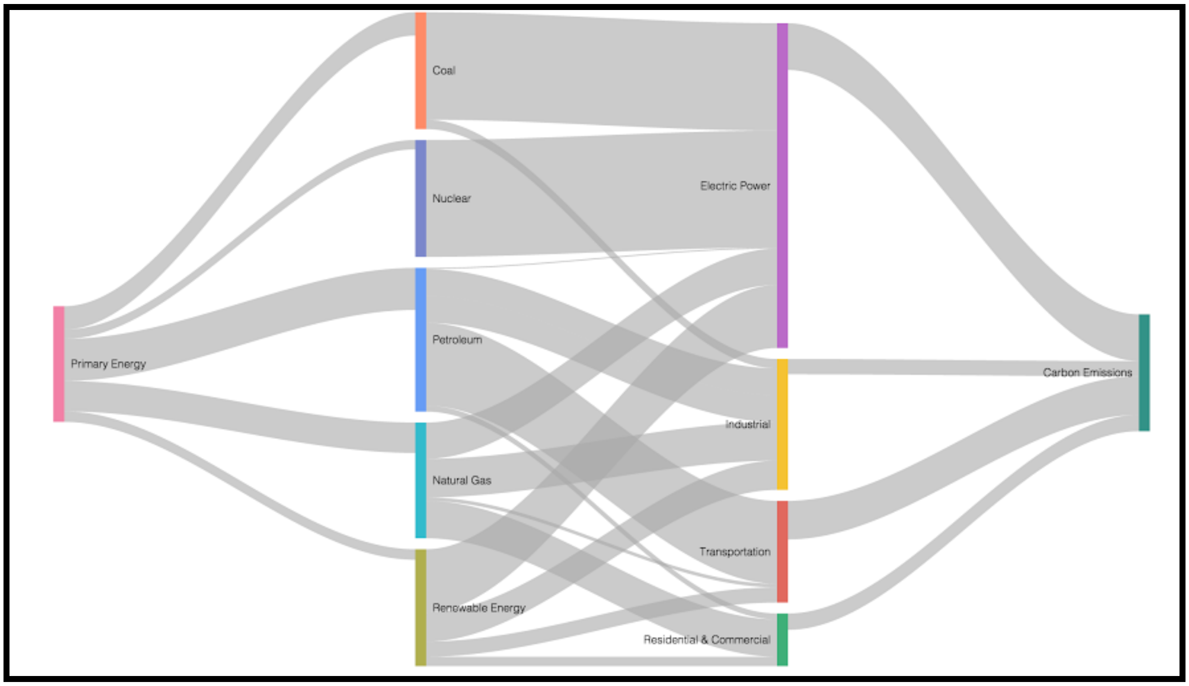


Fig 17

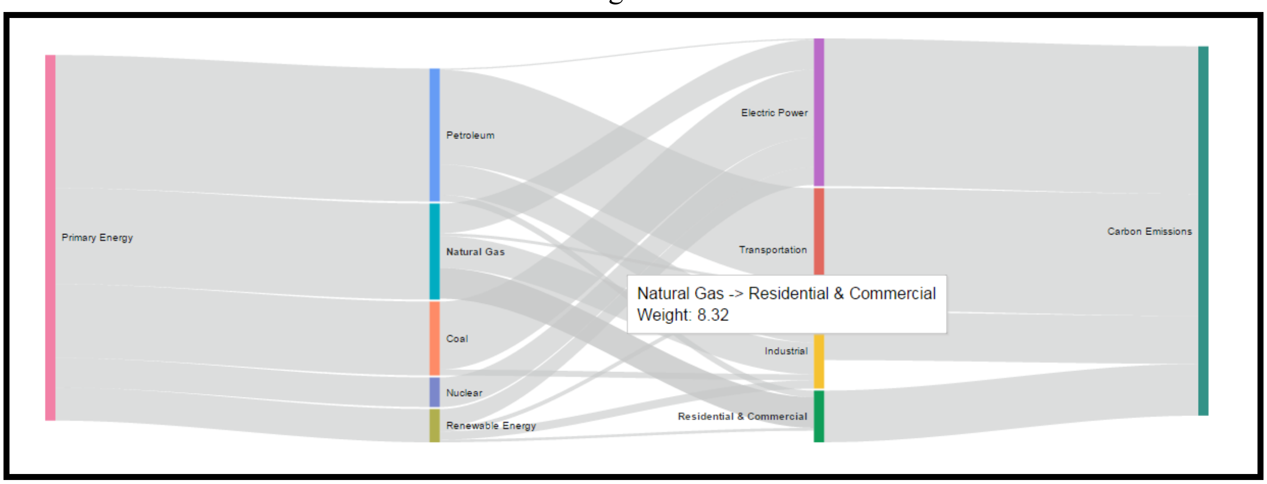


Fig 18

Storytelling

Contextualizing Carbon

In order to give the user a sense of why our visualization is important, we added a few storytelling screens at the beginning of the visualization. The point of these screens is to contextualize the CO2 Emissions data by providing the user with scientific data on climate change.

We added three storytelling screens:

1. An Intro Page -- this allows the user to bypass the storytelling sequence and skip straight to the visualization
2. Global Temperature Changes -- This page provides the user with data on changes in global average surface temperature (See Fig 19)

3. Impact Page -- This page contains graphics which, upon mouse over, tell the user about some of the environmental implications of changing surface data. (See Fig 20)

Of these three, only the Global Temperature Change page required additional visualization efforts. Using data from NASA, we created a new visualization view (defined in **temperaturevis.js)** which consisted of a simple line chart which graphed the change in average temperature between a given year and the average over the 1951-1980 period. Tooltips give the user the ability to mouse over a given node and see the value for that year.

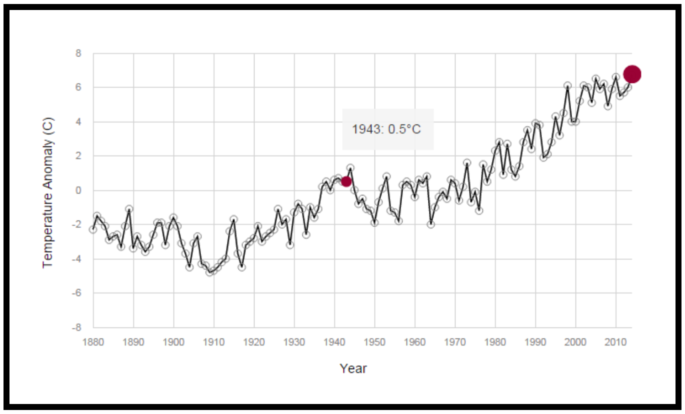


Fig 19

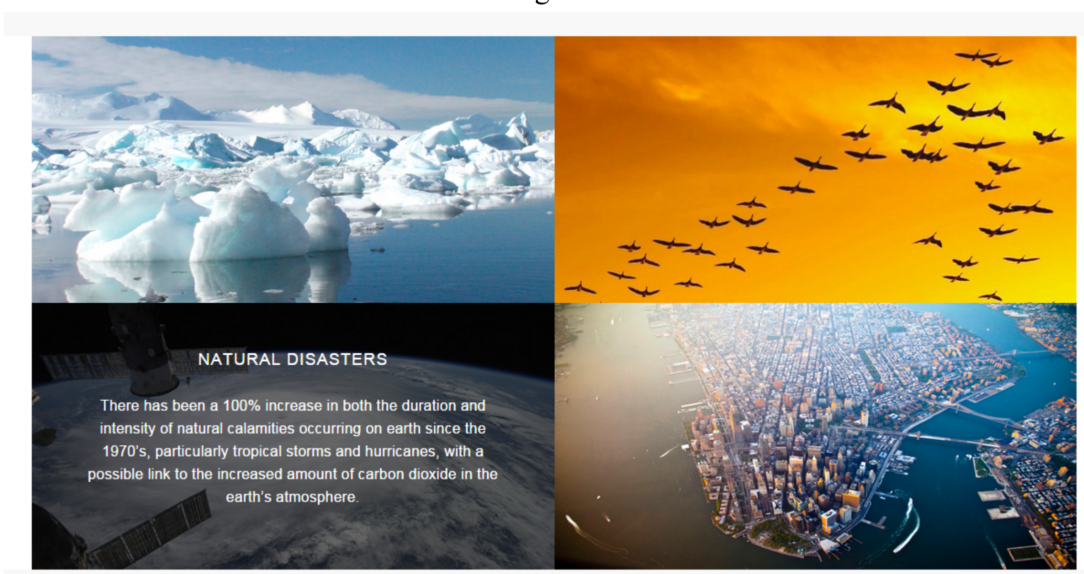


Fig 20

Chapter 1

To orient the user in the most involved aspect of our project, Chapter 1, We added two additional storytelling elements. First, we added an info box which provides additional information on the selected country. This box updates the data displayed according to the year selected by the time slider. (See Fig 21)

Additionally, we added a storytelling box which allows users to zoom in on a particular decade of data. When a decade is selected, the animation jumps to that time period. The storytelling box highlights a particularly interesting aspect of the data for the selected period. (See Fig 22)

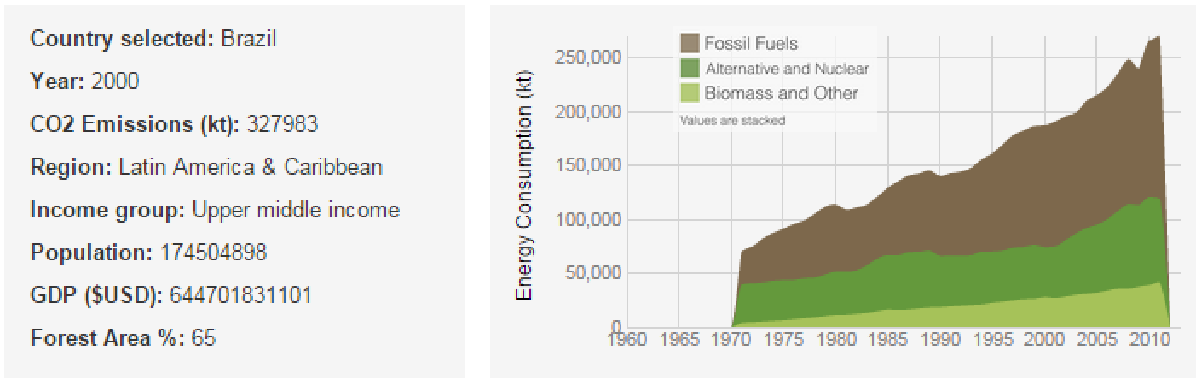


Fig 21

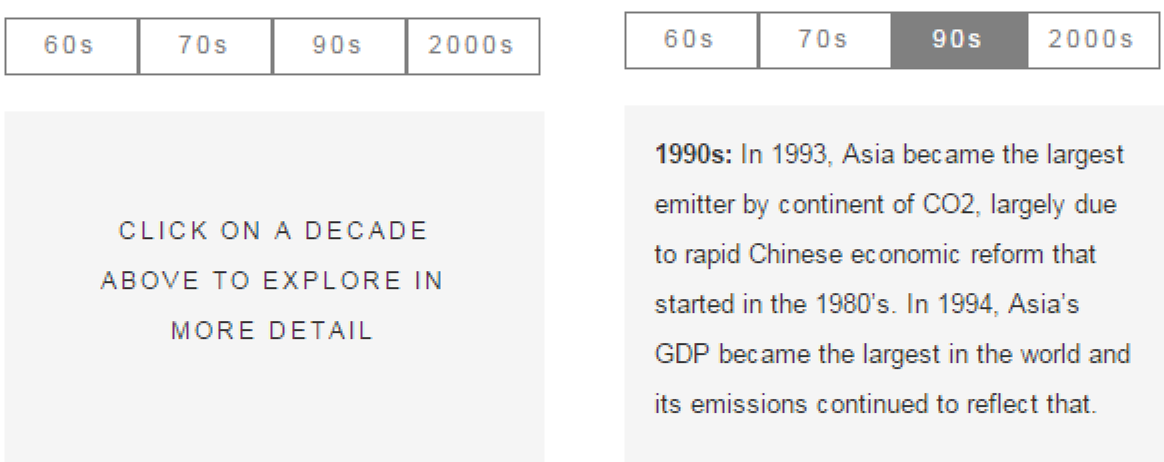


Fig 22