54 YEARS OF WORLD ENERGY

BY THE POWERPLAY UNIT

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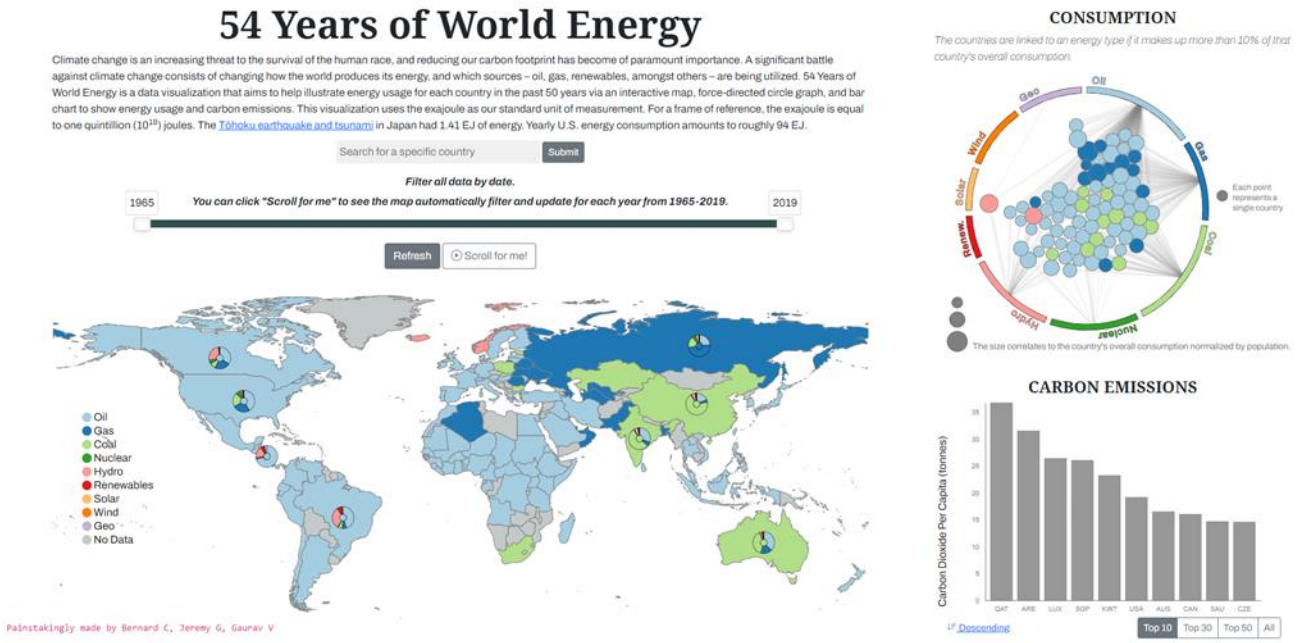
CPSC 436V

Overview

54 Years of Energy is a data visualization that shows how countries across the world have used different sources of energy for the past 40 years. The main view is a world map projection that consists of a choropleth map representing the type of energy that was used most for the currently selected timeframe. The symbol map and hoverable line chart show the detailed usage of energy by type over time. Two secondary visualizations are used: a force-directed circle graph to illustrate which countries are similar in terms of energy usage and a bar chart to encode carbon emissions per capita for different countries. The three views are controlled by a global time slider to filter the data by date, as well as a search bar to find a specific country quickly. Clicking one country in any of the views will highlight said country in all subsequent views. The map also has an automatic scroller that changes the map projection year by year in the form of animation for users to quickly get a holistic view of how energy usage has changed since 1965.

TEASER:



Data

Sources

- **Countries with Lat/Lon:**
  - https://www.kaggle.com/eidanch/counties-geographic-coordinates?select=countries.csv
- **Country Codes:**
  - https://www.iso.org/obp/ui/#search
  - https://en.wikipedia.org/wiki/List_of_ISO_3166_country_codes
- **Population:**
  - https://data.worldbank.org/indicator/SP.POP.TOTL
  - https://www.worldometers.info/population
- **Energy Data:**
  - http://www.bp.com/statisticalreview

    - We choose this dataset over other websites as it gave us data back to 1965, and broke down all the types of energy. Other data sources did not have data ranging that far back, or did not have the breakdown of energy type we were seeking.
- **World Atlas TopoJSON:**
    - https://github.com/topojson/world-atlas

Processing

The latitude/longitude data and the country codes were manually consolidated into ***lat_lon.xlsx*** via Excel. The energy data and population data were programmatically manipulated in Python to match our intended schema, and then all the tables were joined on the country code and name columns (both were unique keys.

The ***Data_Cleaning.ipynb*** contains a detailed step-by-step breakdown of the data pre-processing should it be needed. Things to note were:

1) The dataset did not have data available for all the countries of the world – some countries in the Middle East and South Asia were not part of the dataset (seemingly this data is not collected for some countries), and consequently, some countries on our map do not have data.
2) Any countries that were newly created between 1965 and 2019 were also dropped to eliminate complexity.
3) The dataset consolidated many of the smaller African and Central American countries to groups; we have data for these consolidated groups, but need to do a bit more integration so that the map reflects this consolidation. As of now, we have mapped the countries to their region (West Africa, Middle Africa, etc.) and will be implementing the tooltip such that the information for the region is displayed when hovering over the country.

Detailed Schema

Our final dataset is in the form of a **flat table**. Our final schema is summarized in the table below:

Attribute	**Type**	**Cardinality**	**Notes**
Country	Categorical	85 Unique Values	
Year	Quantitative	[1965, 2019]	
Type	Categorical	9 Unique Values (see below)	Type of energy used
Consumption	Quantitative	[0, 82.441149]	in ExaJoules
Emissions	Quantitative	[0.218804, 9825.801775]	Million Tonnes of CO_2
Country ID	Categorical	85 Unique Values	Country ISO ID
Country Code	Categorical	85 Unique Values	Abbreviation for Country
Population	Quantitative	[73,633, 1,397,715,000]	
Lat	Quantitative	[-40.900557, 64.963051]	
Lon	Quantitative	[-106.346771, 174.885971]	

**Types: Oil, Gas, Coal, Nuclear, Solar, Wind, GeoThermal, and Hydro*

Each item primarily encodes the energy and emissions for a particular type of energy for a certain year and country. Population per year per country and latitude/ longitude were also encoded as they were necessary for our visualizations, but were redundantly encoded in the table. We chose to redundantly store this data as it did not make a substantial difference to performance but made the handling of data in our visualizations much easier, as we eliminated the need to dynamically join information in the browser itself.

Goals and Tasks

Data and Task Abstraction

Based on our M1 usage scenarios and feedback, we have deconstructed our tasks as such:

TASK	DESCRIPTION
T1	Understand how non-renewable resources are being replaced by renewable and clean energy, globally
T2	Compare trends of energy (consumption) over time
T3	Identify which clean energy sources are most pervasive
T4	Identify which countries or parts of the world have similar types of energy production
T5	Identify countries that have high carbon emissions/capita, and how emissions change across time

Abstract Language: {action, target} pairs

- Discover trends
- Discover outliers
- Identify similarity
- Present distribution
- Browse features

Visualization

Map View

The Map view serves as the primary overview of the visualization. By encoding country data using a geographical map, viewers of the visualization immediately and intuitively understand one key aspect of the energy consumption data - the geographical location of each energy consumption data point **(T4)**. Furthermore, imposing a pie chart symbol encoding on the map also allows users to briefly compare and identify the distribution of different energy consumption rates in each country.

As the main idea of the visualization was to communicate where energy was being consumed, we decided that the most appropriate map projection to use would be an equirectangular position. While this projection does distort the sizes of many countries, especially those in the northern hemisphere, it was also the projection that would be most familiar with our viewers, and would thus make it incredibly intuitive to understand which countries our data was associated with. This projection also fits well within a rectangular frame, and made it easy to space with the other views in the project.

The combination of colour hue and geographic location effectively communicate two of the most important data attributes - location and most consumed energy type. The location of a particular data point can easily be identified as a choropleth map, which is a very familiar visual encoding - viewers of the visualization can easily identify which interlocking area corresponds to which country. While the addition of the colour hue channel aids the interlocking areas in popping out, it also allows viewers to digest a wide range of data in a relatively condensed space. Each colour hue is associated with a certain type of energy type that will be consistent across all the views, which makes it easier for a viewer to associate trends and data points across views.

Of course, due to the nature of overview views, it is inevitable that signals within the data may be lost. In addition, the use of a pie chart symbol may introduce issues such as occlusion. This issue is addressed by our limitation on the number of symbols that are present at any given time. In fact, the combination of symbols

and interlocking areas are actually mutually beneficial: the pie chart symbol helps in providing a more in-depth overview of the aggregate data that the choropleth is unable to show and also mitigates potential problems with interference with regards to visual salience (due to variable sizes between each interlocking area) by drawing focus to a different encoding that all have consistent sizes, while the interlocking area provides a redundant but useful spatial location for the symbol encodings.

In the case where a user wants to see even more specific information, particularly energy data year on year **(T2)**, they can hover over a particular country to expose a line chart view of the energy consumption data over the selected range of years. This serves as the most detailed of the three sub-views contained within the map view.

- **Marks**
    - *Interlocking Area Mark (Map):* Each area represents a single country/region. Interlocking area marks work better than any other type of mark to represent a geographic location.
    - *Interlocking Area Mark (Pie Chart):* Represents consumption for a particular energy type. A pie chart is able to show at a high level the relative proportions of energy that each country uses. The shape of the pie chart is also smaller than alternatives, allowing for less occlusion of over the geographic map.
    - *Line Mark (Hover View):* Each line represents a particular energy type. Line marks allow for trends over time to be observed very easily.

- **Channels**
    - *Area Mark Colour Hue:* Encodes the energy type. Color hue allows the user to understand intuitively that each area is associated with a particular energy type.
    - *Pie Chart Colour Hue*: Encodes the energy type. Chosen for the same reason as Area Mark Colour Hue.
    - *Pie Chart Angle*: Encodes the energy consumption proportion
    - *Line Mark Colour Hue*: Encodes the energy type. Chosen for the same reason as Area Mark and Pie Chart Colour Hue.
    - *Position on Common Scale (Vertical, Horizontal)*: Encodes energy consumption rate and year, respectively
- **Interaction**
    - *Hover Tooltip:*
        - Country Area Mark
            - Show energy consumption and year on either axis of line chart
            - Encode each energy type as a line
            - User Color Hue channel to differentiate between different energy types
        - Pie Chart Symbol
            - Show pie chart for country in case pie chart was not visible (for non major country, or is covered by hover tooltip)
        - Line-chart
            - Shows the country's trend of energy usage along with the different types of energy used.
    - Year by Year Animation ("Scroll for me" button)
        - The year by year animation to update the map projection gives the user the ability to automatically see how energy usage changed year over year from 1965-2019, without needing to manually set filters.
            - This enables them to view the change in energy sources directly (T1), and then perhaps focus on a particular year or country they found interesting in the animation.

- *Click:*
    - Highlights the country on the map and updates the other two views: highlighting the node in the force-directed circle graph and bringing the country's bar to the left-hand side in the bar-chart.

Force-Directed Circle Graph

This view serves as one of the two secondary views of the overall visualization. The goal for this view is multifaceted. For one, this view allows users to view a country's overall consumption (aggregated) over time relative to others at a single glance through the size of the points **(T4)**. This view also shows the overall trend of countries and the energy types they use the most via a force directed graph, as the countries are pulled towards the energy types they use most **(T3)**.

- **Marks**
    - *Point:* Each point (or node) represents countries for which we have energy data for. Point marks are used in this case because in a force-directed graph it makes sense for points to be attracted to certain segments of the circle and be affected by other points. It was more initiative than line or interlocking area marks.
    - *Connection Mark - Line:* The lines represent the connection the countries have to energy types that contribute to most of their consumption. Nothing else made sense for a connection mark.

- **Channels**
    - *Point Colour:* Encodes the energy type that is most used by the country. Allows the user to see at a glance several countries' most used energy source. We used colour as in the channel rankings it was the second most effective encoding for categorical attributes.
    - *Point Size:* Encodes the amount of energy consumption normalized by population. It was important to normalize the size so country's with large populations don't dominate the graph. Now it is easier to generally compare points against one another and spot outliers. We used size because the other more effective channels to encode quantitative were already in use or could not be used (angle, length) in our use case.
    - *Point Spatial Positioning:* Encodes the energy type makeup of the country. Depending on the energy makeup of the country, points will be pulled towards sections of the outer rim. The pull will be stronger if the country uses more of that energy type. We used it because it was intuitive for a user to realize that if a point is close to an energy type, then that point (country) must use that type quite a lot.
    - *Line size (width):* Encodes the percentage of the country's energy consumption for that energy type. Used in conjugation with point spatial positioning to show the user what energy type(s) the country favours.
- **Interaction**
    - *Hover Tooltip:*
        - Countries:
            - Show the name of the country.
            - Show the exact percentage of consumption for each energy type.
        - Outer diagram rim
            - Highlight all the points in the center of the diagram that use that energy type the most.
            - Highlight the outer rim itself.
    - *Click:*
        - Countries:

        - When a country's node is clicked, that node is highlighted and its links that attach to specific energy types are also highlighted
        - Also updates the other two views by highlighting the country in the map view, and bringing the country's bar to the left-hand side in the bar-chart
    - Outer diagram rim:
        - Highlights the outer rim section and all the countries that are connected to the energy type with a link (countries that use more than 10% of that energy type).
        - Disallow the user from hovering and selecting on countries that weren't highlighted
        - When a specific country is selected, the user can hover over the outer rim to see how much of that energy type that one country used.

Bar Chart

The bar chart serves one of the two secondary visualizations to our map projection. This chart directly helps to compare carbon emissions across countries over time **(T5)**, along with the use of the global time slider. To render the bar-chart, the additional step of processing the data to give emissions per capita (sum of emissions/sum of population) was done prior to initialization. A breakdown of marks/channels is as follows, with rationale is as follows:

- **Marks:**
    - *Line Mark*: The length of a line corresponds to the carbon emissions/capita for a country
- **Channels:**
    - *Horizontal Position on a common scale*: Encode the country attribute
- **Interaction:**
    - *Radio Buttons*:
        - Radio buttons enable a user to filter between the top 10, top 30, top 50, and entire set of countries available to display on the chart.
        - We implemented this as initially we had all countries part of the graph, but having too many lines makes it difficult to parse information. By introducing the radio buttons, the user is in control of how much data they want to display.
    - *Tooltip:*
        - A tooltip was introduced to display the country name and actual value for carbon emissions per capita. Country names were too long to display on the x-axis for more than a few countries.
        - Despite having the items aligned on a common scale, it is still difficult to parse out the exact numerical value, and adding the tooltip enabled users to identify exact values.
    - *Animations:*
        - When filtering the data, the bars will animate in and out (move positions according to their sorted ranking). This helps with the users' interpretation of countries changing position as the data is filtered.
        - It is far easier to tell that Qatar jumped from third to first over a certain time filter via the animation than relying on memory and cognition from a simple static change.
        - If a country is selected, the bar for that particular country will move to become the first entry of the chart
            - This was done since depending on the radio filter used, the country may not be present in the subset of data that is presented.
    - *Sort:* The data is sortable, either ascending or descending.
        - This simply provides the user sort ascending or descending, to see either side of the spectrum of carbon emissions.
    - *Radio Buttons:* Displaying every country on the graph at once is very dense, and could be hard to read, so top 10, 30, and 50 radio buttons were added.

        - This enables the user to select how dense they would like the visualization to be, and if they want to drill down, they can view a smaller amount of countries on the screen.
- *Click:*
    - Brings the country's bar to the left-hand side and updates the other two views; highlighting the node in the force-directed circle graph and highlights the country in the map view.

Global Filters

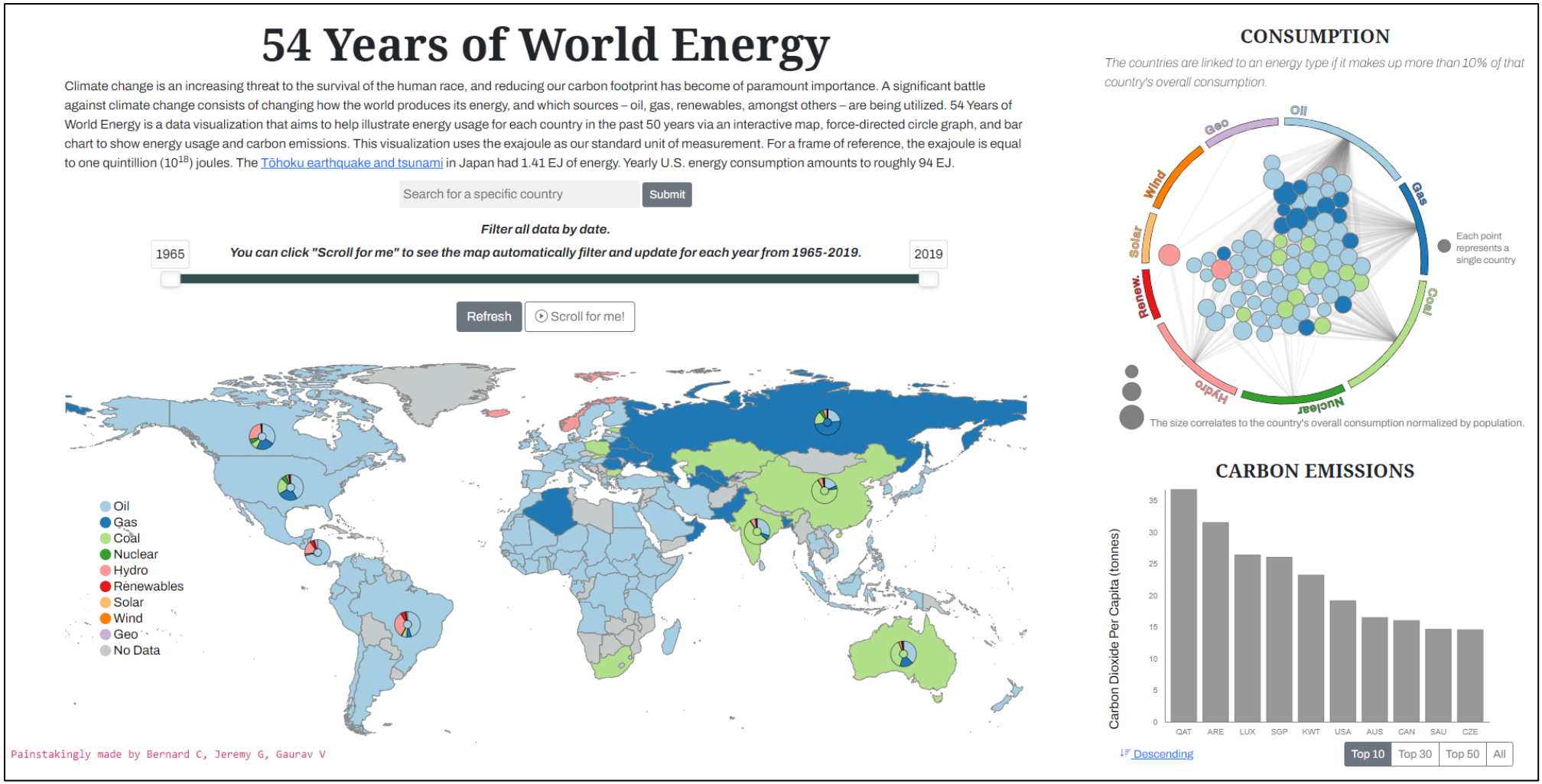
The dataset can be filtered globally by time via the slider. This updates all the visualizations, and resets any existing filters. This filter cannot be accessed whilst the year-by-year animation is playing (nor can any other tooltips/buttons).

The country search bar works the same as clicking a country in any of the visualizations (highlight across the charts).

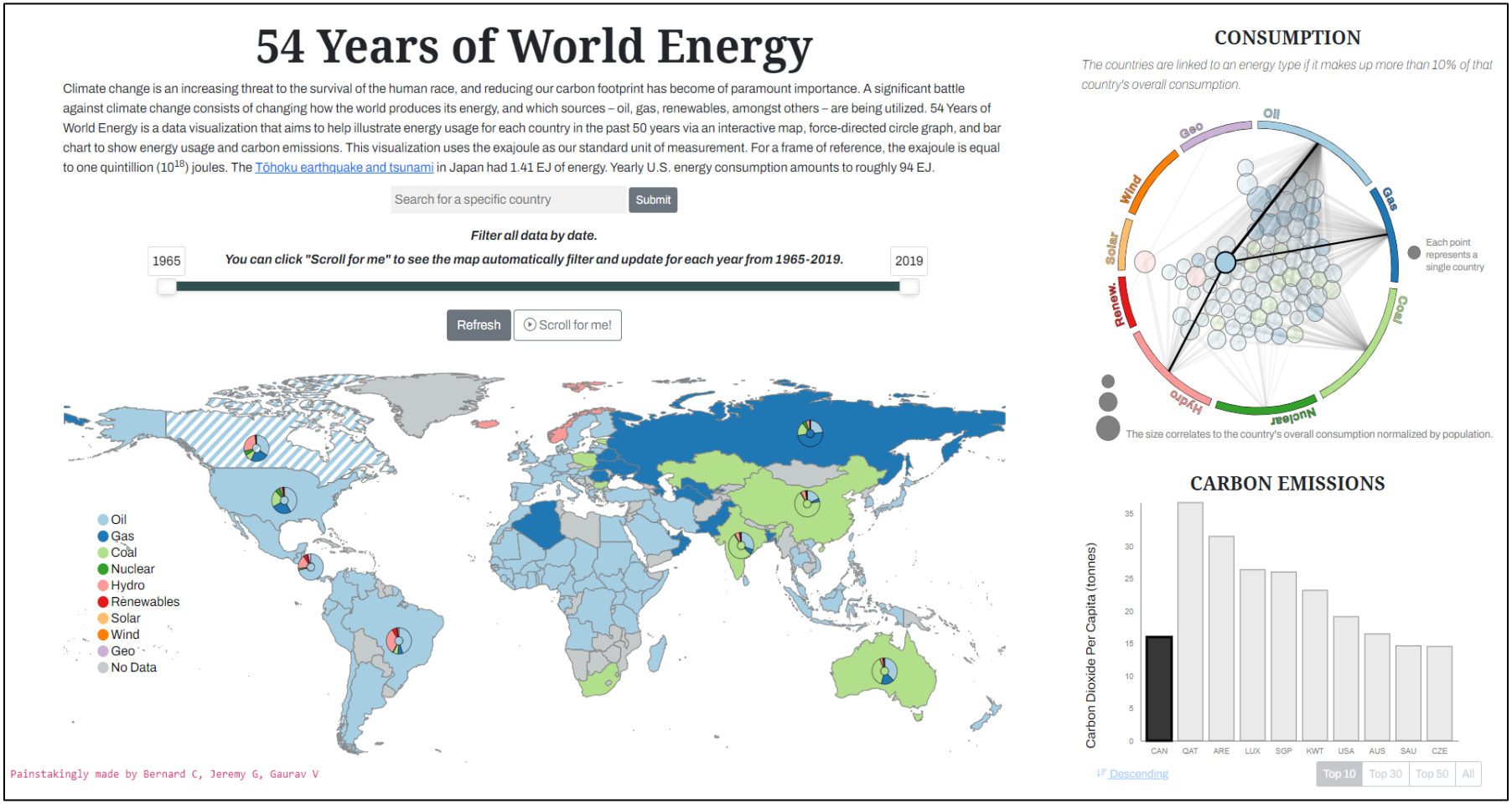
All three views are bi-directionally linked to one another, as selecting a country in any of the views changes the other two.

Usage Scenario with Screenshots

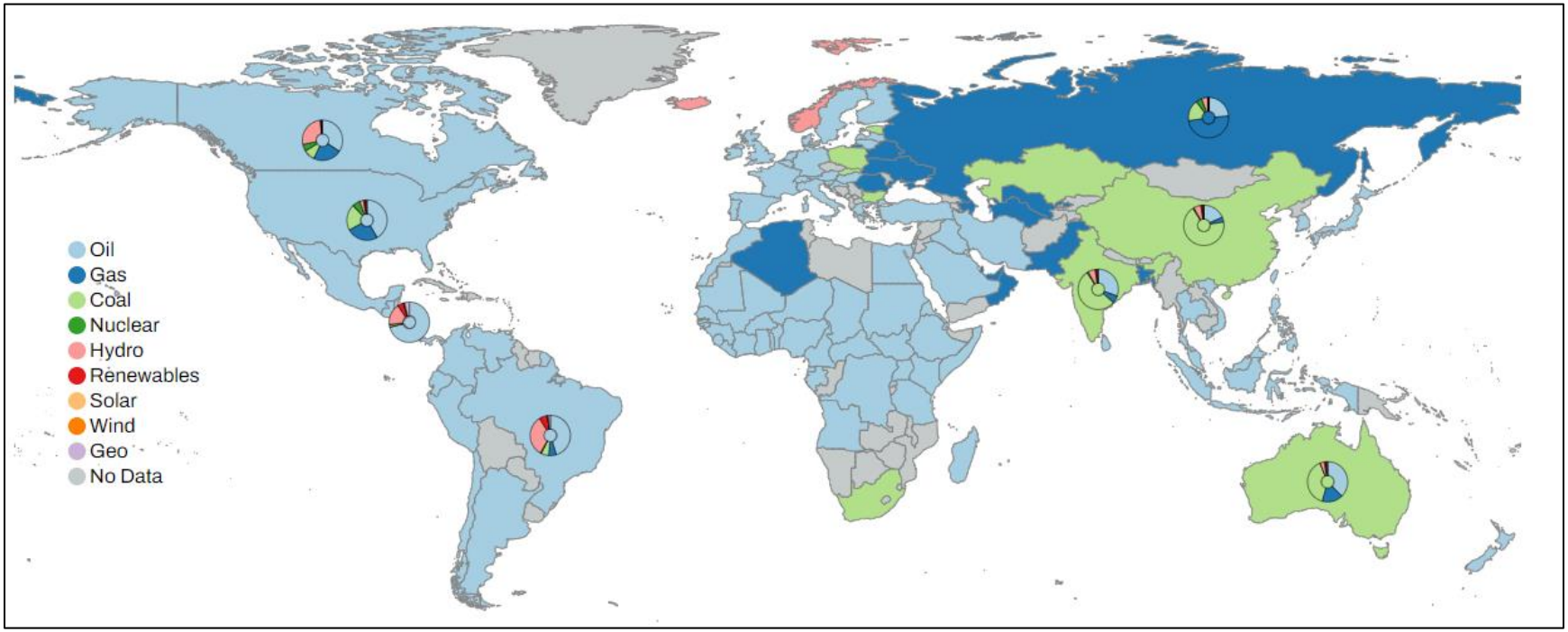
Screenshot 1: The entire visualization. This is what the user initially sees when viewing our visualisation.



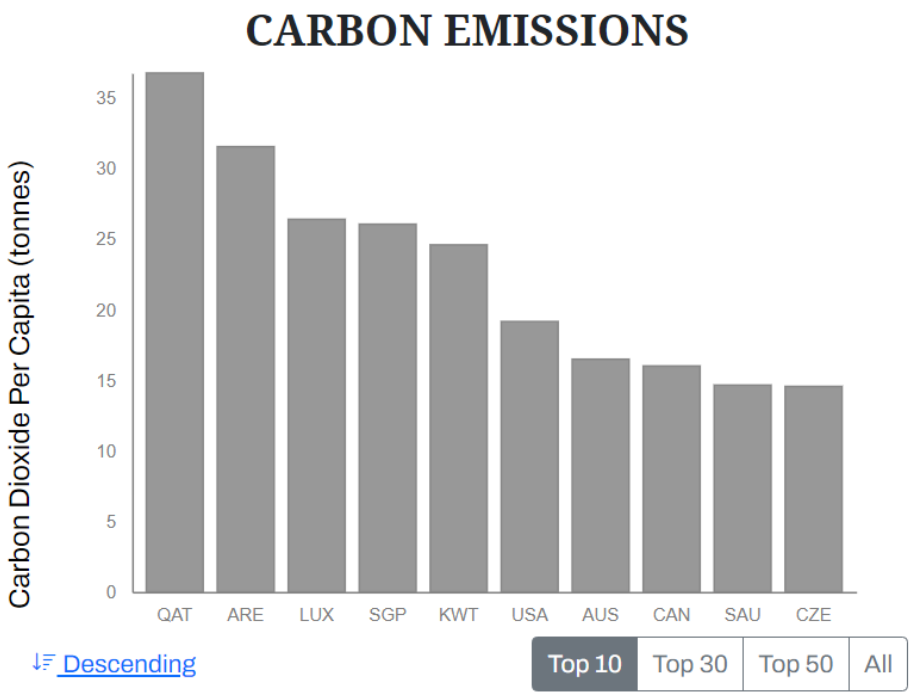
Screenshot 2: A single country selected (Canada); highlights the country on the map, force-directed circle graph, and brings the country to the left side of the bar-chart. If a user wants to get specific information about a country, they can search for it or use any of the three views.



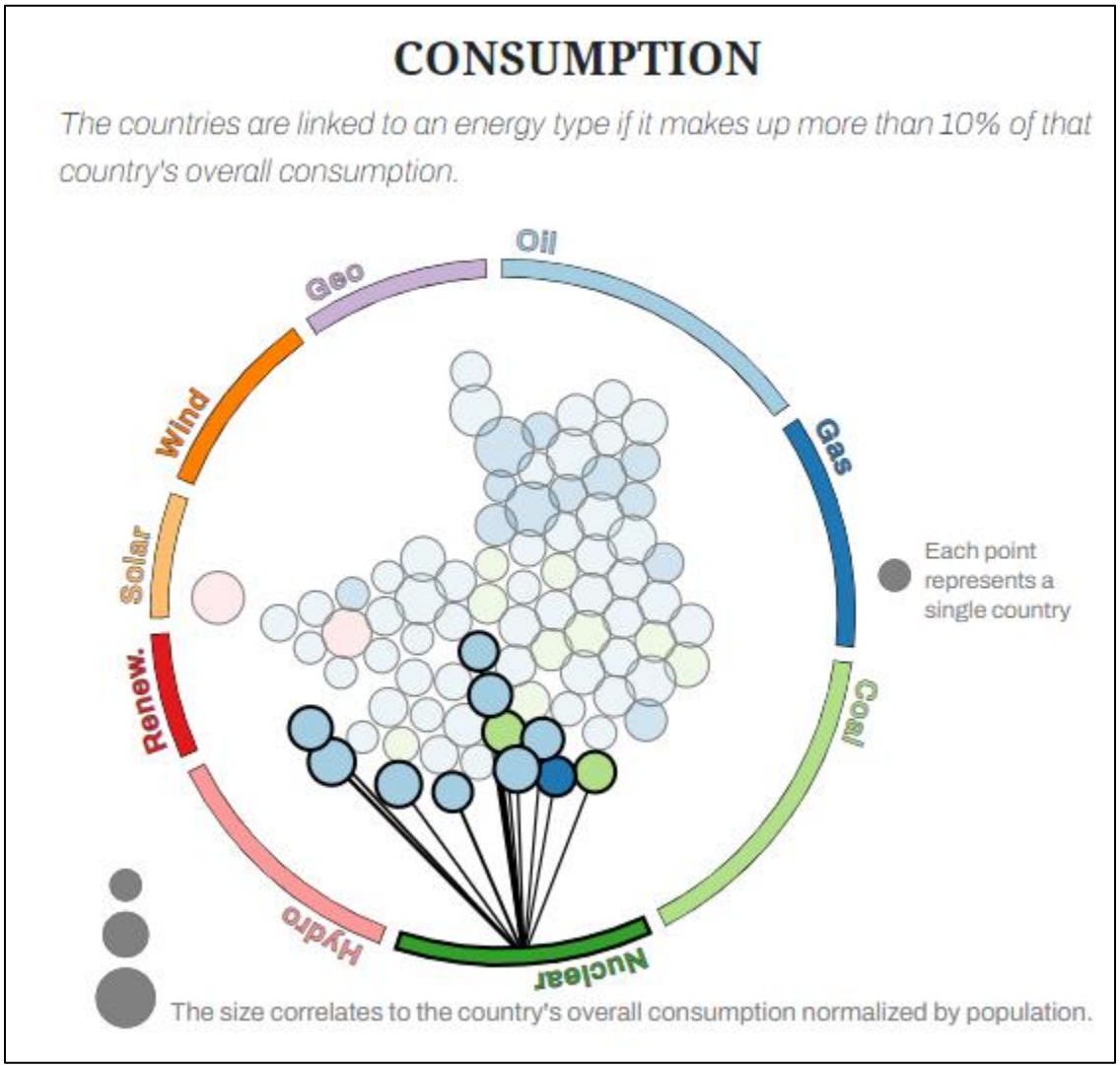
Screenshot 3: Map Chart isolated



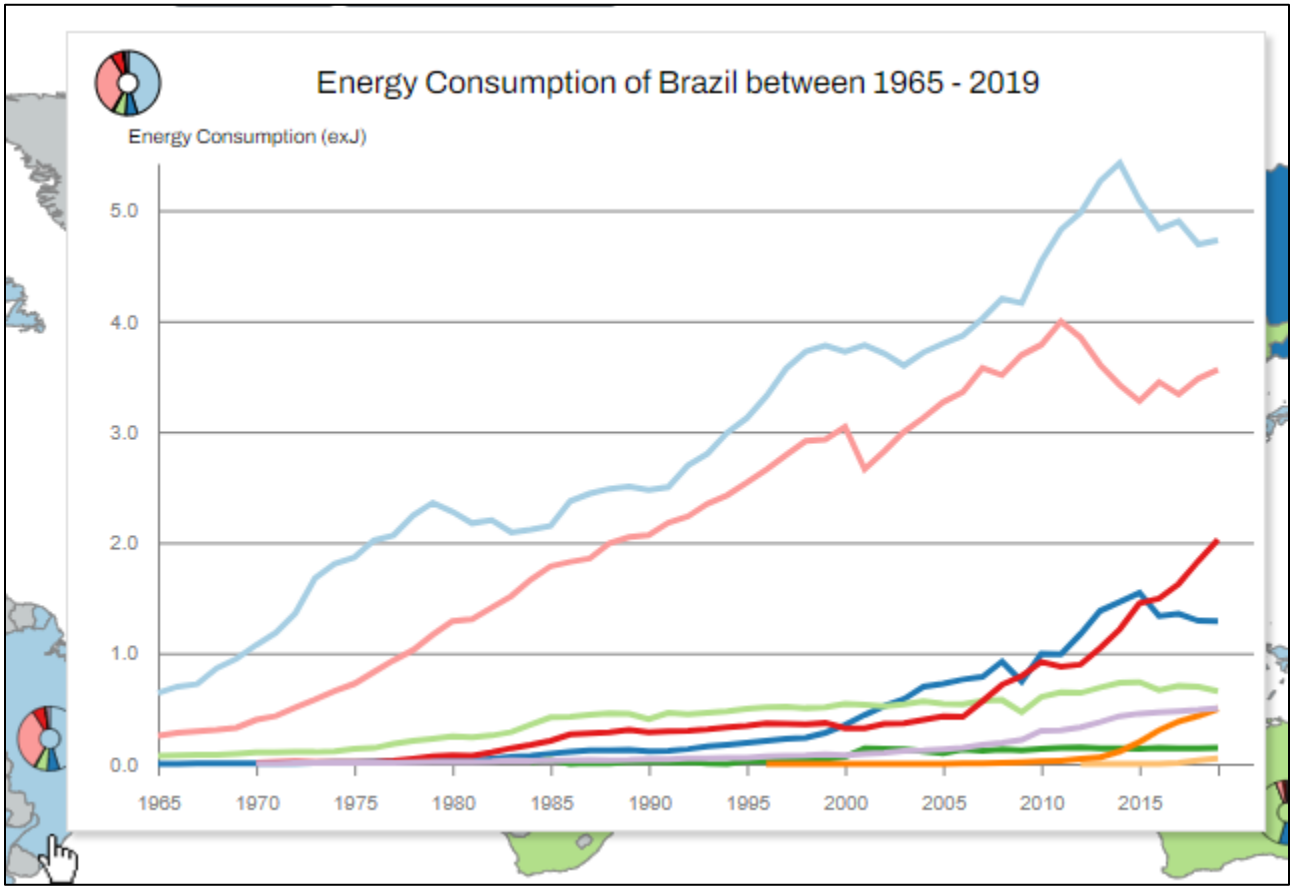
Screenshot 4: Bar-Chart isolated



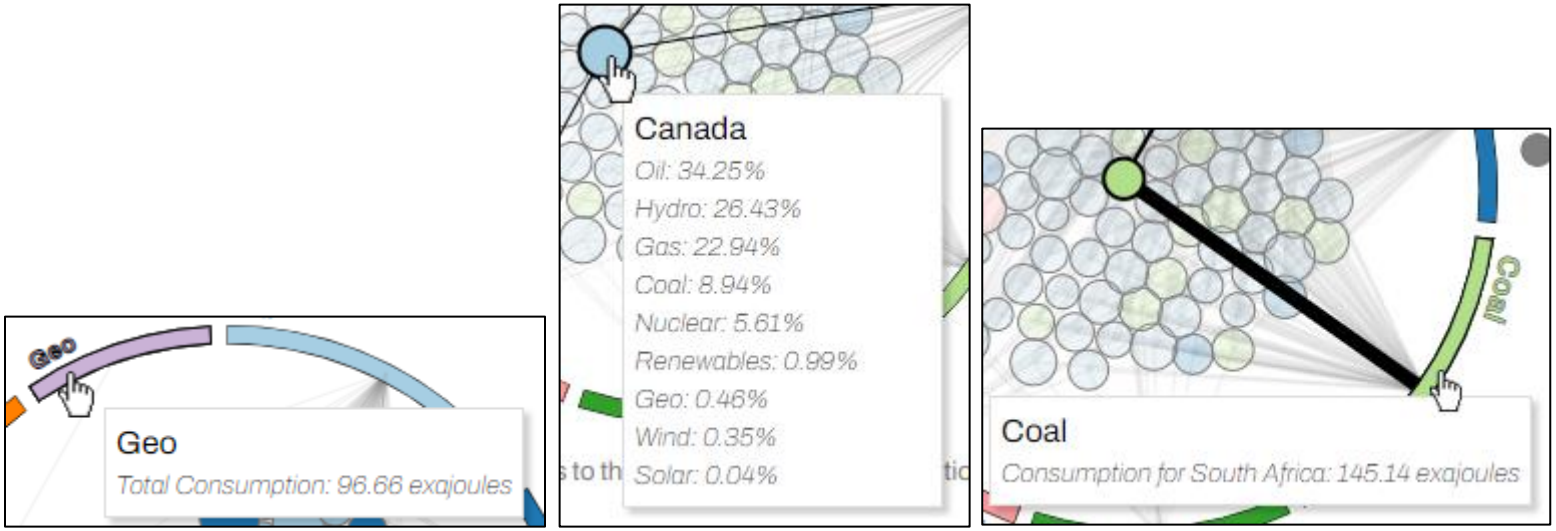
Screenshot 5: Energy type selected on the force-directed circle graph. Here we are able to see that the user selected the energy type “Nuclear” to filter by. The countries/nodes are then highlighted based on if they’re linked to that energy type. (T4)



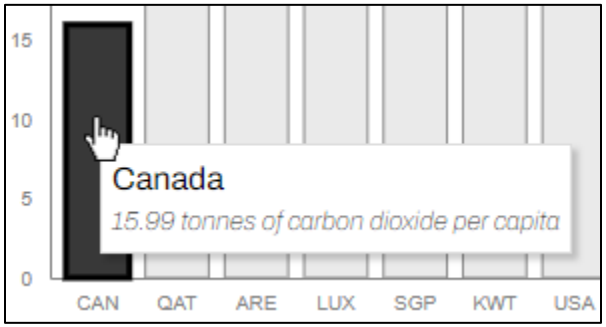
Screenshot 6: Hover tooltip on the world map that shows the line chart. Lets the user see the trend of energy consumption over several years in a specific country by energy type. (T2)



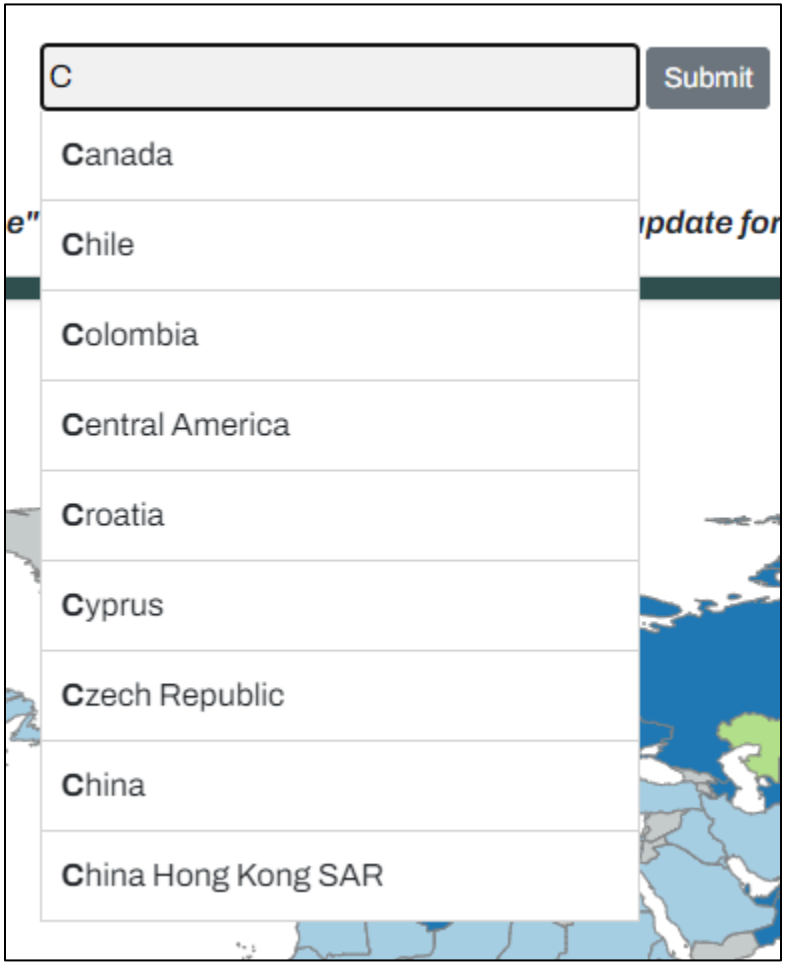
Screenshots 7-9: Hover tooltips on the force-directed circle graph. (T3)



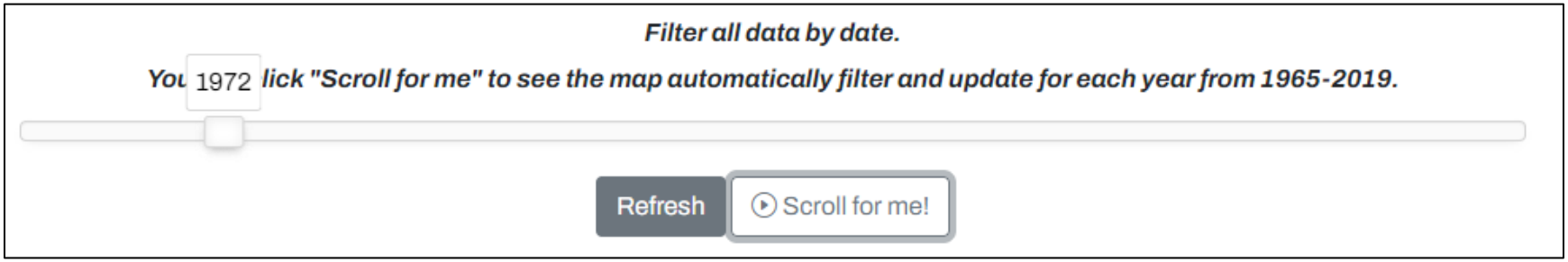
Screenshot 10: Hover tooltip on the bar-chart. (T5)



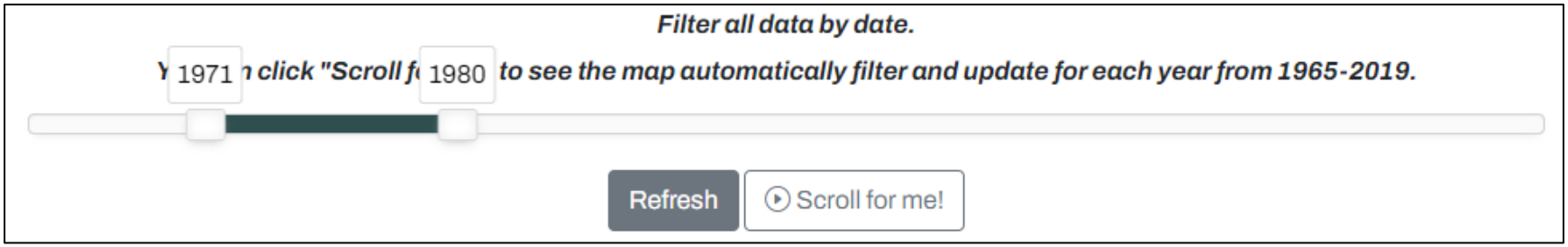
Screenshot 11: Using the search bar with autocomplete.



Screenshot 12: The time slider when in use. (T1)



When the `Scroll for me!` button is pressed, the time slider goes through the years one-by-one showing



Credits

Map Chart

- https://github.com/UBC-InfoVis/2021-436V-tutorials/tree/master/5_D3_tutorial#mapping-geo-data
- https://codesandbox.io/s/github/UBC-InfoVis/2021-436V-examples/tree/master/d3-symbol-map
- https://codesandbox.io/s/github/UBC-InfoVis/2021-436V-examples/tree/master/d3-choropleth-map

Used tutorials as a guide, but substantial changes were made to create our map projection.

Bar Chart

- Past Programming Assignments

P0 and P2 were used to help implement this visualization, but again, major changes to adapt to our visualization. Bootstrap documentation used to create the radio buttons and sorting buttons.

Animations/Transitions

- https://github.com/UBC-InfoVis/2021-436V-tutorials/tree/master/3_D3_Tutorial
- http://bl.ocks.org/nadinesk/99393098950665c471e035ac517c2224

Used as reference point for pie chart animation transition. Used as a guide to implement tooltips and animations

Time Slider

- https://refreshless.com/nouislider/

Used to help implement the time slider. Major chunks of code copied from their templates.

Force-Directed Circle Graph

- https://observablehq.com/@d3/force-directed-graph
- https://codesandbox.io/s/github/UBC-InfoVis/2021-436V-examples/tree/master/d3-force-directed-graph?file=/js/forceDirectedGraph.js
- https://github.com/UBC-InfoVis/2021-436V-tutorials/tree/master/6_D3_tutorial#11-force-directed-graph-layout
- https://github.com/Ethan-Tam/actor-adaptability/blob/master/js/classes/network.js#L265-L271
- https://www.d3-graph-gallery.com/graph/chord_basic.html

Used to help implement the force-directed circle graph. The circular part of the graph was heavily influenced and took design cue elements from the D3 chord chart. The force-directed part of the graph, which was contained within the circle took cues from Tutorial 6, and examples that were on Observable HQ.

Autocomplete Search Bar

- https://www.w3schools.com/howto/howto_js_autocomplete.asp

Copied most of the code from this source for the country search bar.

Reflection

Changes Since Proposal

M1 -> M2

Bar Chart

Some changes were made to the bar chart we proposed. Initially we proposed two bar charts juxtaposed against each other to plot emissions against consumption. However, after trying an initial implementation, the units were vastly different, and this could have been misleading if the positive y-axis was a different unit than the negative y-axis. As such, we decided to plot only emissions, since consumption information was encoded in the other charts as well. Moreover, we broke this down per capita, as otherwise populous countries such as the USA and China would dominate the graph and the visualization would be essentially encoding population data instead of a meaningful look at emissions per capita.

Color Scheme

We adjusted our color scheme we proposed in M, and used https://colorbrewer2.org to pick out categorical colours for 9 data classes (one for each energy type). Unfortunately, there was no color-blind safe option for 9 different hues, but we did take this into consideration before finalizing a color scheme.

Force-Directed Circle Graph

Since we wanted to group countries that had the same energy makeup, we realized that this view couldn't be static, so we moved to a force-directed graph which allowed us to dynamically group countries. This also allowed us to easily update this graph as global filters are applied.

M2 -> M3

Animations

We implemented smooth transitions for all the charts when data is filtered, which we did not specify in our initial proposal or M2. The bar chart was the only chart featuring transitions for M2. We added an automatic scroll feature to go through the data from 1965-2019 and update the map projection as well.

Force-Directed Circle Graph

Initially, we did not allow the users to click on a country's node if they have already selected a specific energy type. However, we found ourselves getting slightly frustrated having to deselect the energy type filter before being able to select a country. Even though it is minor, we made it more intuitive for the user by allowing them to filter by energy type or country at their will without having to deselect the filter first.

Search Functionality

We added a global country search for the visualizations as well, as we realized that it was very difficult to find smaller countries on the map or some users may want to drill down to a specific country right away.

Layout

We moved the secondary visualizations to the right of the map projection to better utilize the screen space. Before, all three visualizations could not fit on a normal 16:9 monitor, so we adjusted the layout as well as the size of some of the charts to fit the entire visualization on one screen. This prevents the user from having to scroll up and down to see how changes on one view changed the other two.

Visualization Goals

The visualization task abstraction and goals did not significantly change as we completed the project. However, we did adjust the visualization to take into account population as opposed to raw energy types. Without per capita information, the secondary visualizations encoded population data as much as energy type. Furthermore, we added features such as a playable scrolling feature to filter through data, and extra filters to the bar chart that we did not initially include as they helped us achieve our task abstraction goals.

Technical Goals

Our technical goals did change somewhat between the proposal and our final project. For the force-directed circle graph in particular, we had planned for the marks (point marks for countries) to be static, but soon realized this was not technically people given what we wanted to encode, which was to group similar countries in terms of energy usage together. We realized we needed to create a force-directed graph in order to encode this information, and run a simulation to compute node positions upon initialization. Furthermore, we encountered a technical limitation with the map projection in terms of distorting the size of certain countries, and the fact that smaller countries were almost impossible to see on the map, and only visible through the other charts or the search functionality. These were simply limitations we had to deal with, as invoking workaround (such as a 3D globe) would have brought other setbacks (no unjustified 3D), and zooming in/out was a limitation in terms of our knowledge of D3 and time we had to complete the project.

How Realistic Our Proposal Was

The original proposal was fairly realistic; the only thing that was really out of the cards was the static chord chart. This was not really possible given the nature of what we wanted to encode, so we adjusted as mentioned in the prior sections. We mistakenly proposed encoding a bar chart with two different axes, which was simply an oversight and not a reflection of an unrealistic visualization. Lastly, we had hoped to encode this information for the entire world from 1965 - 2019, but there simply was not data to encode such information for all countries - not to mention how certain countries moved in and out of existence during that time frame.

Things We Ran Out of Time For

At the final stages of the project, we would have liked to have some sort of interactive zooming or panning so that one could focus on a particular region or continent; areas such as Europe or Southeast Asia became almost impossible to parse due to the fact that there were far too many countries bunched up and even aggressive highlighting choices could not get them to pop-out. Furthermore, we would have added a feature wherein people could select to filter out certain energy types completely. The map is dominated by Oil/Gas primarily, so if people wanted a breakdown of all the other types, they would be able to deselect oil and gas and have the same visualization for the other 6 energy types.

What We Would Do Differently

If we were to do the project again, we certainly would have sought out more feedback earlier. The TA feedback for our proposal was very helpful, and it would have been extremely beneficial to seek out

their advice before we even finalized our proposal. Furthermore, we would have looked at alternative data sources, as we discovered other websites with similar data that was cleaner than the dataset we sought out.

Team Management

Status Update

Find a detailed breakdown of our tasks below. We added items related to the chord chart and introducing the force direction as well as the line thickness, and introduced line items related to linking the views and administrative tasks:

Epic	Task	Assignee	Done	Estimated / [Actual]	Date Due	Date Completed
Data	Preprocessing	Jeremy	Yes	3/6	Mar 12	Mar 18
Map	Implement Choropleth Map	Bernard	Yes	6/8	Mar 29	Mar 30
	Superimpose Pie Charts	Bernard	Yes	3/3	Mar 30	Mar 30
	Color/Legend and other annotations	Bernard	Yes	1/1	Mar 29	Mar 30
	Tooltip of line chart on hover	Bernard	Yes	5/5	Apr 8	Apr 9
Bar	Implement bar chart	Jeremy	Yes	3/2	Mar 26	Mar 28
	Sorting/Radio Buttons to filter data	Jeremy	Yes	2/4	Mar 28	Mar 28
	Tooltip on hover to display country	Jeremy	Yes	1/1	Mar 28	Mar 28
Chord	Base implementation	Gaurav	Yes	6/9	Mar 30	Mar 30
	Tooltip for exact energy breakdown	Gaurav	Yes	2/3	Apr 10	Apr 10
	Line thickness corresponding to weight of each energy type	Gaurav	Yes	3/1	Apr 12	Apr 13
	Force Directed Graph: Countries pulled towards their two most used energy types	Gaurav	Yes	3/10	Apr 12	Apr 6
Linkage	Global data filer by year (time slider)	Jeremy	Yes	2/3	Mar 30	Mar 30
	Link global data filter to all charts (have not integrated chord chart yet)	Jeremy	Yes	4/6	Apr 10	Apr 7
	Linked highlighting between all the charts for a particular country	Jeremy	Yes	3/5	Apr 12	Apr 11
	Global search bar	Bernard	Yes	1/1	Apr 11	Apr 11
Admin	Consistent styling/implement layout	Jeremy	Yes	6/7	Apr 13	Apr 11
	Writeup and documentation	All	Yes	10/5	Apr 13	Apr 12
	Code Cleanup	All	Yes	8/3	Apr 13	Apr 13

Total Hours: 83 hours for implementation; estimated was 72 hours.

Contributions Breakdown

Assigned and completed tasks can be found in the work breakdown. A more detailed explanation of what each team member contributed can be found below:

- **Bernard**
  - Implemented the map visualization, including the choropleth and pie chart symbols that currently exist. This was a major part of the visualization, and took substantial to become familiar with (as none of us had worked with d3 maps before) and to implement.
  - Implement the line chart tooltips for the map projection
  - Implement the country search bar
  - Also contributed to the data pre-processing and introducing country IDs and latitude and longitude into the dataset.
- **Gaurav**
  - Implemented the Force-Directed Circle Graph visualization, our innovative view. This again was a time-consuming task as none of us had worked with a chord chart or force-directed graph before and understanding the chart and fitting our data to the task was challenging.
  - Implement linked highlighting between the chord chart and the map view.
  - Handled all code cleanup and small bug fixes, as well as documenting all of the code.
  - Also took the lead on designing the layout and structure of the visualizations in M1.
- **Jeremy**
  - Implemented the bar chart and associated interactivity.
  - Implemented the global time slider and associated data filtering.
  - Implemented linked highlighting between the bar chart and other two visualizations
  - Handled bulk of the data pre-processing.
  - Also handled the layout and styling for the overall visualization; introduced bootstrap for consistent titles and elements throughout.