SUSTAINABLE ENERGY PROCESS BOOK

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EXECUTIVE SUMMARY

The goal of this process book is to walk the audience through the methods that were used to create this visualisation product. This process book focuses on each individual facet of the visualisation, from the data utilized and how it was processed through the first and ultimate designs of the visualisations themselves.

The introduction includes background information, motivations for developing the visualisations, and the project's goal and schedule. The second section goes over data, including the data sources used for the visualisations and how the data was processed. The third section looks at the visualisation criteria, while the fourth section looks at the visualisation designs, from the initial concept to the finished product.

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1 INTRODUCTION

1.1 Background & Motivation

The purpose of this visualisation report is to provide information about Australia's approach for a sustainable environment for researchers as well as the general population. The reason for our choice of sustainable energy resources is because use of sustainable energy resources has major economic and environmental impacts not only for Australia but also for the world. As the natural resources depleting day by day, we need to figure out how are we going to transition to a sustainable environment. The idea of the project is to encourage the community to focus on renewable energy and start a shift towards renewable energy sources such as solar energy.

To accomplish this mission our group will first visualize the amount of CO_2 emission in Australia by various types of fuels each year to put in perspective the deteriorating condition of our environment followed by the energy consumption statistics for each state and territory in Australia and lastly will display a graph to put through the amount of energy generation via different renewable resources and make the website accessible via internet. This infographic could be important for the audience to understand the size and scale of the problem in Australia, as well as its impact on the environment, so that they could take appropriate action to reduce carbon emission and act for a sustainable environment each day.

1.2 Visualisation Purpose

Primarily the objective of the visualisations is to present the following data to the audience:

- **CO_2 and Greenhouse Gas Emissions** in Australia from the last 20 year & comparison with the growth of using renewable energies. (**Visualisation 1**)
- The **primary Energy consumption in Australia** by state and territory (**Visualisation 2**)
- Growth of Australia's electricity generation through renewable resources. (**Visualisation 3**)

These visualisations could be helpful for scientists as well as people who are interested in environment related issues to answer the following questions:

- How significantly does the CO2 emission changes with the growth in usage of renewable energy sources?
- Which is the major energy consuming state per capita?
- Which type of renewable energy source has shown maximum growth over the past years?
- Does using renewable energy resources really have impact on environmental health?

1.3 Project Schedule

Our group has agreed on the following project timetable in order to complete the visualisation and process book on time:

- Week 1 – Week 6:	Brainstorming the ideas for the infographics, beginning to sketch the design ideas.
- Week 7:	Beginning the process of creating the process book and preparing the databases for the infographic.
- Week 8:	Finishing the dataset search and beginning the visualisation programming.
- Week 9 – Week 11:	Creating the project's necessary visualisations and conducting user validation (if needed, in Week 11).
- From Week 12 to the due date:	Finishing up the process book and the remaining interactivities for infographics.

Table 1. The Timeline for project Schedule

2 DATA

2.1 Data Source

To create the Visualisations our group used the following databases:

- Statistical Review of World Energy 2021, Our World in Data https://ourworldindata.org/fossil-fuels

This Database table mentions the data related to our first visualisation which is CO_2 emission of Australia over the past 20 years. (From 1990-2020).
The data is about the CO2 emission via different materials like oil, coal, gas etc. for different countries in different years.

It Consists of the following Attributes:

ATTRIBUTES	Definition	Type
Entity	The Country for which the data is provided	Nominal
Code	The Country Code for the country for which the data is provided	Nominal
Year	The year for which the data is provided	Interval
Annual CO2 emissions from oil	As the name Suggests Annual CO2 emissions from oil in Australia	Ratio (quantitative)
Annual CO2 emissions from flaring	As the name Suggests Annual CO2 emissions from flaring in Australia	Ratio (quantitative)

Annual CO2 emissions from cement	As the name Suggests Annual CO2 emissions from cement in Australia	Ratio (quantitative)
Annual CO2 emissions from coal	As the name Suggests Annual CO2 emissions from coal in Australia	Ratio (quantitative)
Annual CO2 emissions from gas	As the name Suggests Annual CO2 emissions from gas in Australia	Ratio (quantitative)
Annual CO2 emissions from other industry	As the name Suggests Annual CO2 emissions from other industries in Australia	Ratio (quantitative)

Table 2. The data sources details for visualisation 1

To create the desired visualisation, we need to filter the database to suit our needs, so we need only the data related to Australia. Secondly, we need to clean the data / missing values so that we can put through correct information through our graphs. To do so, we separate the data related to Australia from the database and then we select the years where the complete data set is present. All other parts of the dataset are not included since they are not related to the topic of the visualisation.

A snippet from the filtered dataset is shown below:

92	Australia	AUS	1990	89228503	7304216	3477929	142496722	34605661	2251812
93	Australia	AUS	1991	88986132	7059954	3209697	147306572	33060893	2248299
94	Australia	AUS	1992	88474744	7350201	2941980	151004450	34186240	2374538
95	Australia	AUS	1993	91154922	7197466	3030216	151373333	35972940	2595801
96	Australia	AUS	1994	93922984	7029908	3560062	154668786	37837479	3065042
97	Australia	AUS	1995	97077825	7130735	3390997	157260801	40225371	2936858
98	Australia	AUS	1996	100103592	6857557	3289860	162661635	40332172	3087406
99	Australia	AUS	1997	100484798	6830013	3252474	171244360	41949880	3348029
100	Australia	AUS	1998	100517670	6996458	3523503	180053786	44090202	3515459
101	Australia	AUS	1999	101308163	7230156	3551868	184874589	45961207	3672885
102	Australia	AUS	2000	102976216	8002672	3643479	186942000	46885004	3370227
103	Australia	AUS	2001	103536396	8248443	3573847	191834949	49769358	3491661
104	Australia	AUS	2002	106126629	8131120	3541495	194076948	51352988	3883718
105	Australia	AUS	2003	110743032	7235656	3622382	197461817	50233250	3936909
106	Australia	AUS	2004	114937801	6930287	3591269	204293219	53059073	3954623
107	Australia	AUS	2005	116943646	6942461	3677853	201451589	54680660	3905383
108	Australia	AUS	2006	118868460	7136747	3936702	206941822	56508990	3901990

Figure 1. Dataset for visualisation 1

- Australian Energy Update 2021, Department of Industry, Science and Resources

https://www.energy.gov.au/sites/default/files/Australian%20Energy%20Statistics%202021%20Energy%20Update%20Report.pdf

This is a report about the Australian Energy Update 2021 published by Department of Industry, Science and Resources Government of Australia in September 2021. This Data source contains data regarding the energy consumption of various states and territories in Australia and is shown via visualisation 2.The Data source contains 9 spreadsheets with similar attributes but the data of different states and territories:

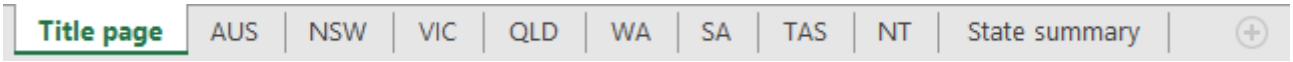


Figure 2. Dataset description for visualisation 2

The tables contain the data related to the annual energy consumption via different resources like oil gas coal etc. in different states and territories of Australia annually.

The attributes present are:

ATTRIBUTES	Definition	Type
Year	The year for which the data is provided	Interval
Coal	Annual Primary Energy Consumption by coal in energy units	Ratio (quantitative)
oil	Annual Primary Energy Consumption by oil in energy units	Ratio (quantitative)
gas	Annual Primary Energy Consumption by gas in energy units	Ratio (quantitative)

Renewables	Annual Primary Energy Consumption by renewables in energy units	Ratio (quantitative)
Statistical Discrepancy	Includes fuels that are unable to be classified, and discrepancies due to the rounding of totals. Some states and territories trade derived fuels (electricity), which is also captured in this discrepancy	Ratio (quantitative)
Total	Total Annual Primary Energy Consumption by All Sources for a State.	Ratio (quantitative)

Table 3. The data sources details for visualisation 2

This dataset was decently clean to begin with, in this data set the data for Energy Consumption from Coal, Oil, Gas, Renewables will be used because they are the most significant data for the visualisation. This visualisation planned with this dataset is a choropleth which will require the total value as well to define the color saturation of the graph according to the data. i.e., the state that consumes higher energy will have high saturation in the visualisation.

The figure below shows the snippet of the data from one of the tables:

Table C2

Primary energy consumption in New South Wales, by fuel, energy units a

	Coal	Oil	Gas	Renewables	Statistical Discrepancy b	Total
	PJ	PJ	PJ	PJ	PJ	PJ
2011-12	692.7	687.3	142.1	71.1	28.0	1,621.3
2012-13	643.0	677.4	157.4	70.9	19.8	1,568.4
2013-14	603.5	666.2	157.4	72.8	16.7	1,516.5
2014-15	587.8	621.1	151.7	71.0	35.1	1,466.8
2015-16	620.9	633.2	156.4	82.4	22.5	1,515.5
2016-17	625.9	652.2	133.7	84.5	26.4	1,522.7
2017-18	636.7	672.4	133.8	86.6	24.9	1,554.5
2018-19	640.3	665.0	131.4	90.4	20.7	1,547.8
2019-20	606.6	611.4	132.9	95.6	22.3	1,468.8

a Total net energy consumption is the total quantity (in energy units) of primary and derived fuels consumed less the quantity of derived fuels produced.

b Includes fuels that are unable to be classified, and discrepancies due to the rounding of totals.

Some states and territories trade derived fuels (electricity), which is also captured in this discrepancy.

Data for NSW includes ACT

Figure 3. Dataset for visualisation 2

For our third visualisation the following data source is used

- Australian Energy Statistics 2021, Department of Industry, Science Energy and Resources

https://www.energy.gov.au/sites/default/files/Australian%20Energy%20Statistics%202021%20Energy%20Update%20Report.pdf

This report provides information on Australia's electricity generation through various renewable Resources. The data in the tables is spread from 1994 to 2020 but according to the time frame of rest of the visualisations which we are showing through other graphs we are going to consider data from 1990 to 2020 only. The data is not organized properly so we had to clean and process the data before putting it through. The steps taken to clean the data set is discussed in the data processing part of the report.

The attributes in this database are:

ATTRIBUTES	Definition	Type
Year	The year for which the data is provided	Interval
Renewable Resource Type	The various types of Renewable resources used to generate electricity	Nominal
Electricity Produced	Production of electricity by various renewable energy sources in Gigawatt hours.	Ratio (quantitative)

Table 4. The data sources details for visualisation 3

The figure below shows a snippet from the data source for visualisation 3.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	**Figure 3.6: Australian electricity generation from renewable sources, by fuel type**													
2														
3	Gigawatt hours													
4		1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06	2006–07
5	Hydro	16,239.0	15,731.0	16,852.0	15,733.0	16,563.0	16,720.0	16,933.0	16,054.0	16,490.0	16,331.1	15,612.2	16,029.2	14,517.0
6	Wind	7.0	7.0	7.0	8.0	28.0	58.0	210.0	364.0	703.1	705.0	885.0	1,713.1	2,611.1
7	Bioenergy	723.0	928.0	965.0	1,029.0	1,133.0	1,134.0	645.0	950.0	1,583.6	1,799.5	3,830.0	3,911.0	3,953.0
8	Solar	18.9	23.4	27.8	33.5	37.7	43.5	50.0	58.3	58.3	68.6	78.3	90.8	105.2
9														

Figure 4. Dataset for visualisation 3

2.2 Data Processing

Data cleaning is an important step to present the correct information in front of the audience.
For the same reason our team did various steps to get the data ready as per the requirements.

2.1 For the CO_2 emission visualisation

The source data set for this visualisation contained a vast amount of Details including data for every country so firstly we separate the data related to Australia from the database and then we select the years where the complete data set is present which is from year 1990 – 2020 to only include clean data. For the ease of coding, we had to change the names of attributes from the data sources. The changes can be seen in the table 5 below:

ATTRIBUTES	CHANGED NAME
Entity	Entity
Code	Code
Year	Code
Annual CO2 emissions from oil	Oil_CO2_emissions
Annual CO2 emissions from flaring	Flaring_CO2_emissions
Annual CO2 emissions from cement	Cement_CO2_emissions
Annual CO2 emissions from coal	Coal_CO2_emissions
Annual CO2 emissions from gas	Gas_CO2_emissions
Annual CO2 emissions from other industry	Other_CO2_emissions

Table 5. final data sources details for visualisation 1

A snippet from the final data source used for the visualisation can be seen in figure 5 below:

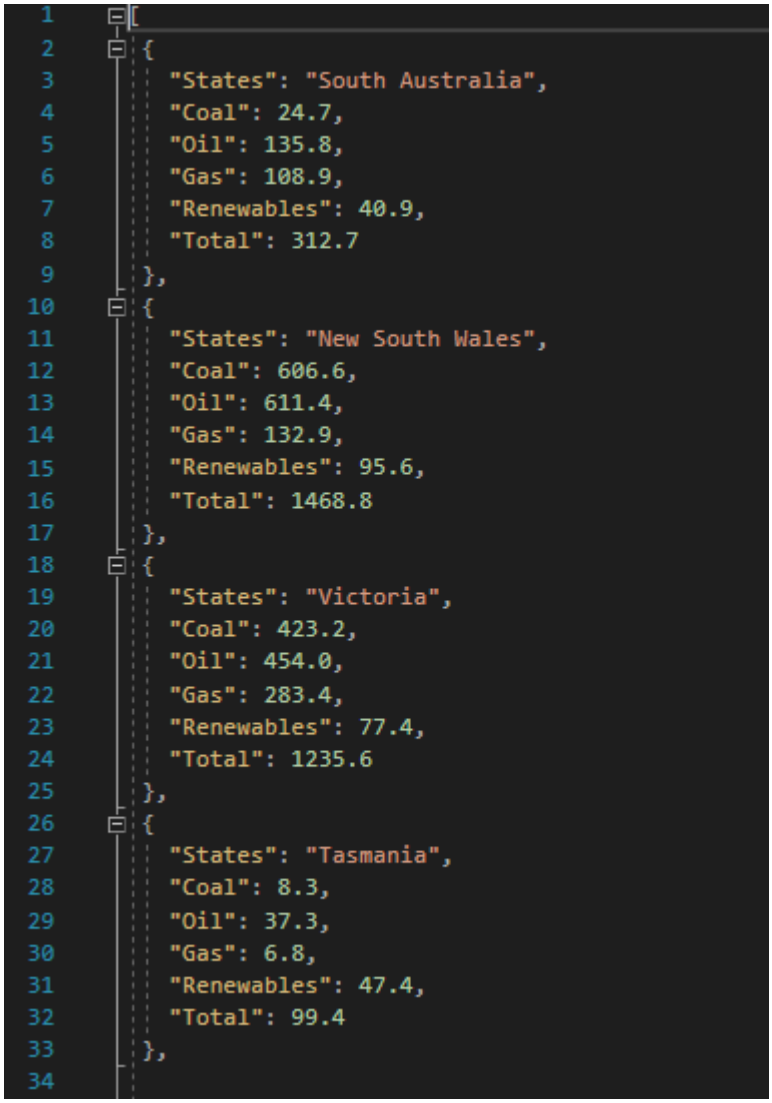
	Entity	Code	Year	oil_co2_emissions	flaring_co2_emissions	cement_co2_emissions	coal_co2_emissions	gas_co2_emissions	other_co2_emis
2	Australia	AUS	1990	89228503	7304216	3477929	142496722	34605661	2251812
3	Australia	AUS	1991	88986132	7059954	3209697	147306572	33060893	2248299
4	Australia	AUS	1992	88474744	7350201	2941980	151004450	34186240	2374538
5	Australia	AUS	1993	91154922	7197466	3030216	151373333	35972940	2595801
6	Australia	AUS	1994	93922984	7029908	3560062	154668786	37837479	3065042
7	Australia	AUS	1995	97077825	7130735	3390997	157260801	40225371	2936858
8	Australia	AUS	1996	100103592	6857557	3289860	162661635	40332172	3087406
9	Australia	AUS	1997	100484798	6830013	3252474	171244360	41949880	3348029
10	Australia	AUS	1998	100517670	6996458	3523503	180053786	44090202	3515459
11	Australia	AUS	1999	101308163	7230156	3551868	184874589	45961207	3672885
12	Australia	AUS	2000	102976216	8002672	3643479	186942000	46885004	3370227
13	Australia	AUS	2001	103536396	8248443	3573847	191834949	49769358	3491661

Figure 5. Dataset for visualisation 2

2.2 For the energy consumption visualisation

It was vital for this research to only contain continuous data in order to present accurate information to the public. For this reason, we only included data from 1990 to 2020 because we have a complete dataset between these years. We need to separate these data from the original file and create a new CSV file for them.The final step is to convert this data to a JSON file and change the state names to match those in the Australia GeoJSON file.

A snippet from the JSON file can be seen in figure 6 below:




```
[
  {
    "States": "South Australia",
    "Coal": 24.7,
    "Oil": 135.8,
    "Gas": 108.9,
    "Renewables": 40.9,
    "Total": 312.7
  },
  {
    "States": "New South Wales",
    "Coal": 606.6,
    "Oil": 611.4,
    "Gas": 132.9,
    "Renewables": 95.6,
    "Total": 1468.8
  },
  {
    "States": "Victoria",
    "Coal": 423.2,
    "Oil": 454.0,
    "Gas": 283.4,
    "Renewables": 77.4,
    "Total": 1235.6
  },
  {
    "States": "Tasmania",
    "Coal": 8.3,
    "Oil": 37.3,
    "Gas": 6.8,
    "Renewables": 47.4,
    "Total": 99.4
  },
```


Figure 6. The final JSON file used for visualisation 2

2.3 For the electricity generation Visualisation

The source data for this visualisation was very unorganized to start with.
So, we had to change the orientation of the data source. Initially the data was organized in a horizontal fashion, we had to reorganize it into vertical columns so we can a call the csv file through our code and display the data through our visualisation.

The source data looked something like the figure7 shown below:

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Figure 3.6: Australian electricity generation from renewable sources, by fuel type**												
2													
3	Gigawatt hours												
4		1994–95	1995–96	1996–97	1997–98	1998–99	1999–00	2000–01	2001–02	2002–03	2003–04	2004–05	2005–06
5	Hydro	16,239.0	15,731.0	16,852.0	15,733.0	16,563.0	16,720.0	16,933.0	16,054.0	16,490.0	16,331.1	15,612.2	16,029.2
6	Wind	7.0	7.0	7.0	8.0	28.0	58.0	210.0	364.0	703.1	705.0	885.0	1,713.1
7	Bioenergy	723.0	928.0	965.0	1,029.0	1,133.0	1,134.0	645.0	950.0	1,583.6	1,799.5	3,830.0	3,911.0
8	Solar	18.9	23.4	27.8	33.5	37.7	43.5	50.0	58.3	58.3	68.6	78.3	90.8
9													

Figure 7. The final JSON file used for visualisation 3

We had to add one more attribute column “Period” to add the data according to time period. The data set was continuous in terms of data values hence after the clean process the final data set looked like the figure 8 shown below.

	A	B	C	D	E	F	G	H
1	Period	Hydro	Wind	Bioenergy	Solar			
2	1995	16,239.00	7	723	18.9			
3	1996	15,731.00	7	928	23.4			
4	1997	16,852.00	7	965	27.8			
5	1998	15,733.00	8	1,029.00	33.5			
6	1999	16,563.00	28	1,133.00	37.7			
7	2000	16,720.00	58	1,134.00	43.5			
8	2001	16,933.00	210	645	50			
9	2002	16,054.00	364	950	58.3			
10	2003	16,490.00	703.1	1,583.60	58.3			
11	2004	16,331.10	705	1,799.50	68.6			
12	2005	15,612.20	885	3,830.00	78.3			
13	2006	16,029.20	1,713.10	3,911.00	90.8			
14	2007	14,517.00	2,611.10	3,953.00	105.2			
15	2008	12,056.90	3,093.10	4,596.00	123.3			
16	2009	11,869.40	3,823.80	2,795.20	156.1			
17	2010	13,548.70	5,051.70	2,777.40	425.4			
18	2011	16,806.70	6,084.90	2,101.70	1,530.90			
19	2012	14,083.30	6,969.70	3,043.70	2,559.20			
20	2013	18,269.60	7,959.60	3,143.50	3,826.80			
21	2014	18,421.00	10,252.00	3,499.40	4,416.50			
22	2015	13,445.00	11,466.60	3,592.20	5,531.90			
23	2016	15,318.20	12,199.50	3,789.90	6,838.50			
24	2017	16,284.90	12,597.00	3,500.50	8,072.20			
25	2018	16,020.80	15,174.40	3,517.70	9,929.90			
26	2019	15,967.30	17,712.00	3,495.90	14,848.50			

Figure 8. The final JSON file used for visualisation 3

3. REQUIREMENTS

3.1 Must Have Features

For this visualisation project , there are several features that could be considered necessary and without them, the project could not be called a success:

1. For each of the graphs, proper color schemes should be chosen so that it is easier for the audience to understand the graph.

2. For every graph proper labelling and legends should be made so that the audience can understand the meaning which the graph is trying to convey. Use of tool tips can also be considered.

3. For visualisation 2 the choropleth graph that describes the amount of annual energy consumed by each state and territory in Australia should have proper color legend to help readers figure out about what color (or symbol) representing a which state and also the graph should have a pop-up effect showing the details of energy consumption of a particular state when the user hovers over at a particular place in the chart.

4. For visualisation 3 the stacked area chart that describes the electricity production of Australia by different renewable energy sources the graph should pop up the data of a particular resources and display that amount of energy produced when a user hovers over a particular part.

All the Requirements have been met with in the due date time:
The color schemes are chosen according to the Tufte’s design principle standards to cater a large portion of the audience. Proper legends and labels are used to make the user understand the meaning of various parts of the visualisation.

3.2 Optional Features

Features cited below could be considered optional:

3.2.1 For Visualisation 1, the line chart showing the CO_2 emission by various energy sources in Australia annually, the following features could be incorporated:

- When hovered over a particular part on the line the amount of CO_2 emission could pop up and blur every other part of the graph to make the user focus on a particular part of the graph.
- The user could find the amount of CO_2 emission by different resources by selecting different buttons.

3.2.2 For Visualisation 2, the choropleth showing the primary Energy consumption in Australia by state and territory, the following features could be incorporated:

- The name of each state could be displayed via tooltip or directly.
- The percentage or the amount of energy consumed for resource type could be mentioned when hovering on each state/territory, being split into the various types of energy (alongside the total amount).

3.2.3 For Visualisation 3, Australia's electricity generation through renewable resources the following features could be incorporated:

- The user could find out electricity generation data by different Resource by selecting different buttons.
- The graph could blur the background and only highlight a particular resources data when a specific button is clicked for a particular resource type

4 VISUALISATION DESIGNS

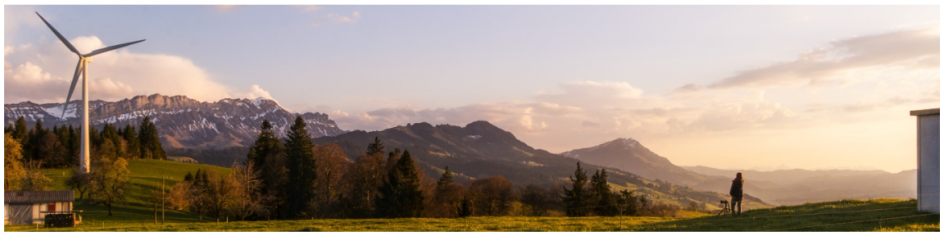
4.1 Website Template Design

According to the initial design our team plan to develop a website which looks something like the figure shown 9 below. we planned to go for minimalistic design for our website so that the user majorly focuses upon the visualisations which we are trying to showcase.

Figure 9. Initial Website Template Design

After the complete development of our project the final design of the website looks like the image 10 shown below:

Sustainable Energy Home

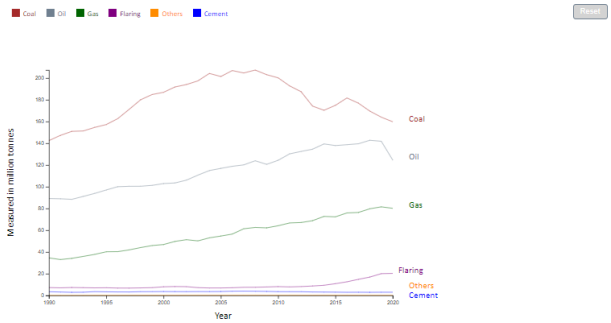


IT IS TIME FOR AUSTRALIA TO INVEST MORE IN RENEWABLE ENERGY

As time passes, the globe must transition towards adopting renewable energy resources in order to maintain a sustainable ecosystem. In present circumstances, the over use of fossil fuels has harmed the ecosystem and has accelerated the rate of climate change. The main goal of these visualisations is to demonstrate that renewable energy resources emit less carbon dioxide (CO_2), therefore if we transition to utilising renewable energy as the primary source of energy, we can have a healthy and sustainable environment.

We will demonstrate the detrimental effects of burning fossil fuels by displaying CO2 emissions from various fuel resources in Australia during the last 20 years in the first visualisation on this page (1990 - 2020). The following visualisation depicts the energy mix of Australia's energy consumption by various states and territory during the last 20 years (1990-2020). This offers us an idea of which fuel resource is most commonly used to carry out state services in Australia. Finally, the third visualisation will show the increasing trend in the use of renewable energy sources in Australia, such as hydro, solar, and wind energy, during the last 20 years (1990- 2020).

CO_2 emission by fuel, Australia



Visualisation Description

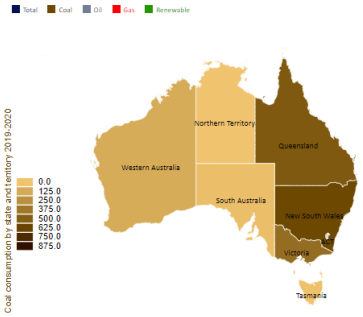
This visualisation is a line chart that depicts the carbon dioxide (CO2) emissions from various types of fuels in Australia. The x axis depicts the period in years from 1990 to 2020. The amount of carbon dioxide (CO2) emitted into the atmosphere in billion tonnes is represented on the y-axis. Each sort of fuel resource is encoded with a particular colour, and the higher the line, the more CO2 emitted into the environment by that form of fuel.
The bold colours employed in this design are an efficient visual encoding for qualitative data (the type of resource).

For Example we have :

- brick red for coal.
- grey for oil.
- green for gas.
- blue for cement.
- purple for flaring.
- yellow for others.

It is also much easier to compare the amount of CO2 emitted by different fuel supplies by examining their own lines for each source.

Australian energy mix, by state and territory 2019- 2020



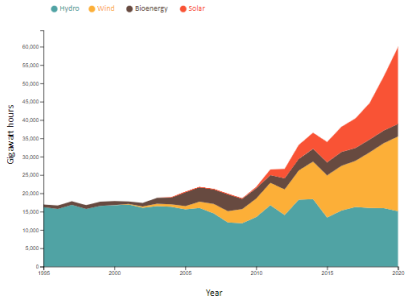
Visualisation Description

This is a choropleth graphic that illustrates an Australian map including all states and territories (borders for each state are marked as white, for a better separation between states). The quantity of energy spent by each state is represented by a sequential colour scale with varied colour saturation for different data kinds.

- Different shades of blue for total for the energy consumption.
- Different shades of brown for data of energy consumption through coal
- Different shades of grey for data of energy consumption through oil
- Different shades of red for data of energy consumption through gas
- Different shades of green for data of energy consumption through renewable resources

This design is useful in many aspects, such as the colour saturation being able to efficiently transmit quantitative data. Displaying the quantity of energy consumed for each resource type will assist in comparing how much energy mix is consumed by a state for optimal operation.

Australian electricity generation renewable sources



Visualisation Description

This visualisation is a Stacked area chart where the x-axis is encoded with the timeline in years from 1990- 2020. And the y-axis is displaying the amount of electricity generated in gigawatt hours. Each energy type is encoded with a separate colour to make it easily distinguishable between different energy types.

For reference:

- Hydro energy is encoded with aqua color.
- Wind energy is encoded with yellow color.
- Bioenergy is encoded with brown color.
- Solar energy is encoded with deep orange color.

This design pattern is very useful for showing the relationships between many categories. It is also often the best type of area chart to show the contribution that each category makes to the overall data.

COS30045 Data Visualisation Khiem Truong, Ayush Upadhyay

Figure 10. Final Website Design

5 TYPES OF CHARTS USED ON THE WEBSITE

5.1 Line Chart (Visualisation 1)

For the first visualisation, our team decided to put through the idea of showing the harmful effects of using the fossil fuel energy by showing CO_2 emission by fuel in Australia.

5.1.1 Initial Designs:

In the beginning we thought to present the data via a line graph that included the amount of energy used from fossil fuels and renewable resources respectively and then the amount of CO_2 emission produced by the burning the fossil fuels each year in Australia.

The initial sketch of the visualisation which we planned to present is given below:

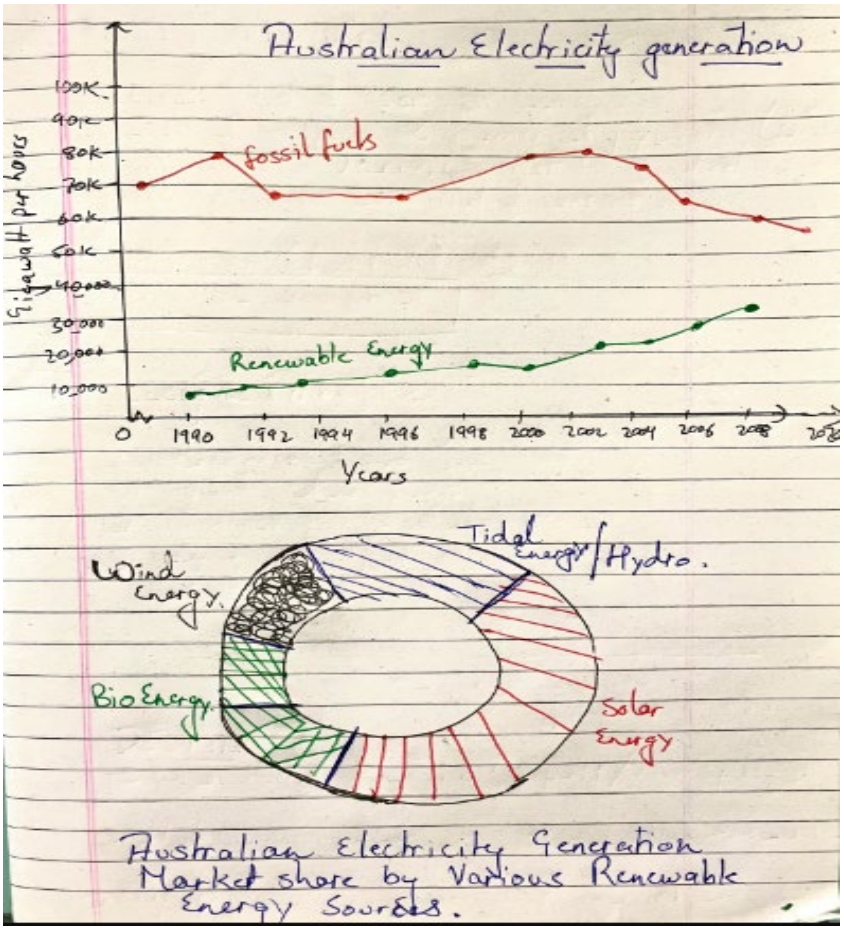


Figure 11. Initial Visualisation Design for graph 1

here the x-axis is encoded with year and the y-axis signifies the amount of energy in gigawatt hour. A pop-up donut chart was also planned to show the market share of various resources design but was later changed as it didn't give much information about the CO2 emission.

While this design has some advantages (as people could figure out how much was the market share by seeing the variable sectors of the donut chart). But there were some limitations.

- There were not proper data for market share of renewable resources for each consecutive year. And displaying the data of every year through a donut chart could be a cumbersome task.
- The donut chart could only give an idea of relative values but not the overall energy consumptions hence can be misleading sometimes.

In the later part of the project, we created one more iteration for the design which shows the amount of CO2 emission by fuel where x-axis represent the year and y-axis represent the amount of CO2 in million tonnes.

The benefit of this design is that it helps to show the information which was planned in the correct order.

- The users can investigate about the overall trend from the line and use the positions of the axes to find out the data of a particular part of the graph.

- The user can hover over the chart and find the CO2 emission by fuel of a particular year.

5.1.2 Final Designs:

The final design of this visualisation is a line chart displaying the Carbon dioxide (CO_2) emission by different kind of fuels in Australia. The x axis represents the timeline in years starting from 1990- 2020. The y- axis is encoded with the amount of carbon dioxide (CO_2) released in the atmosphere in million tonnes. Each type of fuel resource is encoded with a different color and the higher the line, the higher the amount of CO2 emitted by that type of fuel in the atmosphere.
As far as the colors used in this visualisation, we have a vibrant color pallet to make is easy to distinguish between the data for different types of resources. For reference we used colors with Hex encoding as:

- #F42F05 (brick red) for coal,
- #C0BEBD (grey) for oil ,
- #0CB607 (dark green) for gas,
- #2310F1 (blue) for cement,
- #F10795 (purple) for flaring ,
- #FFAF00 (yellow) for others.

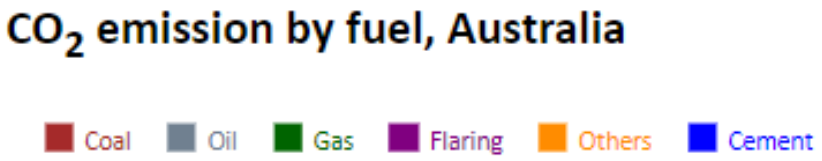


Figure 12. Color pallet for visualisation 1

This option would ensure that those who are not colorblind see the same colour as persons who have Deuteranopia (the most frequent kind of colorblindness (Department of Health Australia, n.d.).) (Cravit, 2020), allowing both categories of individuals to have a comparable experience.

The legend for this chart will work as buttons so that user can click on them to view that data of a specific fuel type. Something like this figure 10 shown below:

Figure 13. interactivity for visualisation 1

One of the benefits of this visualisation is that when the viewer hovers their mouse over a certain year on the x-axis or on the graph , a pop-up window will appear, displaying CO_2 emission data for that year by different fuel types, as illustrated in figure 11 below:

Figure 14. interactivity for visualisation 1

This design is beneficial in many ways:

- Color is an efficient visual encoding for qualitative data (the sort of resource).
- Since all individuals will learn about the quantity of carbon dioxide emitted into the environment each year by the fuel resources that they use, the audience, i.e., the general public, will realize the consequences of their activities.
- It is also much easier to compare the amount of CO_2 emitted by different fuel supplies by examining their own lines for each source.
- Using a transition between the charts would allow for a seamless flow.

The results for this visualisation could be seen in Figure 15 & 16 below.

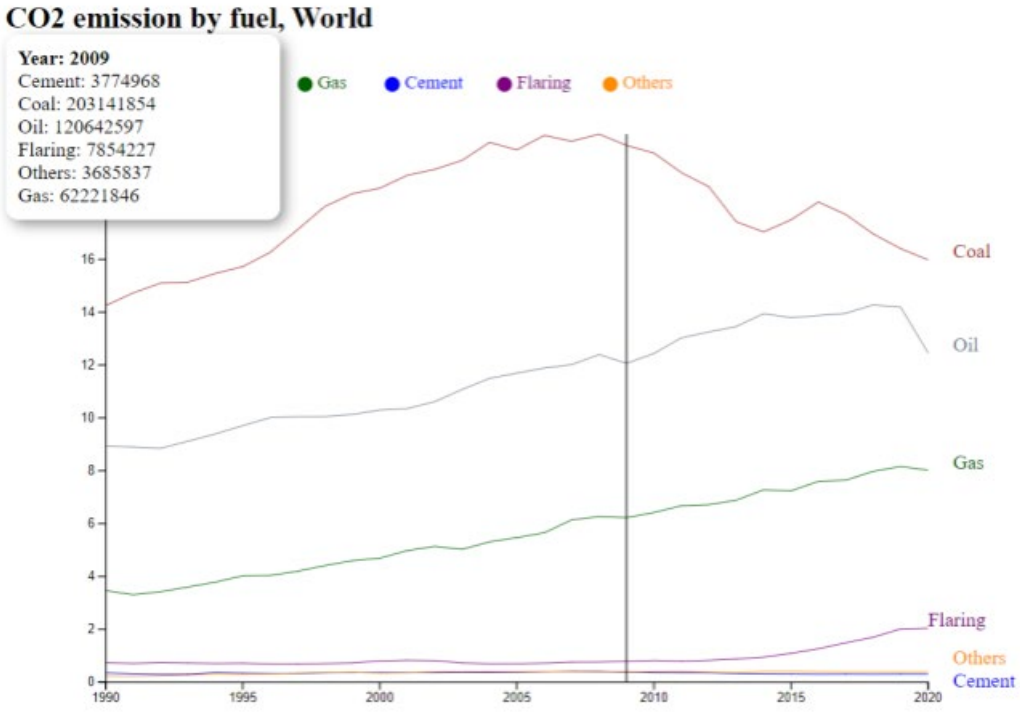


Figure 15. final result for visualisation 1

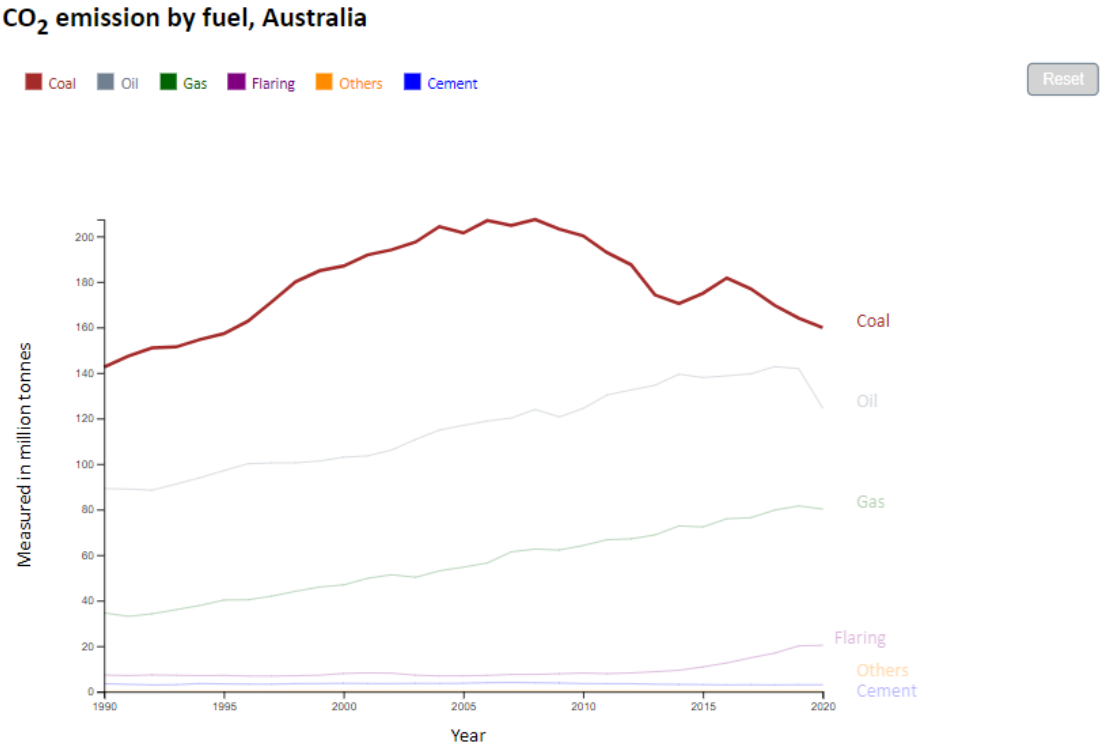


Figure 16. final result for visualisation 1

5.2 Choropleth/Heat Map (Visualisation 2)

Through this visualisation our team decided to show the energy consumption of different states and territories in Australia (from 2019-2020)

5.2.1 Initial Designs:

In the initial phase of the visualisation design, we planned to go with a stacked bar chart showing the percentage share of energy consumption through various kind of resources.
In the visualisation the x-axis would show the percentage share of energy mix while the y-axis would show the different states of Australia and the data with different hues will show the different types of energy source used.
The initial visualisation design can be seen in the figure below:

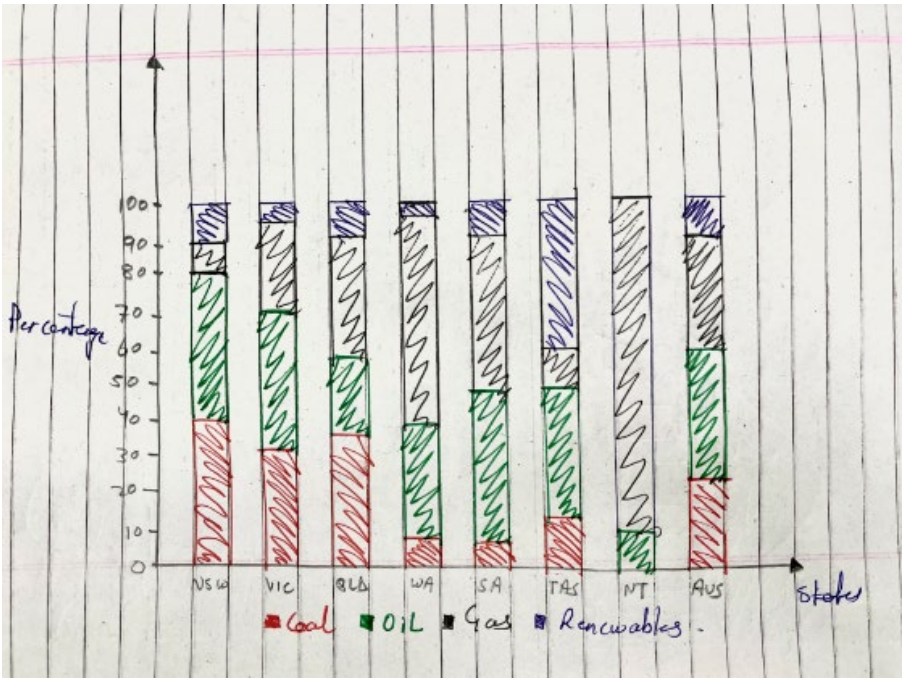


Figure 17. Initial Visualisation Design for graph 2

When the visualisation design was presented, there were several things that the team discovered from the point of view of the audience. They were:

- The graph only showed the percentage share of energy consumption without taking into consideration the difference in the population of different states in Australia. While this visualisation can give basic idea and can be helpful for scientific findings, but it is less useful for general masses of the audience.

- Another issue with this visualisation was that the arrangement of bars in the chart (from lowest to highest) does not follow the rules of thumb for the stacked bar chart (arranging values from largest to smallest) (Yi, 2019).

After the team discussion another iteration for the design was put through which was a choropleth. In the Choropleth the visualisation has different color saturation according to the data for the total energy consumption by a state.

This visualisation will possess features like:

- pop up effect when the user hovers over a specific state. The pop up shows the data for the different market share for energy consumption via different resources as well as the total energy consumed by the state.

- The user can press the buttons present with the legend to show up data for a specific state.

A prototype planned for visualisation 2 is shown below in figure 18:

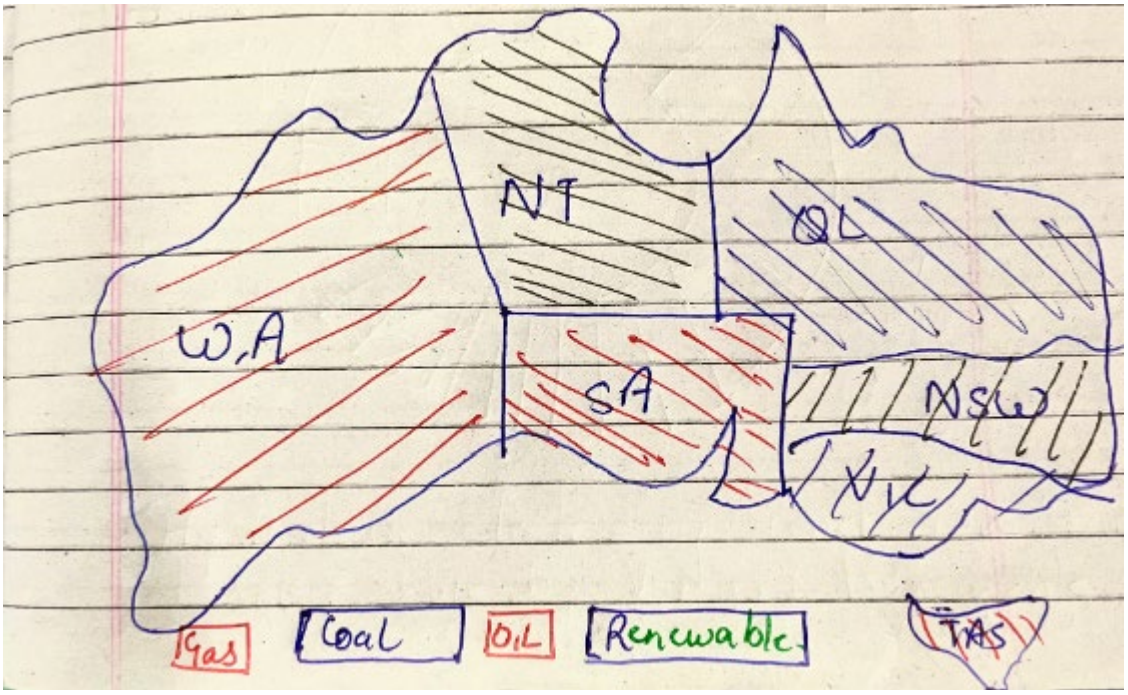


Figure 18. Initial Visualisation Design for graph 2

5.2.2 Final Designs:

The final design for this visualisation is a choropleth chart which depicts an Australian map with all states and territories (borders for each state are marked as white, for a better separation between states). The amount of energy consumed by each state is marked by a sequential colour scale with different saturation of colour for different data types.

- .range(["#BBE1FC", "#57B4F8"]); for total for the energy consumption.
- .range(["#FFE8BA", "#F1BF5C"]); for data of energy consumption through coal
- .range(["#DCD8D0", "#B0ADA7"]); for data of energy consumption through oil
- .range(["#FECECE", "#F70707"]); for data of energy consumption through gas
- .range(["#EDFFE7", "#60F730"]); for data of energy consumption through renewable resources.

Figure 19. Colour pallet used for visualisation 2

(The color scale is taken from Color Brewer: https://colorbrewer2.org/#type=sequential&scheme=YlOrRd&n=6 using linear scale for state's energy , like in Figure 20). The higher the amount of energy Consumption, the darker the colour for each state.)

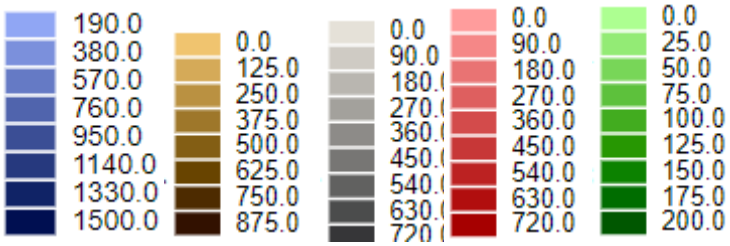


Figure 20. Colour pallet used for visualisation 2

The final design is similar to the prototype designed after few iterations for the visualisation design. The user could hover over each state or territory to view the amount of total energy consumption and bifurcation of energy sources displayed by the tooltip.

The various energy resources for which the data pop-ups via tool tip are:

Coal
oil
gas
Renewables
Total

Table 6. energy source details for visualisation 2

Also, user can click on the legend of particular resource types to see the data values of that resources over the map of Australia.

This approach has numerous benefits for both the audience and the developers:

- The colour saturation could be efficiently used to encode quantitative data (total amount of energy consumption), despite being less effective than the area of the stacked bar chart (Munzner, 2015).

- Showing the amount of energy consumption for each resource type (Coal, Oil, Gas, Renewables) could help the users to compare how much energy mix is being consumed by a state for their proper functioning.

The final design pictures along with interactivities can be seen in figures below:

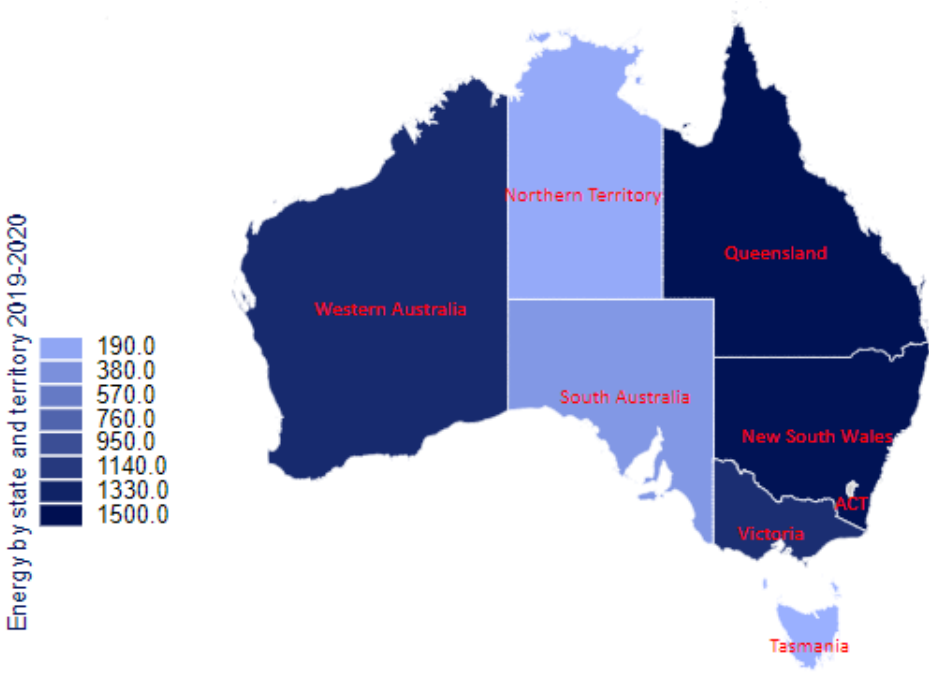


Figure 21. Final design for visualisation 2

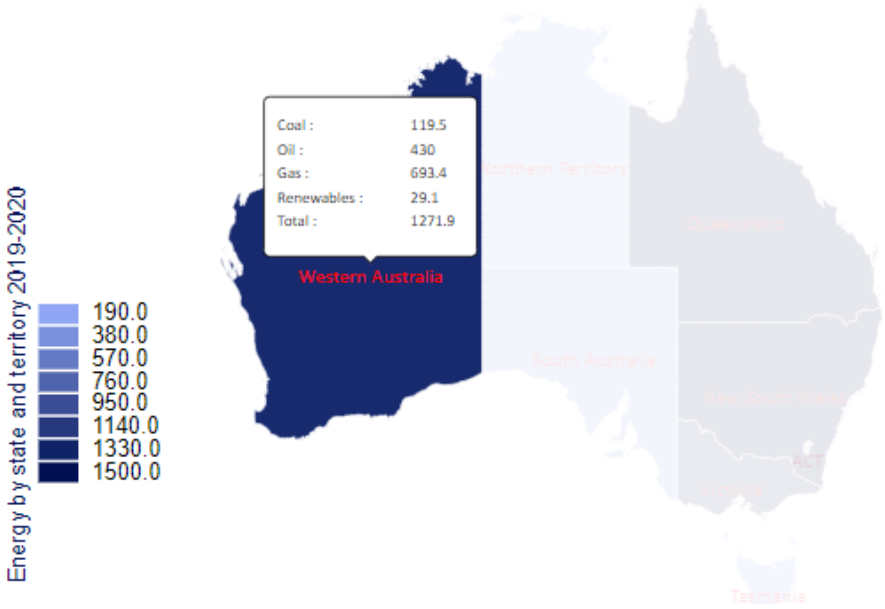


Figure 22. Interactivities for visualisation 2

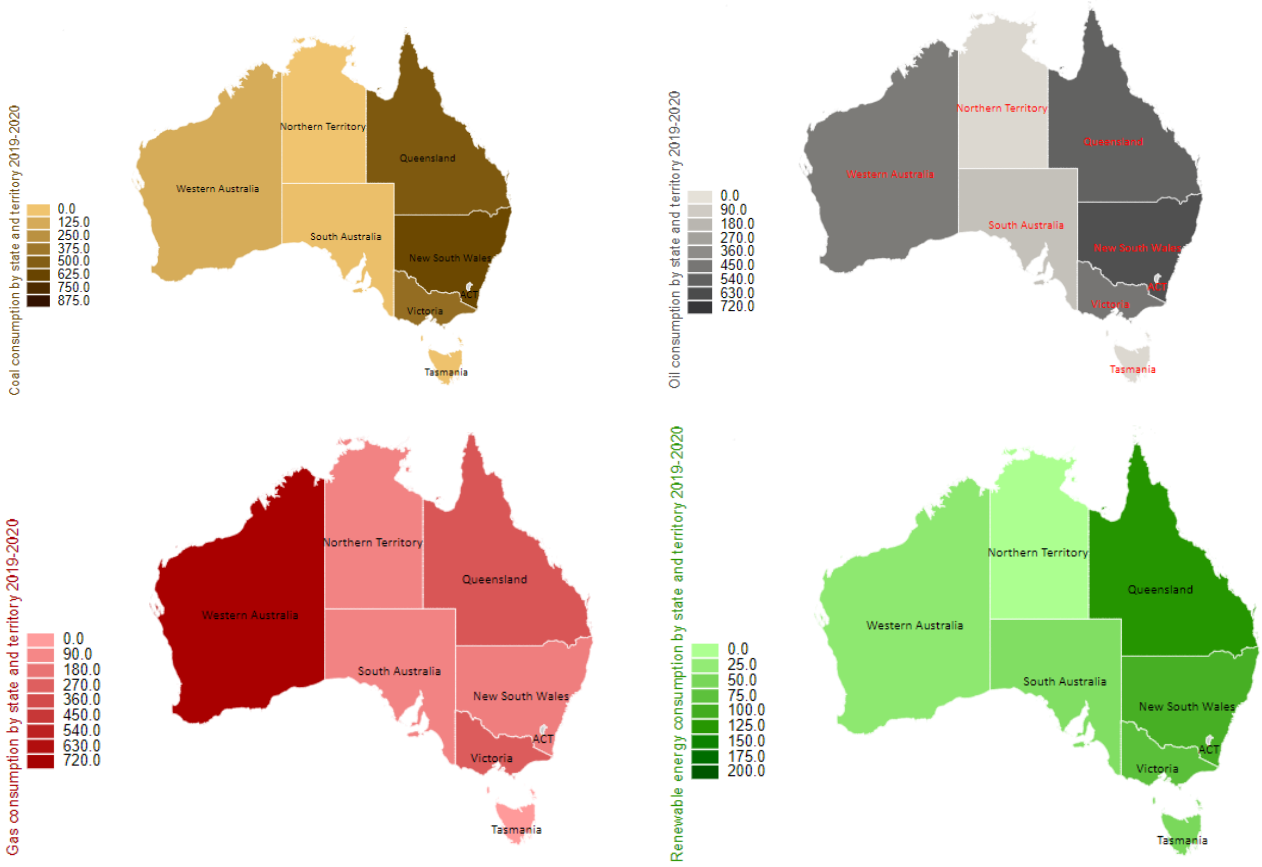


Figure 23. Final design for visualisation 2

5.3 Stacked Area Chart (Visualisation 3)

For the third visualisation our team planned to put through the data about the Australia's electricity generation through Renewable Resources.

5.3.1 Initial Designs:

Our team already had a design in our mind to go for, hence there was no such need of multiple iteration to go for the final design we were very much clear in thoughts with how we need to display the data for Australia's electricity generation through Renewable Resources.
We planned to go with a Stacked area chart where the x-axis is encoded with the timeline in years from 1990- 2020. And the y-axis is displaying the amount of electricity generated in gigawatt hours .Each energy type is encoded with a separate colour to make it easily distinguishable between different energy types.

The low fidelity prototype for our visualisation can be seen in figure 24 below:

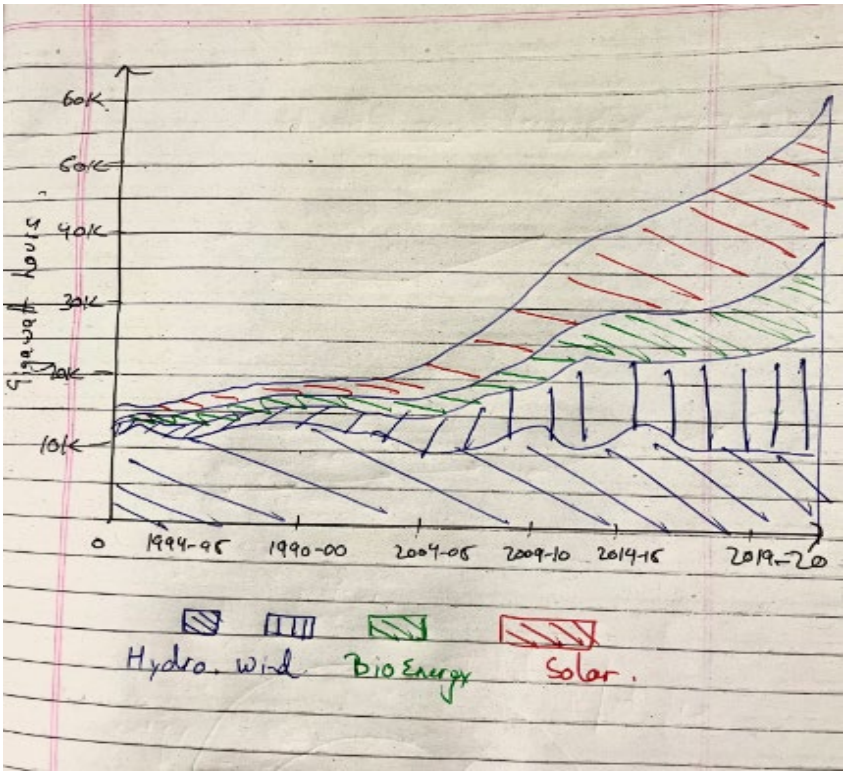


Figure 24. Initial design for visualisation 3

5.3.2 Final Designs:

This visualisation's final design is a stacked area chart depicting Australia's electricity generation through renewable resources from 1995 to 2020. The chronology in years from 1990 to 2020 is represented on the x-axis. The amount of electricity generated in gigawatt hours is shown on the y-axis. To make it easy to distinguish between different energy kinds, each one is encoded with a different colour.

The following interactivities have been added to the stacked area chart:

- Hovering over the legends activates a pop-up effect, which pops out the data of the resource where the user is hovering, blurring the background.

- when the viewer hovers their mouse over a certain year on the x-axis or on the graph , a pop-up window will appear, displaying electricity generation data for that year by that resource, as illustrated in figure 25 below:

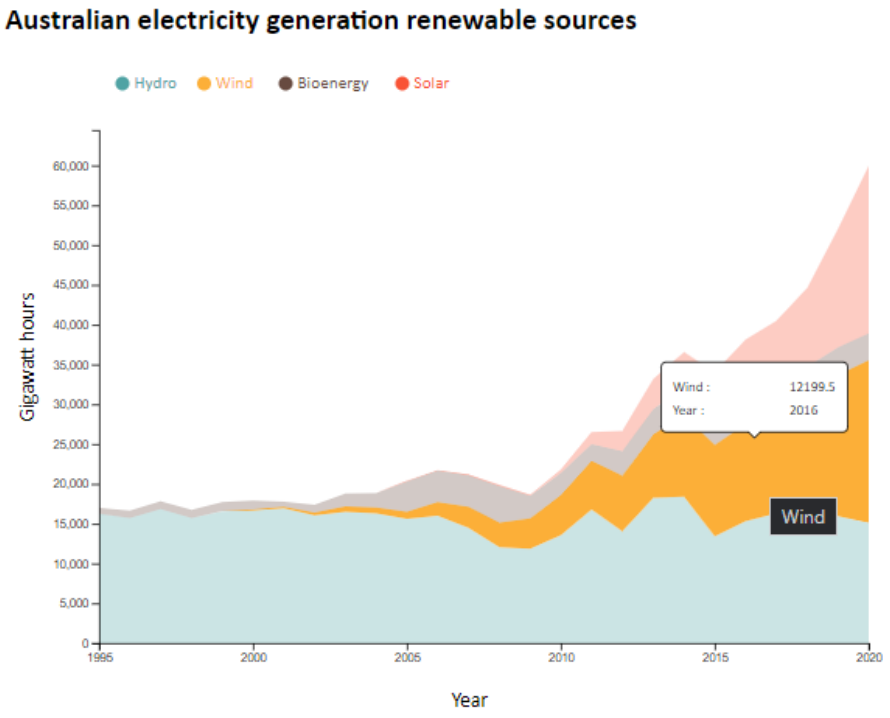


Figure 25. Interactivities for visualisation 3

- tooltips are also added to display any data where the user rests there mouse.

Final design pictures are displayed in the figure 26 -27 below:

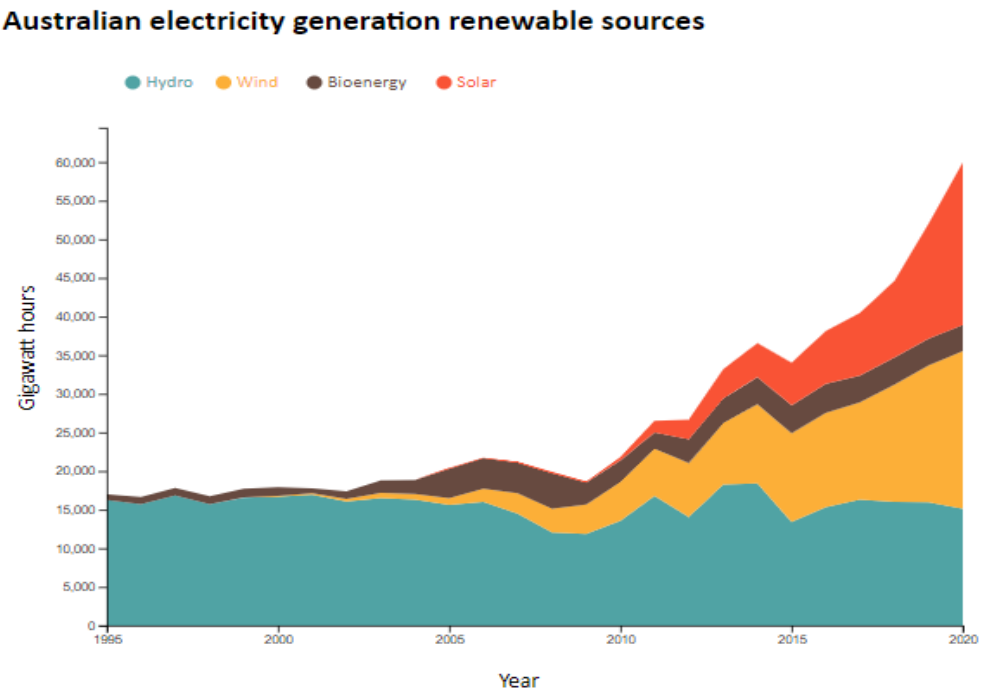


Figure 26. Final design for visualisation 3

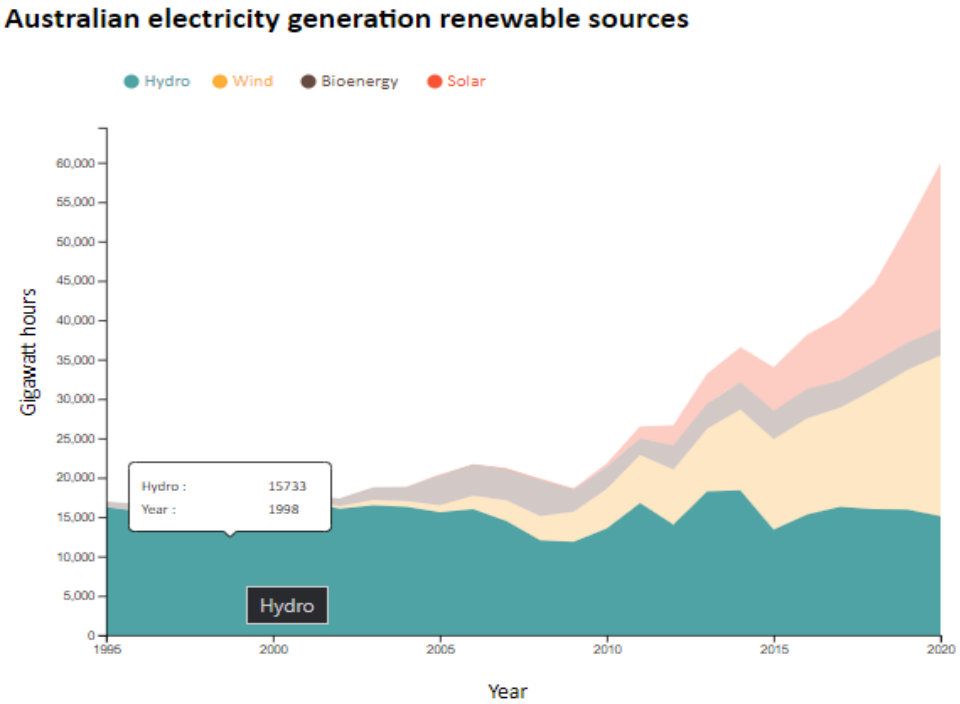


Figure 27. Final design for visualisation 2 with interactivity

6 VALIDATIONS

ROHAN SONI (PEER)

The outlook of the website seems appealing and at the first glance the visualisations look eye catching. Reading through the content the flow of the visualisations has been placed appropriately defining the problem in the first visualisation the reason in the second visualisation and the apt solution in the third visualisation.

Talking more about the visualisations the first visualisation neatly defines the CO2 emission over different years and the line chart seems very appropriate for the data that you are trying to show The natural instinct of a person is to click over the legend and text that’s usually displayed and you have made clicking the legend as an interactivity to show the data of a specify fuel resource type that’s very interesting to go for and the visual blur effect that makes the data of a specific fuel pop up really makes the user focus on that particular part also the interactivity where the user can hover over a particular year to find the CO2 emission data for all resources in that year makes it really easy to get data for general audience as well as for researcher.

ADNAN ZAFAR (PEER)

In the second visualisation, the data is shown on a map of Australia, which looks fantastic. It's quite useful to be able to interact with the legend and see different types of energy by state and territory. The labels are simpler to see because their colours are distinct from the map's. The hover option, which allows you to see the state's precise information, is one of my favourites.

MOHHAMED ABUBAKAR (PEER)

I prefer the colors in the third visualisation since they are distinct from the others and complement each other well. The highlight feature is especially handy for observing certain data over time. It's also the ideal sort of area chart for displaying how much each category contributes to the overall data.

7 CONCLUSIONS

In this report we discussed how the whole process took place for this visualisation project. We initially discussed how our team addressed the topic of sustainable energy and then planned the visualisations to go with. Our team decided to go with 3 different visualisations with showed different data to encourage the community to focus on renewable energy and start a shift towards renewable energy sources such as solar energy.

Coming on to the visualisations which we made, we looked at the CO2 emission by fossil fuel burning over 20 years from 1990-2020 for Australia this visualisation was the chosen to be the first one to establish the fact that if we continue to use fossil fuels its going to be problematic in the long run. This is meant to make them aware of the broad damage being done. Then in the second visualisation we saw that how energy is consumed in different states and territories in Australia which states are the major consumers of energy. Then in the third visualisation we put through the data which shows the electricity generation via different renewable sources of energy over the past 20 years (1990- 2020).

Various challenges arose throughout the production of the visualisations, like as
we used the D3 library version 6, which changes greatly from prior versions and requires further study to complete. Because the majority of the resources are based on previous versions, the restricted resources necessitated more work in development and testing. It was also challenging at times to highlight each component in order to display tooltips on the visualisation because it was heavily reliant on the mouse event, which we had to understand the purpose of and how it returned the information. But we research and help from tutor we were able to overcome every obstacle.

Through this visualisation project we acquired invaluable knowledge and learned various valuable skills about how to choose and analyse a real-world dataset, how to develop an infographic, and how to apply the chosen concepts as a web-based visualisation. All these skills will be helpful in our future endeavors.

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