BC2402: Designing & Developing Databases

Seminar 5 Group 5

The Green World Project

Prof Chan Wai Xin
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Group Members

SCSE EUGENE WEE JUN LIN (U2120698A)

SCSE TAY JIA YING, DENISE (U2122458K)

SCSE SHERMAINE NG JINGLIN (U2121773F)

SCSE TOMMY WEE CHUNG KIAT (U2120448F)

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1. Introduction

1.1. Context of The Green World Project

Our report intends to shed light on the gaps in sustainability knowledge as well as highlight the urgency of tackling environmental issues through the use of data-driven findings. Through this report, we hope that our readers will better grasp and understand the impact of our actions on climate change and take steps to mitigate this dire environmental problem.

1.2. Differences between Relational & Non-relational Implementation

Relational database is a structured schema with multiple tables linked by well-defined relationships, containing normalised data. On the other hand, non-relational databases run on a schemaless structure with multiple embedded documents storing different data structures using key-value pairs. Fundamentally, their structures differ significantly which ultimately leads to different database implementations.

2. Relational Database Design (mySQL)

2.1. Principles in Relational Database Design

Relational databases are built on a schema design, by modelling data into multiple tables linked via relationships. Each record refers to an entity which contains individual attributes, and each entity is linked by primary and foreign keys.

2.2. Data Cleaning, Re-structuring & External Datasets

Our raw dataset was already segmented into their respective tables, therefore we only had to perform data cleaning on our existing tables. In addition to our existing dataset, we also used external datasets (Refer to Table 1) to supplement our approach for Q15.

We performed the following steps for our data cleaning process:

1) Converted missing values to null.
2) Converted data type of numeric field from string to double or float.
3) Extracted relevant columns for our tables

Table 1: External Datasets

S/N	Dataset Name
1	Climate-change related Natural Disaster Frequency (International Monetary Fund, 2020)
2	Deaths from Natural Disasters by Type (OurWorldInData, 2020)
3	Direct Economic Loss from Natural Disaster
4	Internal Displacement for Natural Disasters (Internal Displacement Monitoring System, 2021)
5	Economic Damage from Natural Disaster (Our World In Data, 2020)
6	Population living 5 metres above sea level (The World Bank, 2021)
7	Sea level Changes (Datahub.io, 2015)
8	Sustainability (From Assignment Schema)

To speed up our queries, we also broke down our OWID energy data into their respective tables which we then used for our queries (Refer to Figure 2).

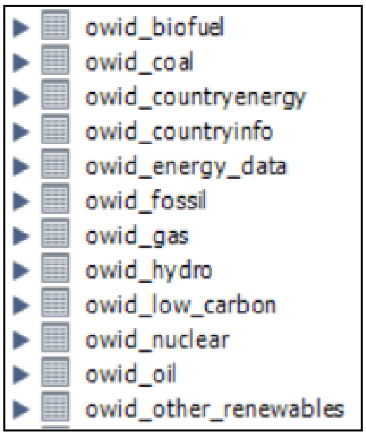
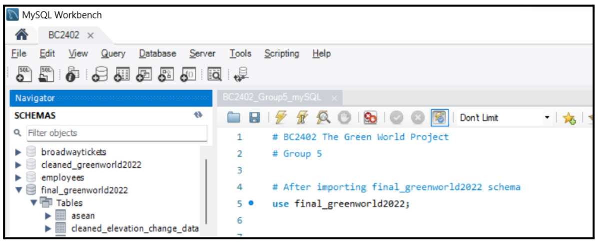
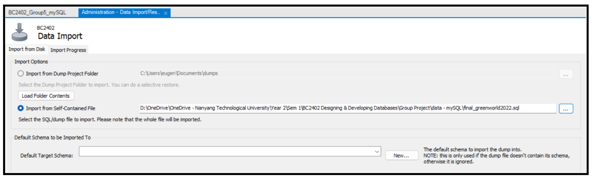
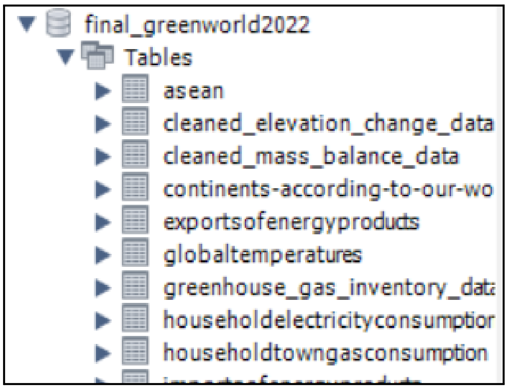


Figure 2: Breakdown of OWID energy data

2.3. Instructions on mySQL Database Implementation

S/N	Instructions	Reference
1	**Save Project Folder**	Resources are under 'data - mySQL' folder
2	**Open mySQL**	
3	**Import Database** **Data Source:** final_greenworld2022.sql 1) Go to Server > Data Import 2) Select Import from Self-Contained File 3) Select 'final_greenworld2022.sql' 4) Go to Import Progress > Start Import	 **<u>Schema imported</u>** 
5	**Run mySQL Script** **Query Source:** mySQL_DataCleaning	

<u>Notes</u>

- Data Cleaning Script (data - mySQL/mySQL_DataCleaning)
- Query Script (BC2402_Group5_mySQL)

3. Non-relational Database Design (noSQL)

3.1. Principles in Non-relational Database Design

Non-relational databases are built on a schemaless design which does not rely on extensive tables or relationship mapping. Instead, it is structured based on embedded documents which uses key-value pairs to store a wide variety of data types which gives it the flexibility of handling unstructured data and facilitates horizontal scaling of databases.

3.2. Structure of noSQL Database

Our raw database provided contains 5 collections, which mimics the relational database design. Given the source and relationship between collections, we decided to restructure and consolidate our database into two main collections for quicker and easier referencing using the dot notation.

finalYearlyEnergyData consists of energy consumption data in Singapore while finalOWIDdata consists of the complete Energy dataset maintained by Our World in Data. We also sourced for an external database consisting of OWID list of countries (*Refer to Appendix 6.4 for noSQL Database Structure).*

Table 3: Consolidation of Database Collection

S/N	Raw Database Collection	Consolidated Collection
1	householdElectricityConsumption	finalYearlyEnergyData
2	householdTownGasConsumption	
3	importsOfEnergyProducts	
4	exportsOfEnergyProducts	
5	owid_energy_data	finalOWIDdata
6	continents-according-to-our-world-in-data (*External data for list of countries*)	countriesOWID

3.3. Data Cleaning & Restructuring

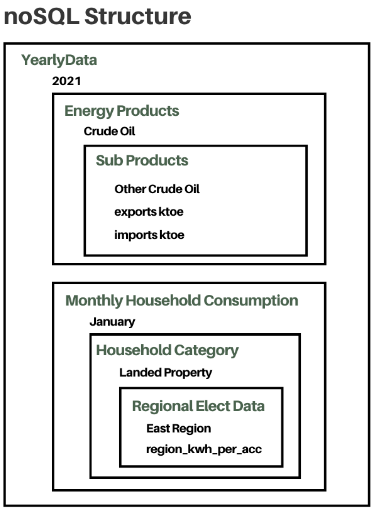
We performed the following steps for our data cleaning process:

1) Converted null and missing values to 0 for standardisation.
2) Converted data type of numeric field from string to double or float.
3) Standardised the naming convention for sub-categories to ensure consistency.

Singapore Energy Data

We structured our database by year, followed by the yearly household consumption and imports/ exports as separate documents respectively. (Refer to Figure 5 and Appendix 6.4.1 for finalSGYearlyData).

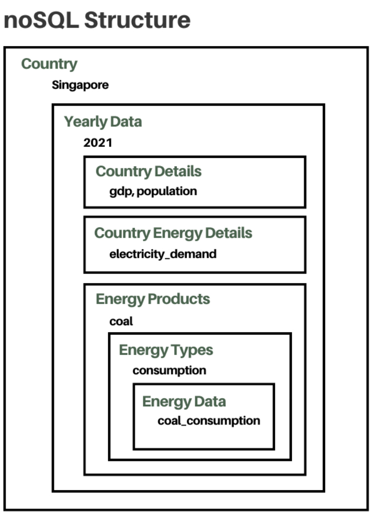
Table 5: noSQL Structure for finalSGYearlyData



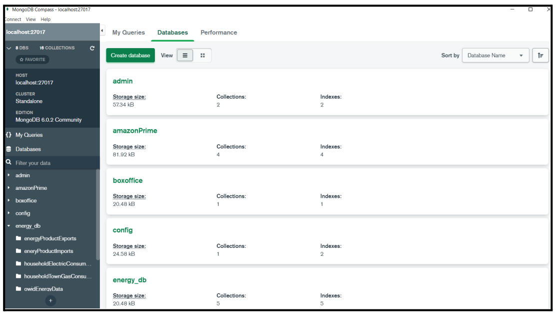
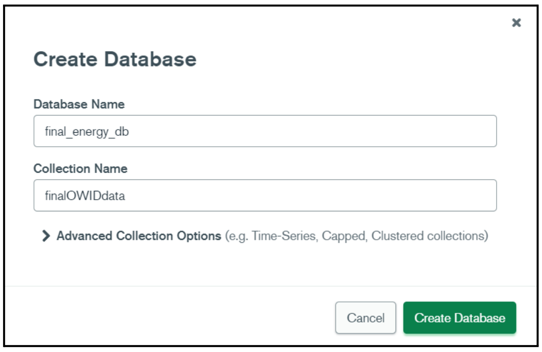
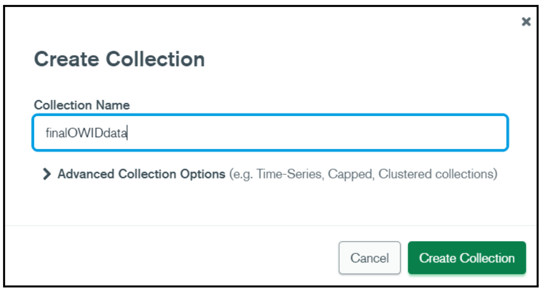
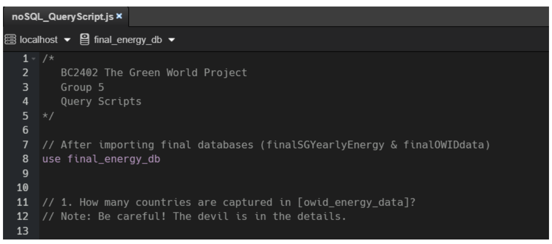
OWID Energy Data

For our database structure, we split the data by country, followed by their corresponding yearly energy data since the majority of the queries revolved around the country yearly data. We also further split the data into energy products and their respective sub energy products, making it easier to query based on energy categories (Refer to Table 6 and Appendix 6.4.2 for finalOWIDdata).

Table 6: noSQL Structure for finalOWIDdata



3.4. Instructions on noSQL Database Implementation

S/N	Instructions	Reference
1	**Save Project Folder**	Resources are under ‘data - noSQL’ folder
2	**Open MongoDB**	
3	**Create Database in MongoDB** **Database Name:** final_energy_db	
4	**Create Collections** **Collection Names:** - finalOWIDdata - finalSGYearlyData - countriesOWID **Data Sources:** - finalOWIDdata.json - finalSGYearlyData.json - continents-according-to-our-world-in-data.csv	
5	**Run noSQL Script** **Query Source:** BC2402_Group5_noSQL	

Notes
- Database Implementation Script (data - noSQL/noSQL_DatabaseImplementation) - Query Script (BC2402_Group5_noSQL)

4. Energy vs Electricity

Before we dive into our insights, we have to draw the key distinction between energy and electricity used in our discussion. Energy refers to the capacity to work, which is derived from various energy sources and expanded during consumption. Electricity is a specific type of energy which can be generated from renewable sources (i.e. Solar, Wind, Hydroelectric). However, currently in the U.S., only 40% of energy is being supplied by electricity with the remaining 60% being directly supplied by non-renewables sources (i.e. Fossil Fuels). Electrification aims to make electricity the main energy source for technology, in the pursuit for carbon-free electricity (Dillemuth, 2021).

5. Singapore's Energy Performance (Q12)

Question: How has Singapore been performing in terms of energy consumption? Find a comparable reference(s) to illustrate changes in energy per capita, energy per GDP, and various types of energy (e.g., solar, gas, and oil) over the years.

Hong Kong and Japan as Comparable Country

To evaluate Singapore's performance in terms of energy consumption, we will first find a comparable country with similar GDP per capita. Since Singapore's GDP is only available from the year 1965 to the year 2018, we will only consider these years for the other countries as well. The continent has to be taken into account as well, since we would want to find a comparable country with similar geographical location and hence, similar energy types. It can be found that Hong Kong and Japan have the closest average GDP per capita from 1965 to 2018, and are also located in Asia.

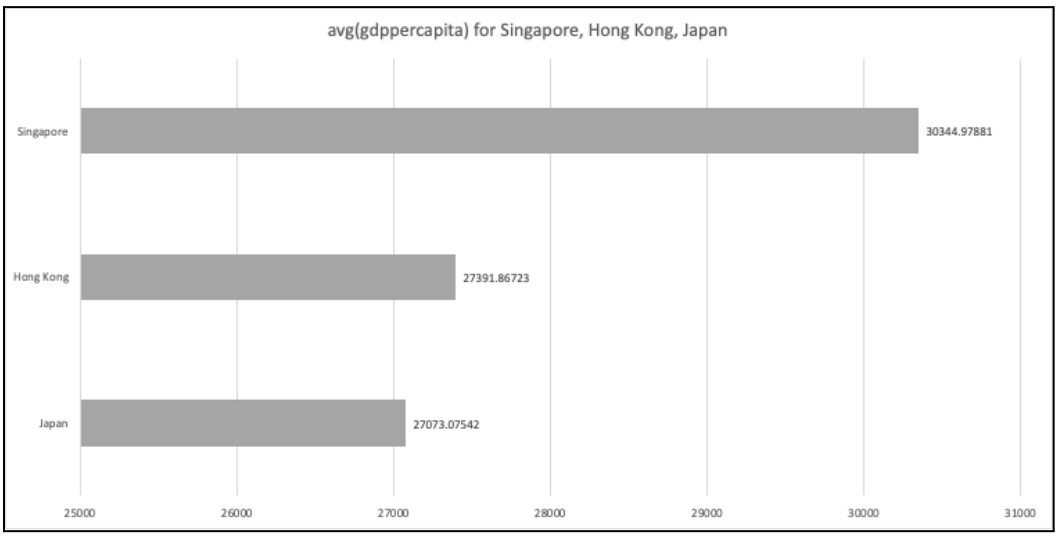


Figure 3: Average GDP per capita for Singapore, Hong Kong and Japan (1965 - 2020)

Energy per GDP

The energy per GDP significantly decreased for Singapore, from 1965 to 2018, whereas that of Hong Kong and Japan remained relatively stagnant. Energy per GDP is the energy intensity and emphasises the efficiency of energy use. A lower energy per GDP means that the country is being more energy efficient. Hence, Singapore's decrease in energy per GDP implies that Singapore is becoming more energy efficient.

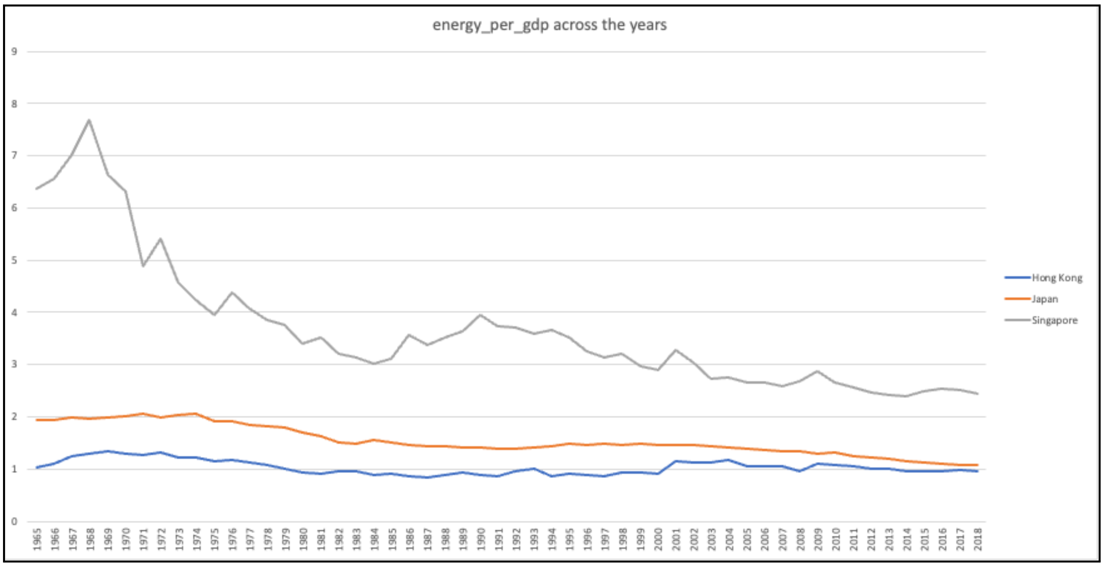


Figure 4: Energy per GDP for Singapore, Hong Kong and Japan (1965 - 2020)

Energy per Capita

The energy per capita for all three countries increased from 1965 to 2018. However, Singapore's energy per capita increased much more significantly as compared to that of Hong Kong and Japan. This meant that Singapore's energy consumption per person increased more on average.

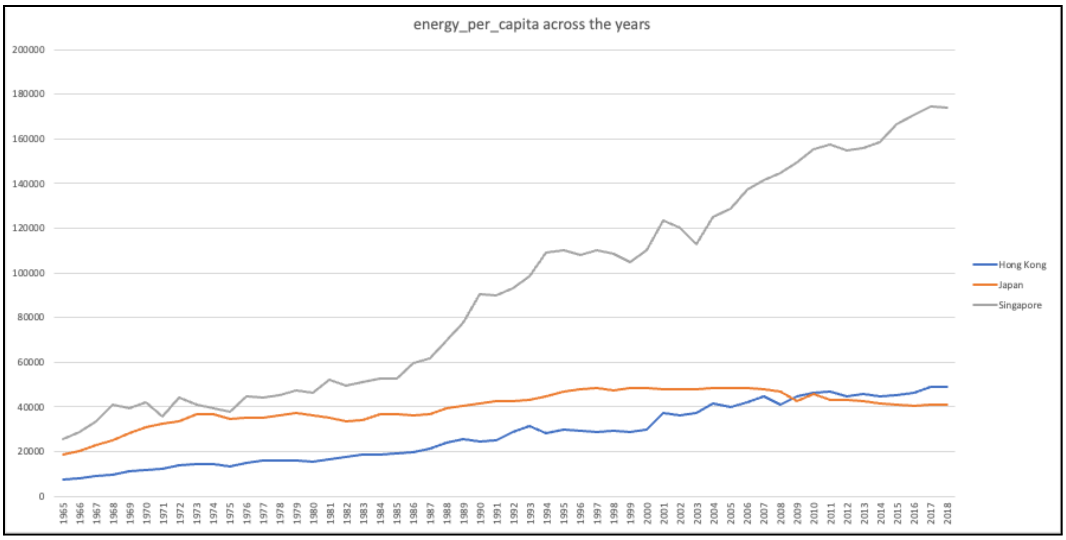


Figure 5: Energy per capita for Singapore, Hong Kong and Japan (1965 - 2020)

Energy Share

Singapore only has energy data from 1965 to 2020, hence we will only consider these years.

To evaluate Singapore's energy consumption, we will first consider the 3 broad energy categories - Renewable, Nuclear and Fossil Fuel. Due to their geographical location, there is no nuclear energy data for both Singapore and Hong Kong. The share of energy consumption for the 3 types of energy categories are shown below. From 1965 to 2020, Singapore and Hong Kong saw an increase in the proportion of renewable energy consumption and a decrease in the proportion of fossil fuel energy consumption. Japan, however, saw a decrease in the proportion of renewable energy consumption and fossil fuel energy consumption, but an increase in the proportion of nuclear energy consumption. The increase in nuclear energy consumption for Japan is mainly due to its move to diversify its energy resources and not depend on any particular energy type. This ensures sustainability for Japan which has little natural resources and relies largely on imported energy resources.

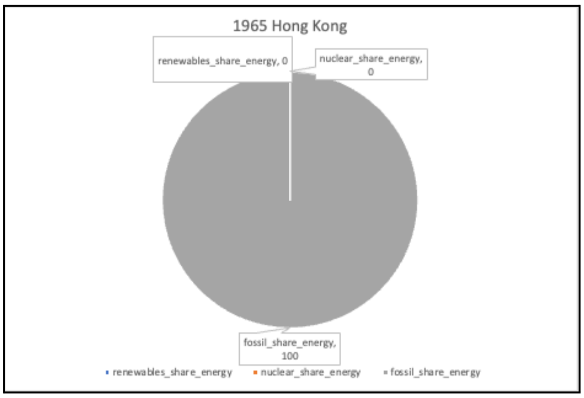


Figure 6: Energy Share for Hong Kong (1965)

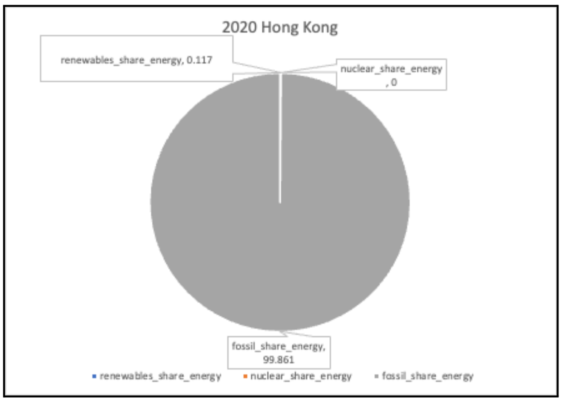


Figure 7: Energy Share for Hong Kong (2020)

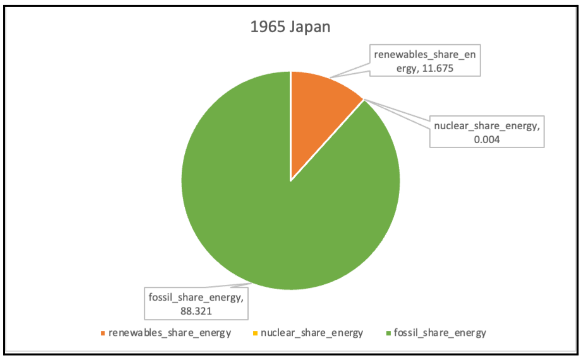


Figure 8: Energy Share for Japan (1965)

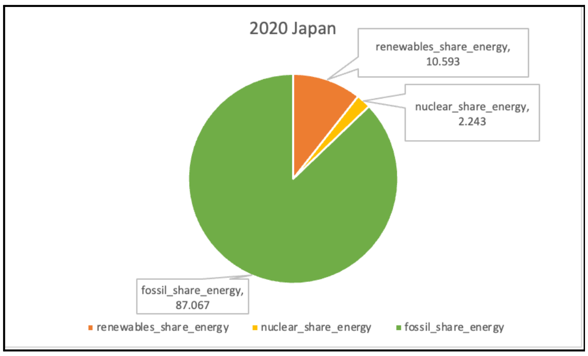


Figure 9: Energy Share for Japan (2020)

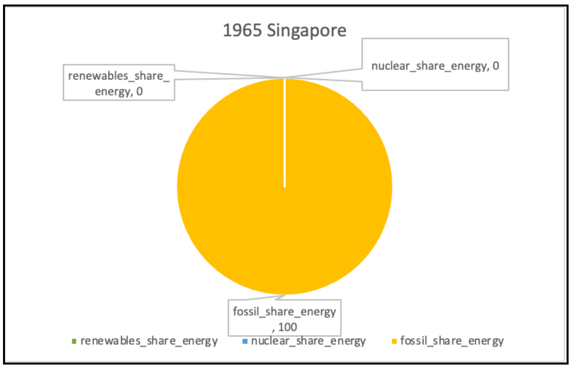


Figure 10: Energy Share for Singapore (1965)

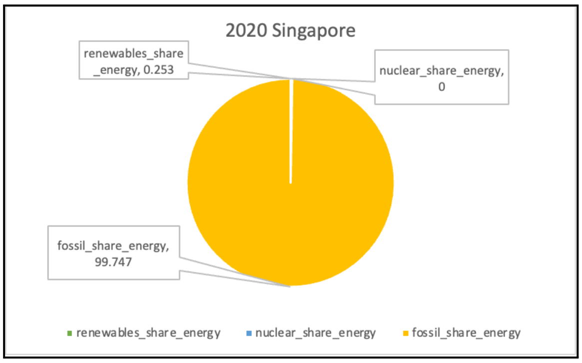


Figure 11: Energy Share for Singapore (2020)

Renewables vs Fossils

From 1965 to 2020, all 3 countries saw an increase in renewable energy consumption and fossil fuel consumption. The percentage increase in fossil fuel consumption is the greatest for Singapore, followed by Hong Kong, and lastly Japan. Both Singapore and Hong Kong recently started using renewable energy, but Singapore saw a greater increase than Hong Kong. For Japan, the percentage increase in nuclear consumption is the greatest, followed by that of fossil fuel consumption and lastly, renewable energy consumption. Fossil fuel remains as the main type of energy consumed for all 3 countries, though renewable energy consumption has been rising for all 3 countries.

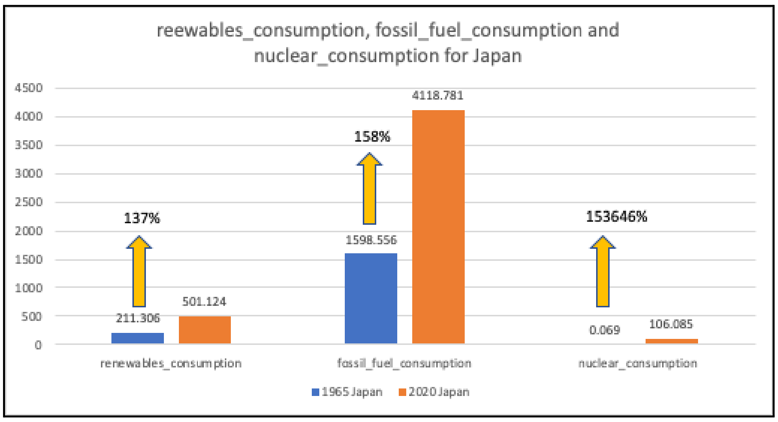


Figure 12: Consumption of Renewables, Fossil Fuels and Nuclear for Japan (1965 & 2020)

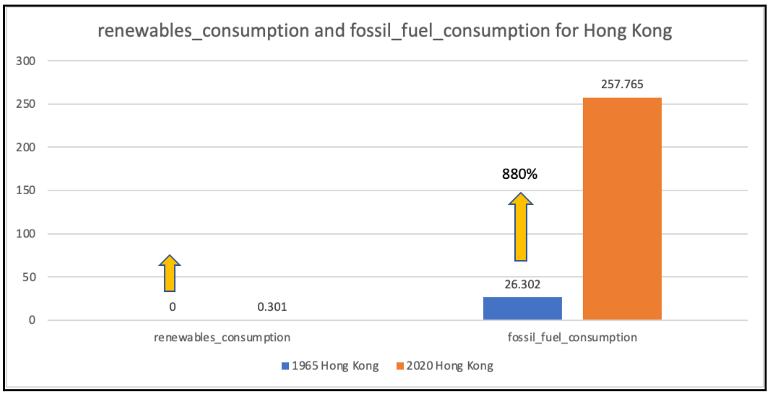


Figure 13: Consumption of Renewables and Fossil Fuels for Hong Kong (1965 & 2020)

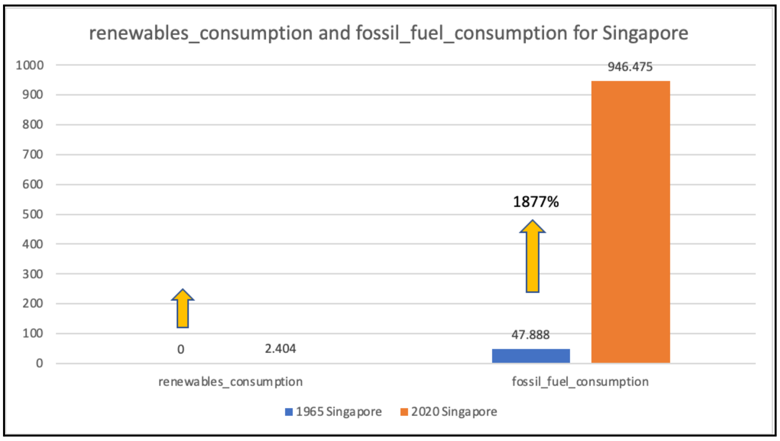


Figure 14: Consumption of Renewables and Fossil Fuels for Singapore (1965 & 2020)

Renewable Energy Consumption

Renewable energy consists of other renewables, biofuel, solar, wind and hydro energy. The charts below show the breakdown of the types of renewable energy consumption for all 3 countries, across 1965 and 2020. For Singapore, biofuel, wind and hydro energy are not present. Hence, only other renewables energy and solar energy saw an increase in energy consumption. Singapore saw a more significant increase in these two types of energy consumption, as compared to Hong Kong, but a less significant increase in these two types of energy consumption, as compared to Japan. Besides, Hong Kong had a slight increase in wind energy consumption, while Japan saw a greater increase in wind energy consumption. Hydro energy consumption for Japan fell from 1965 to 2020.

Since renewable energy is derived from renewable resources and generates lower amounts of carbon emissions resulting in global warming, an increase in consumption of renewable energy means that countries are becoming more environmentally friendly and hence beneficial. Thus, based on the renewable energy consumption for all 3 countries from 1965 to 2020, we can say that Singapore is doing better than Hong Kong by switching to renewable energy alternatives and increasing the renewable energy consumption, but is still losing out to Japan in that aspect.

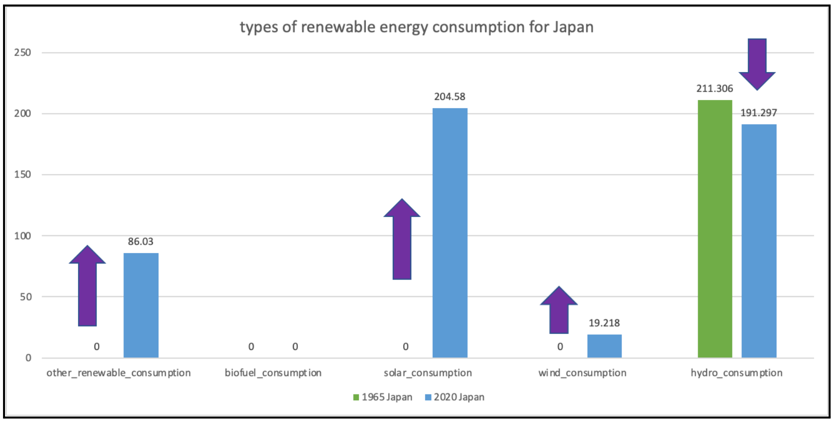


Figure 15: Consumption of the different types of Renewables for Japan (1965 & 2020)

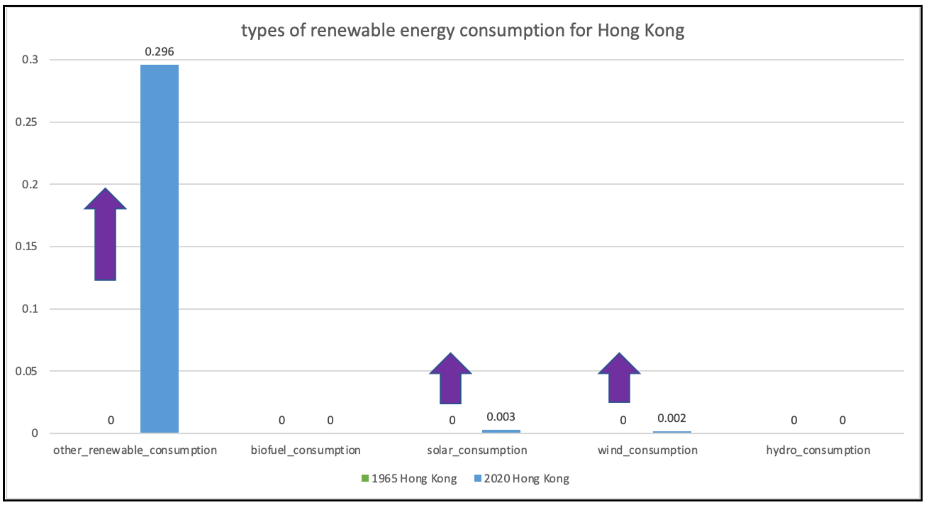


Figure 16: Consumption of the different types of Renewables for Hong Kong (1965 & 2020)

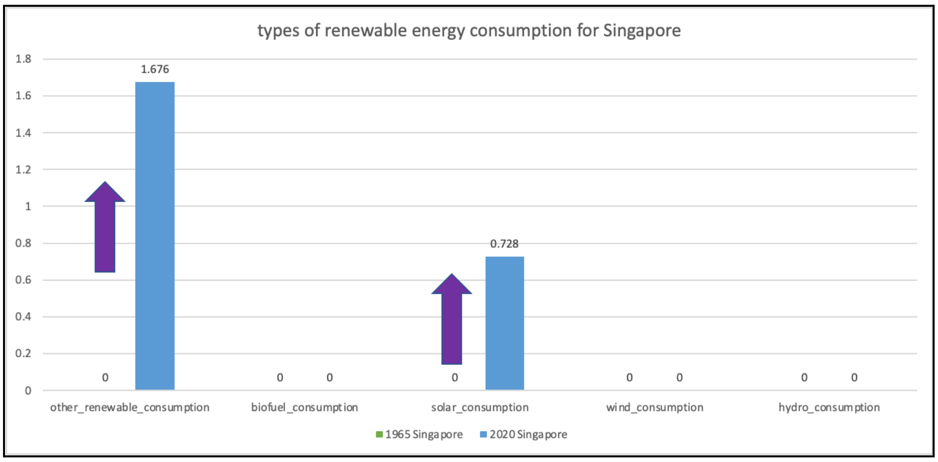


Figure 17: Consumption of the different types of Renewables for Singapore (1965 & 2020)

Fossil Fuels Energy Consumption

Fossil fuel energy consists of oil, coal and gas energy. The charts below show the breakdown of the types of fossil fuel energy consumption for all 3 countries, between 1965 and 2020. From 1965 to

2020, all 3 types of fossil fuel energy consumption increased for all 3 countries. Previously in 1965, Singapore and Hong Kong did not consume any gas energy, but only started consuming recently. Singapore saw a more significant increase in gas energy consumption, as compared to Hong Kong. For both oil and coal energy consumption, Singapore and Hong Kong saw a significant increase, but the percentage increase for Singapore is greater than that of Hong Kong. For Japan, the greatest increase in fossil fuel energy consumption stemmed from gas energy consumption and the percentage increase for oil and coal energy consumption is lower than that of Singapore or Hong Kong.

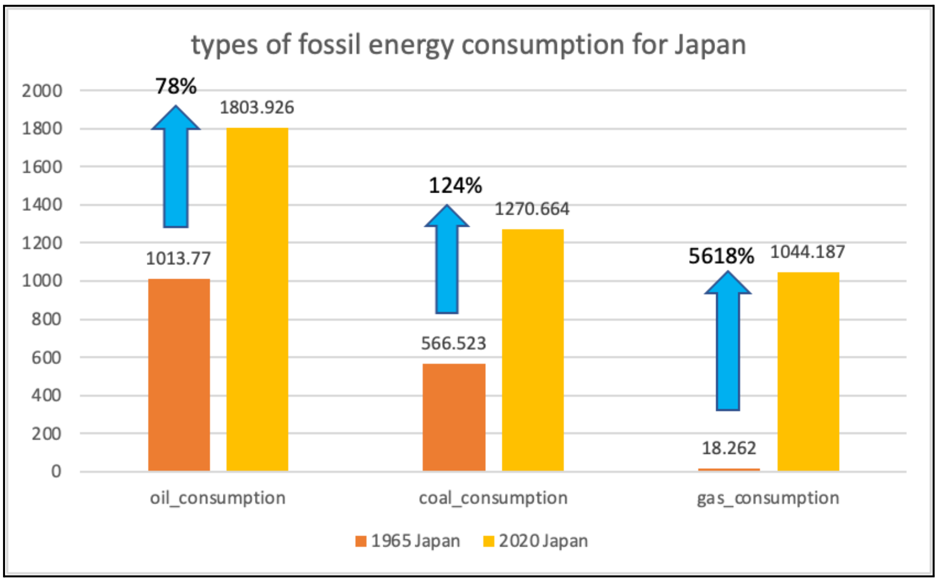


Figure 18: Consumption of the different types of Fossil Fuels for Japan (1965 & 2020)

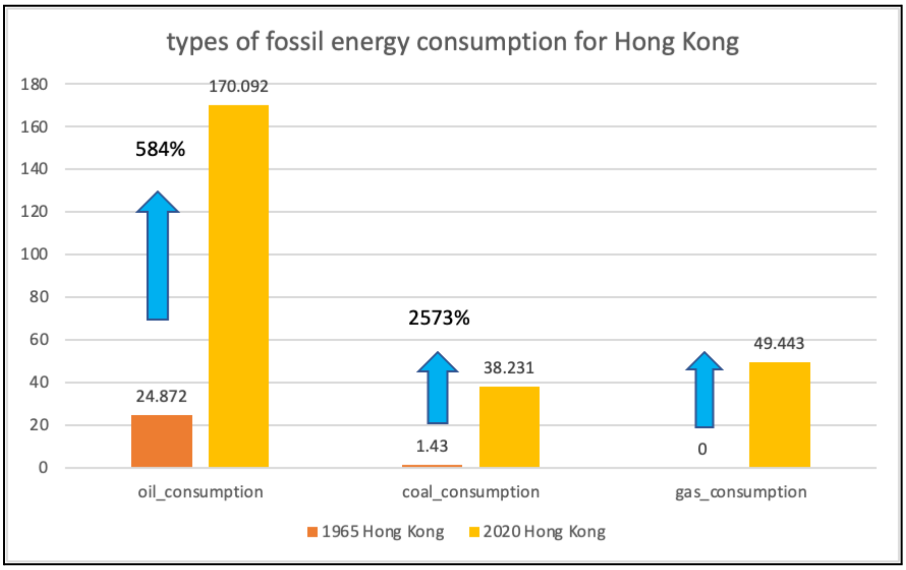


Figure 19: Consumption of the different types of Fossil Fuels for Hong Kong (1965 & 2020)

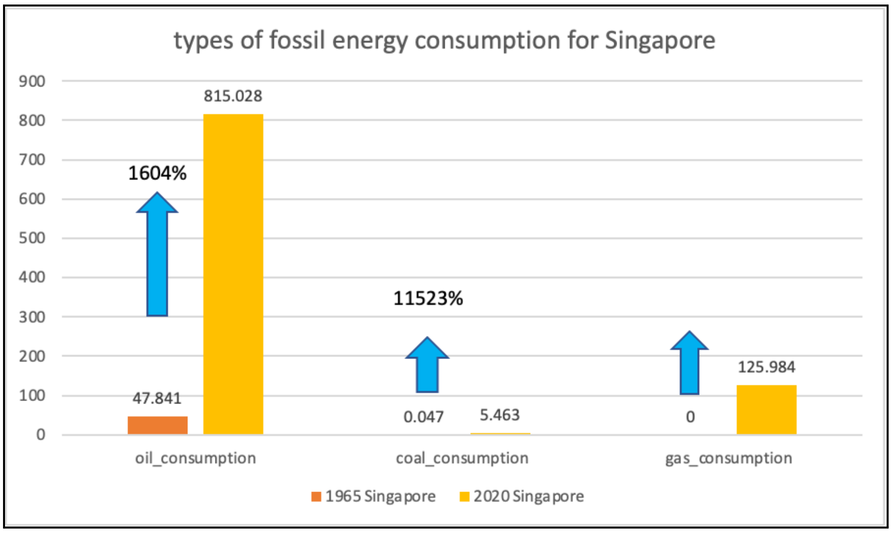


Figure 20: Consumption of the different types of Fossil Fuels for Singapore (1965 & 2020)

Conclusion

In conclusion, based on energy consumption, Singapore is performing better than Hong Kong, but can continue to learn from Japan. Based on energy per GDP, Singapore saw the greatest decrease, hence implying that Singapore is making the greatest progress to becoming more efficient in its energy use. Based on energy per capita, Singapore saw the greatest increase, hence implying that Singapore's energy consumption has increased most significantly across the years. Though fossil fuels remain as the main source of energy, Singapore is performing better than Hong Kong since the proportion of renewable energy consumption has increased more significantly, which implies that efforts to transition towards renewable and low carbon energy sources to replace fossil fuels have been made. As for Japan, it optimally utilises a variety of energy types. Singapore can learn from Japan to diversify its energy resources since both countries are poor on natural resources and rely largely on imports.

6. Perspective on Renewable Energy (Q13)

Question: Can renewable energy adequately power continued economic growth?

Proposed Approach

To evaluate whether renewable energy can adequately power continued economic growth, we look at 3 key aspects - Rising Energy Demand, Adequate Renewables Production and Economic Viability of Renewable Sources. In our analysis, we will be examining energy as the broad umbrella, before diving deeper into electricity as our primary focus, as carbon-free electricity is the eventual goal for renewable energy.

Sustaining Rising Energy Demand

As of 2021, the world's population stands at 7.8 billion, which is a 28.3% increase since the start of the 21st century. Energy and electricity are also facing massive surges in demand, soaring by 41.1% and 83.7% respectively (see Figure 21). For renewable energy to be a viable source, it needs to be able to sustain this rising trend for both existing and future generations.

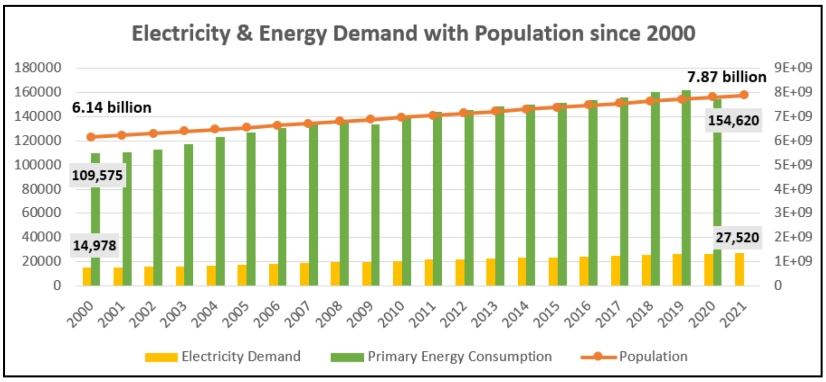


Figure 21: World Population, Energy & Electricity Demand since 2000

Surge in Renewables Consumption

Diving deeper into energy consumption, we can notice that renewable energy consumption has experienced a surge since 2000, whereas the increase was less significant for fossil fuel and even declined for nuclear energy (see Figure 22). This illustrates a greater transition towards renewable energy consumption since the start of the century.

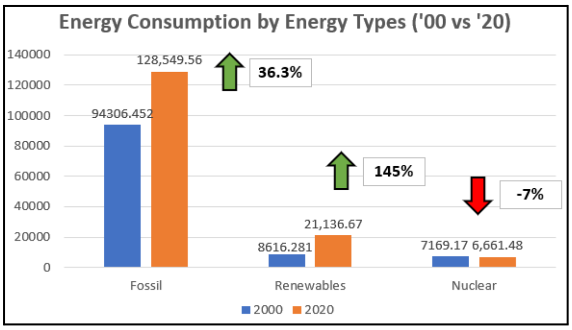


Figure 22: World Energy & Electricity Consumption by Type ('00 vs '20)

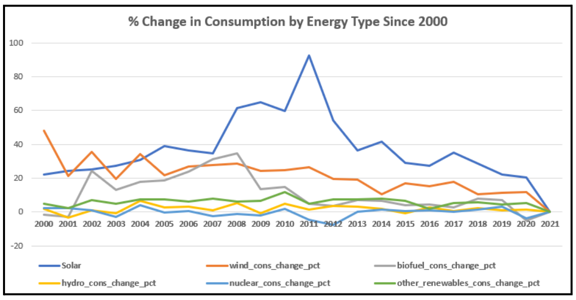


Figure 23: Percentage Change in Energy Consumption by Type Since 2000

Declining Renewable Uptake in Recent Years

Narrowing our focus towards renewable energy, we analysed how the consumption patterns for each renewable type changed over the years (see Figure 23). Generally, renewables consumption has been positive since 2000, with solar and wind energy contributing the bulk of this increase. However, in recent years, this positive rate of uptake has been declining which could signal slowing conversion to renewable energy.

Adequate Renewable Energy Production

To evaluate whether renewable energy is adequate to sustain overall energy and electricity production, we study their composition by energy type. Based on OWID energy data, renewable energy (excluding nuclear) only makes up 13% of the world's total energy share whereas in the case of electricity, renewable sources contribute a slightly higher proportion of 28% of the world's electricity share (see Figure 24 & 25). In this regard, fossil fuels still encompass a significant portion of electricity generation, which may be an indicator that renewable energy supplies are insufficient to independently sustain the growing demand.

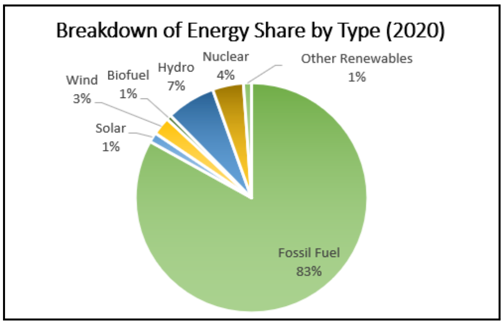


Figure 24: Breakdown of Energy Share Generation by Type in 2020

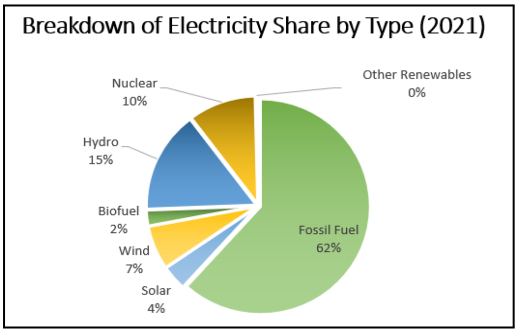


Figure 25: Breakdown of Electricity Share Generation by Type in 2021

Gradual Increase in Electricity Generation of Renewables

Analysing the world's electricity generation across the years, the gradual increase of 10.5% in renewable energy contribution indicates a shift away from fossil fuels, towards more carbon neutral electricity sources (see Figure 26). However, to evaluate whether renewables sources can sustain the rising demand for electricity, we further analysed each renewable type growth rate.

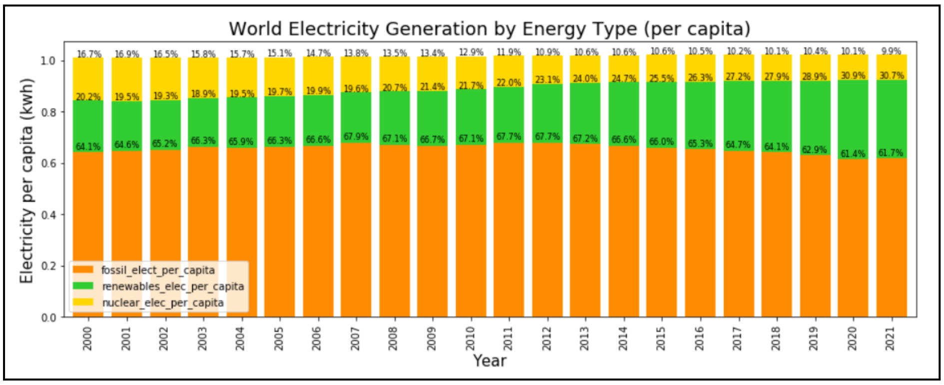


Figure 26: World Electricity Generation by Type (per capita) since 2000

Rising Trend for Solar and Wind Energy

For renewables, we can notice that even though hydroelectric energy currently dominates electricity generation, solar and wind energy have been gaining traction in recent years (see Figure 27). However, at its current rate of growth, renewable sources may be inadequate to generate sufficient electricity to meet the rising electricity demand.

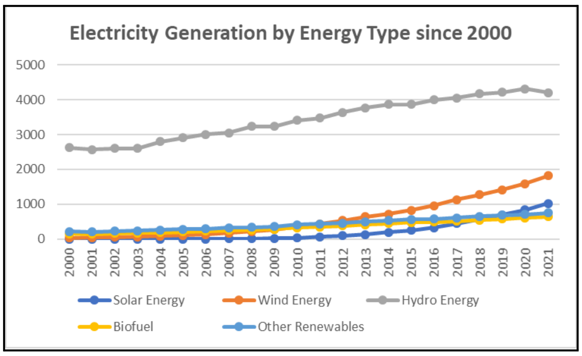


Figure 27: Electricity Generation by Energy Types since 2000

Continent's Geographical, Economic and Resource Limitations on Electricity Sources

Lastly, we investigated each continents' contribution towards switching to renewable energy sources to assess their capability to power continued economic growth (see Figure 28). We can observe that Europe, North and South America have made successful transitions towards renewable sources whereas Asia, Africa and Oceania have lesser uptake of renewables. This, however, could be due to their geographical regions and economic status, which limits their capacity to generate and rely on renewable energy as an alternative source.

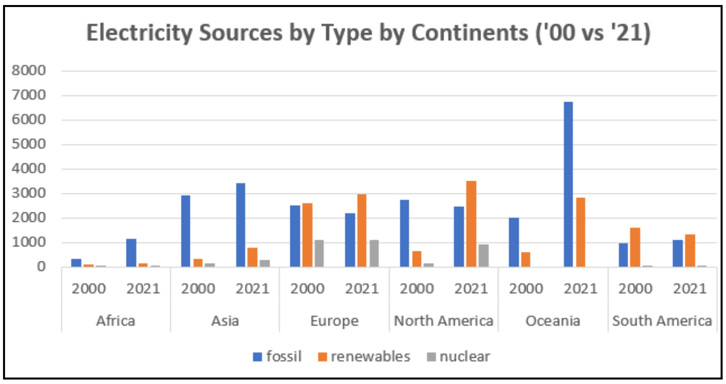


Figure 28: Electricity Source by Continent (2000 vs 2021)

Economic Viability of Renewable Energy

After understanding each continent's main source of electricity generation, we selected Europe and South America continents as our main focus for our subsequent analysis on the economic viability of renewable energy. Based on Figure 29, we can observe that these regions use renewables as their main source of electricity and have significant differences in terms of GDP per capita.

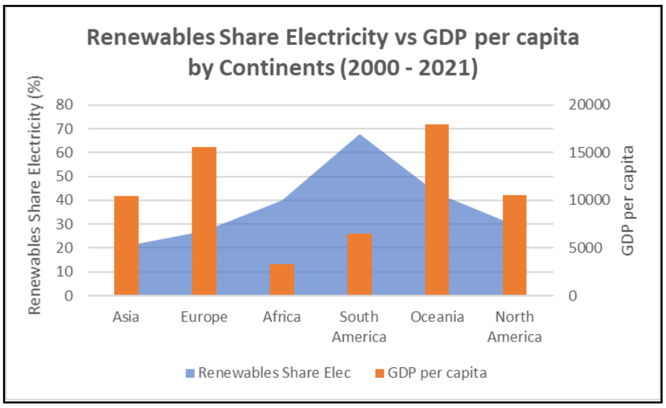
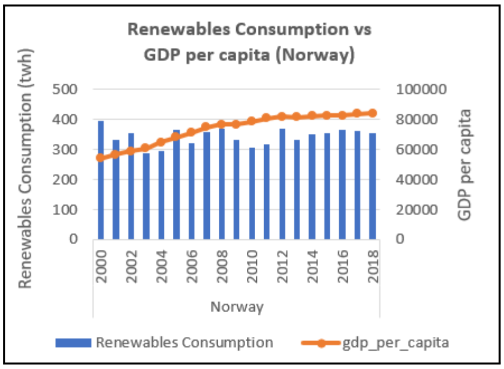


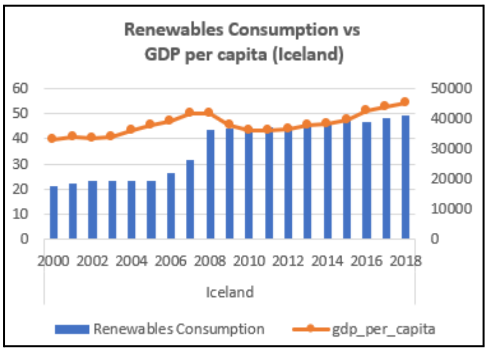
Figure 29: Renewable Share Electricity vs GDP per capita by Continents (2000 - 2021)

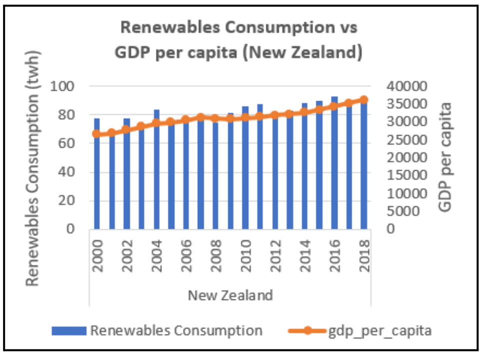
Time-series Analysis on Economic Benefits of Renewables Energy

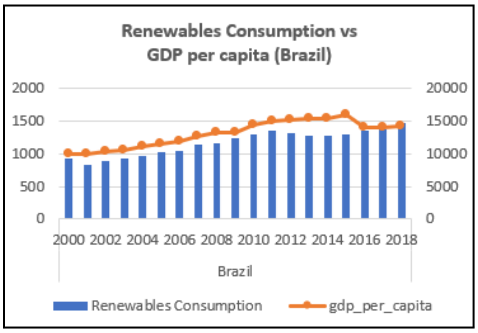
To evaluate the economic benefits of renewable sources, we extracted the top 5 countries leading in renewable energy consumption globally and evaluated their corresponding GDP per capita changes during the period of 2000 and 2018. Across these countries, we observe that GDP per capita still managed to grow at a gradual pace as they shifted towards renewable sources, indicating that renewables could be an economically viable option.

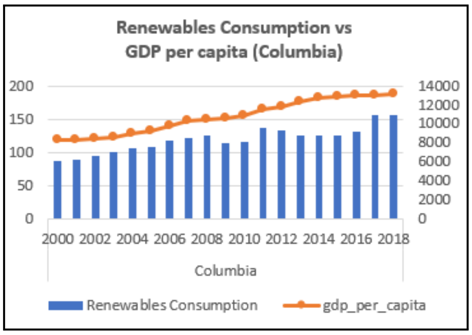
Figure 30: Top 5 countries leading in Renewables Consumption and GDP per capita (2000 - 2018)











Positive Economic Impact on High Economic Regions

Subsequently, we extracted the leading countries in renewables consumption and compared their GDP per capita against the continent's average.

For Europe and North America, the leading countries' GDP per capita were above average, and Norway in particular had the highest GDP per capita as well as renewable share of electricity. These are indicators that renewable energy has a positive economic impact on the economy and serves as evidence that it can power economic growth.

Drawing comparisons to a lower economic region like South America, we can observe that only Brazil and Venezuela maintained above average GDP per capita against the continent's average, which could indicate that the potential benefits are limited for countries with limited economic resources.

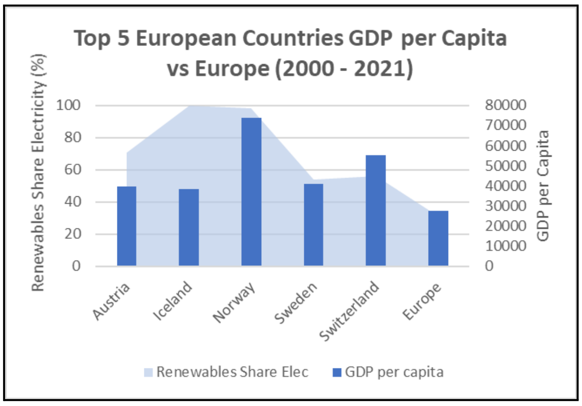


Figure 31: GDP per capita (Europe)

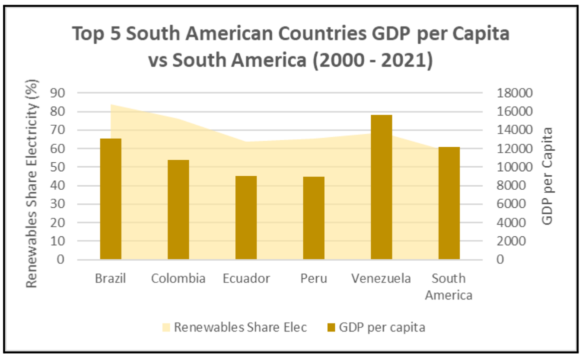


Figure 32: GDP per capita (South America)

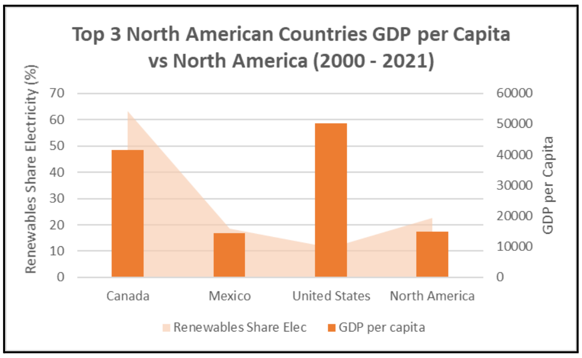


Figure 33: GDP per capita (North America)[1]

[1] Given the demographics of North America, we extracted the significant countries for our analysis.

Most Significant Impact by Wind Energy

Lastly, we evaluated the economic impact of each renewable energy type on GDP per capita based on the respective leading countries. From the charts, we can deduce that wind energy has the most significant economic impact during its progressive adoption, with gradual increases in GDP per capita over the years. In recent years, the operating cost of wind generators has been on the decline, and countries can leverage on the efficient land usage of wind energy, enabling positive economic impact (EnergySage, 2022).

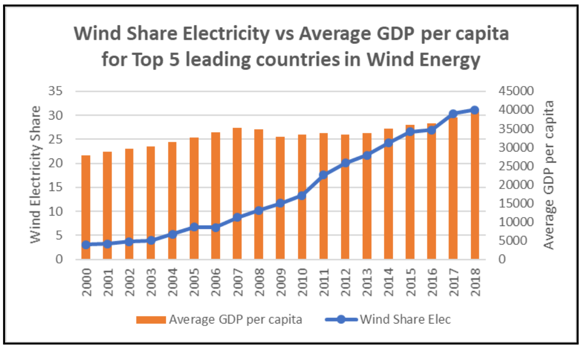


Figure 34: Wind Share Electricity vs Average GDP per capita for leading countries

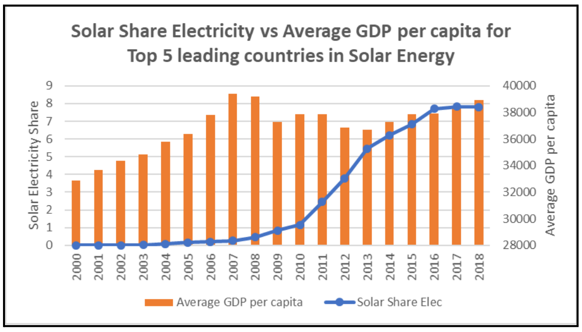


Figure 35: Solar Share Electricity vs Average GDP per capita for leading countries

High Barriers to Entry for Solar Energy

For Solar energy, we can observe that even though GDP per capita dipped during the initial transitioning phase between 2007 - 2009, GDP per capita levels rose back in subsequent years. This could be an indicator of the high initial and maintenance cost of setting up solar panels. However, the cost of solar panels has declined substantially in recent years, making it more affordable to transition towards solar electricity (Rollet, 2020).

Positive Economic Impact of Hydro Energy

For Hydroelectricity, even though there was a decline in share electricity across the years, the share of electricity still encompasses the bulk of electricity production of 73%. Countries engaging in hydroelectricity can greatly benefit from the abundance of low-cost energy and immunity to rising costs of fossil fuels. Furthermore, since these hydroelectric dams were built in the past when construction costs

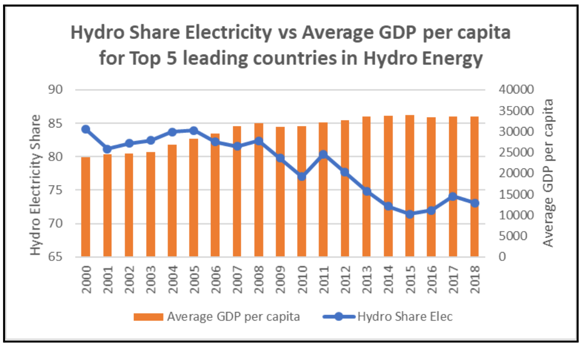


Figure 36: Hydro Share Electricity vs Average GDP per capita for leading countries

were low, countries could enjoy better economic
benefits (Institute for Water Resources, 2021).

Conclusion

In conclusion, despite the recent developments and global efforts in transitioning towards renewable sources for electricity generation, our team views that at its current stage, renewables production is still inadequate to match the fast-growing energy demand. Fossil fuels are still heavily relied on as the main energy source, and huge developments into the renewable energy space are required to improve its capacity to accommodate the growing demand. Nevertheless, our data-driven findings provide sufficient evidence in showing that renewables have the potential to power continued economic growth, particularly countries with higher economic status who can capitalise on their natural renewable resource to replace fossil fuels.

7. Our Stance on Nuclear Energy (Q14)

Question: Say micro-nuclear reactors have become environmentally viable and economically feasible for Singapore. Shall we go nuclear? Why / why not? Substantiate your team's opinion with the data provided.

Proposed Approach

To evaluate whether Singapore should go nuclear, we base our analysis on 3 broad aspects: Singapore's nature of high import dependency, Singapore's raised climate ambitions and current renewable energy landscape and nuclear energy and its implementations in singapore.

Singapore's High Import Reliance

As of 2020, fossil fuels generate 98% of Singapore's electricity (see Figure 37), which are harnessed from **imported** liquefied forms of natural gas through pipes from neighbouring countries Indonesia and Malaysia (Tan, 2019), with the majority of the total electricity produced being used to power the nation's industrial and commercial sectors (Energy Market Authority, 2020).

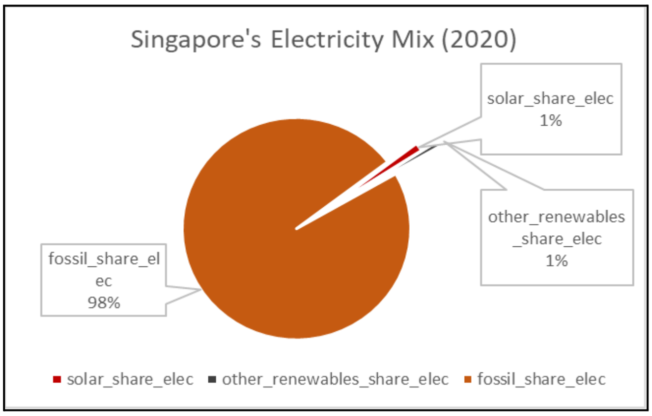


Figure 37: Singapore's Electricity Mix (2020)

The ongoing pandemic has laid bare the volatility of oil markets and confirmed that electricity supplies are crucial to all aspects of life in a wired economy, including the need to be able to work from home. In order to mitigate her vulnerability to future price shocks and supply chain disruptions, Singapore would be well-advised to consider incorporating alternative energy sources suitable for Singapore's needs.

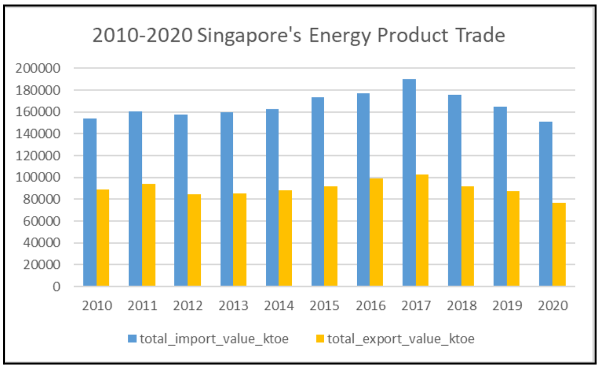


Figure 38: 2010-2020 Singapore's Energy Product Trade

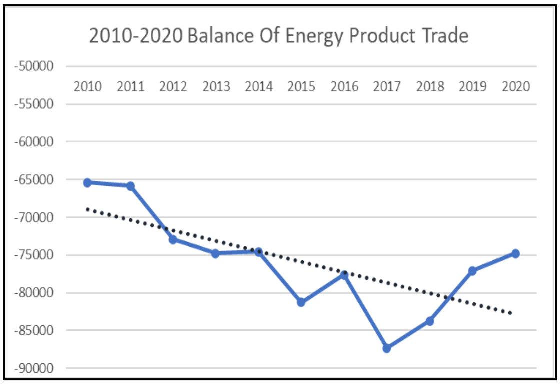


Figure 39: 2010-2020 Balance of energy product trade

Additionally, a common trend is observed in Singapore's energy product trade, where the value of total imported energy products are continuously larger than total exported energy products (see Figure 38) meaning that Singapore is suffering from a negative trade balance for its energy products. (see Figure 39).Implications of an increasingly negative balance of trade as observed in Figure 39 are the monetary losses that Singapore is making on its energy product trade due to her high import reliance.

All in all, Singapore's high import reliance on energy needs result in a high susceptibility to volatile energy markets and monetary losses due to a negative trade balance on energy products. This necessitates Singapore to steer away from her high import reliance on natural gas and venture deeper into exploring alternative energy options to reduce import dependency and improve its self-sustainability.

Singapore's Climate Ambition

During Budget 2022, Minister for Finance Mr Lawrence Wong has announced plans to raise its climate ambitions in order to achieve net-zero emissions by 2050, further stressing the need to transition to a low carbon economy (National Climate Change Secretariat, 2022).

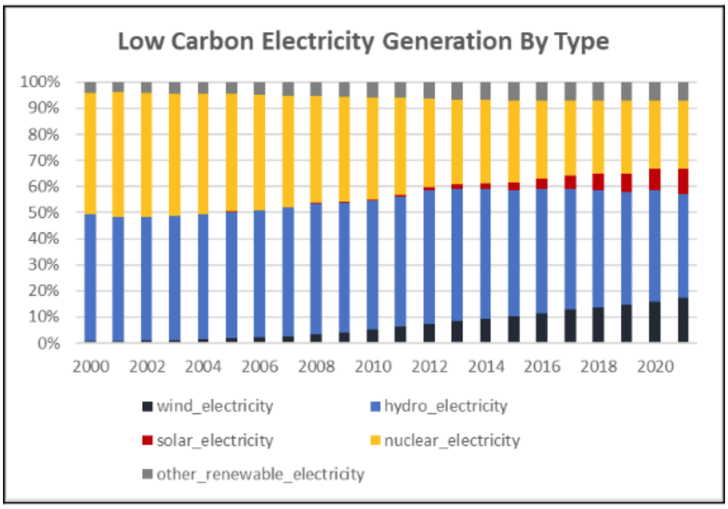


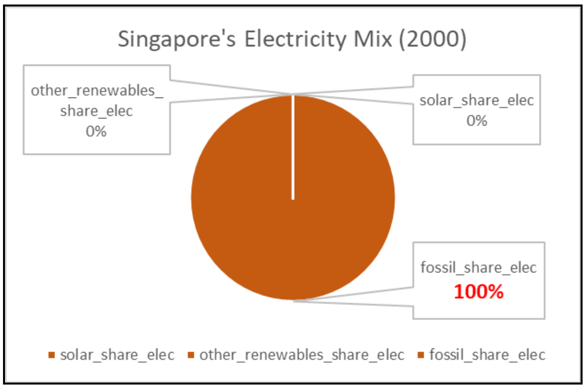
Figure 40: Low Carbon Electricity Generation By Type

We extracted values of electricity generation for low carbon electricity sources and plotted a stacked chart to observe the proportions by type. From Figure 40, we can observe that Hydro electricity is the World's largest source of low carbon electricity, followed by nuclear, wind, solar and lastly other renewables.

Singapore's Renewable Energy Landscape

Although hydroelectricity is the largest source of low carbon electricity, it is not an option for Singapore as hydroelectric power cannot be harnessed due to a lack of a fast flowing river system. Likewise, Singapore's low wind speeds leave her little options left for renewable energy (Energy Market Authority, 2022).

However, it is noteworthy that the share of solar energy in Singapore's electricity mix has risen significantly, where Singapore's solar share of electricity as of 2020 makes up about 1% as compared to a fully fossil-dominated electricity mix in 2000 (see Figure 41 & 42).



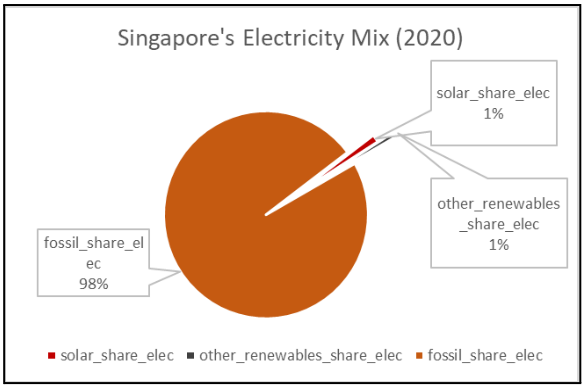


Figure 41: Singapore's Electricity Mix (2000)

Figure 42: Singapore's Electricity Mix(2020)

We extracted electricity generation and energy consumption of various energy types in Singapore and computed electricity generation/energy consumption to produce a measure of efficiency, then plotted a graph to display efficiency of energy sources by type (see Figure 43).

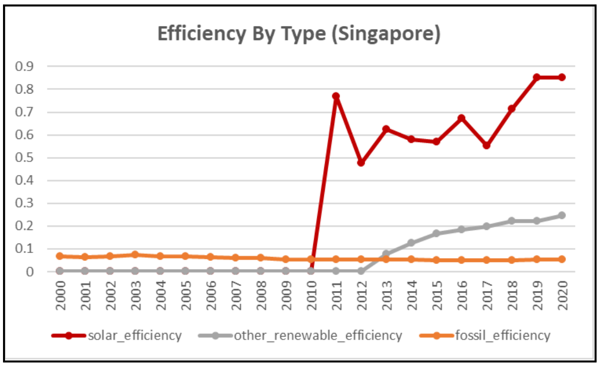


Figure 43: Efficiency by type (Singapore)

Our analysis reveals that solar efficiency has the highest efficiency followed by other renewables and fossil fuels. However, solar efficiency has large fluctuations as compared to that of other renewables and fossils. This could be attributed to solar panel's nature of intermittent electricity generation, which is further worsened by Singapore's overcast skies and high rainfall.

As such, solar electricity generation in Singapore is highly unreliable, making it challenging for Singapore to scale up its solar generation capacity.

Going Nuclear in Singapore

To examine the impact of nuclear energy in the World, we extracted the shares of energy and electricity of various energy types in the world and observed that as of 2020, nuclear power generates about **4.3%** of the world's total energy generation, contributing to an astounding **10.1%** of the world's electricity. (see Figure 44 & 45).

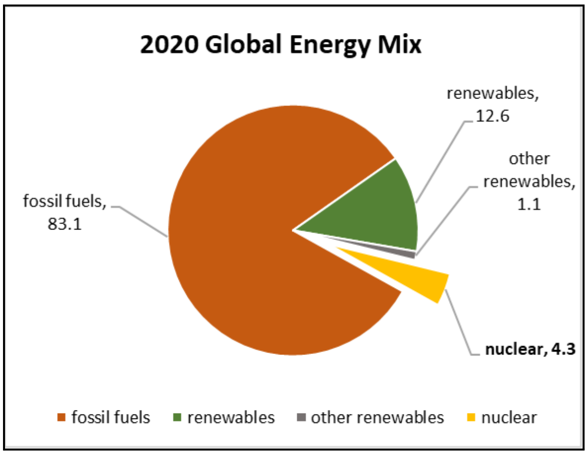


Figure 44: 2020 Global Energy Mix

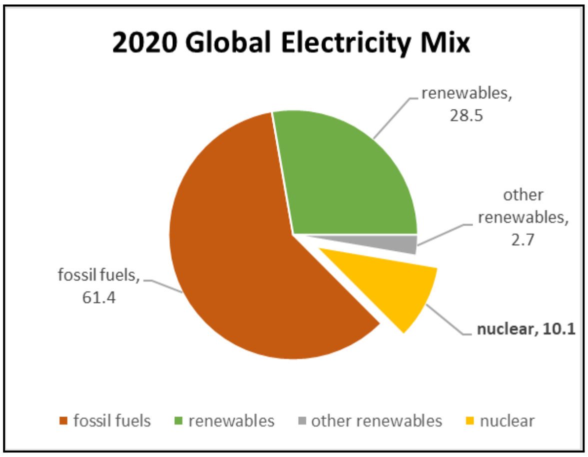


Figure 45: 2020 Global Electricity Mix

Since Singapore has yet to venture into nuclear energy, we conducted an analysis on the Top 3 Nuclear Generating Countries of the world, namely: Russia, France, and the United States.

Nuclear Energy and Its Impact on Carbon Intensity of Electricity

Analysis on the trends of carbon intensity of electricity in the Top 3 Nuclear Generating Countries reveal a trend of falling Carbon Intensity. This could be attributed to Nuclear energy's nature of net zero emissions. According to the Nuclear Energy Institute (NEI), the United States successfully avoided approximately 470 million metric tons of carbon dioxide emissions in 2020 from the nuclear industry (Nuclear energy Institute, 2020).

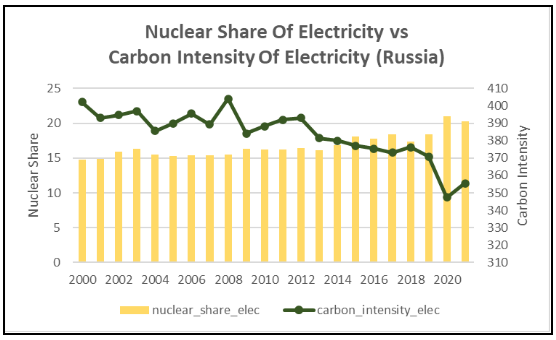
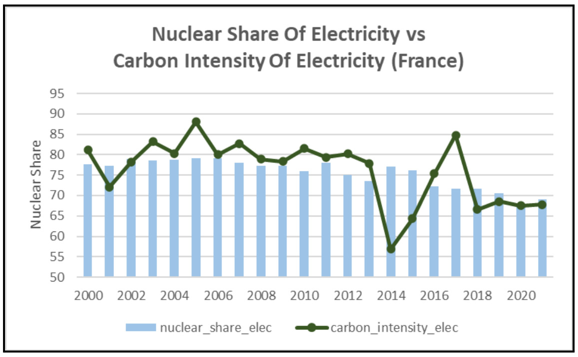


Figure 46: Nuclear Share of Electricity vs Carbon Intensity of Electricity (Russia)



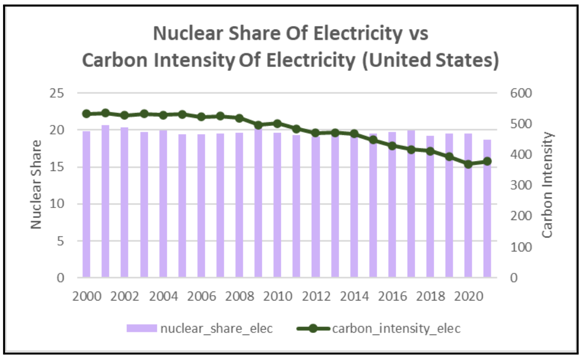


Figure 47: Nuclear Share of Electricity vs Carbon Intensity of Electricity (France)

Figure 48: Nuclear Share of Electricity vs Carbon Intensity of Electricity (United States)

Nuclear Energy and Its Impact on Economic Growth

For Russia, GDP per capita seems to have a positive relationship with nuclear share of electricity where GDP per capita increases proportionately as nuclear share electricity increases. For France, periods of high nuclear share (2000-2007) are accompanied by high GDP growth. For the United States, a relatively constant nuclear share of electricity with gradual increase in gdp per capita is observed. Hence, showing that nuclear energy is indeed economically feasible in terms of GDP.

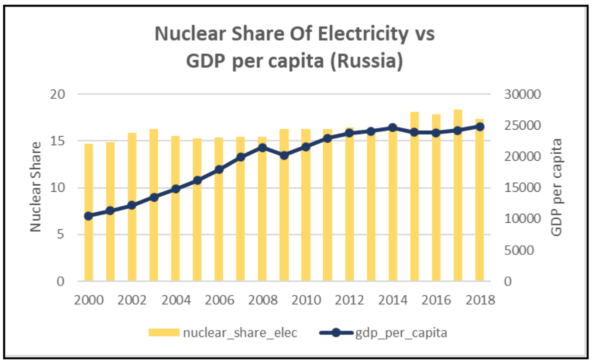
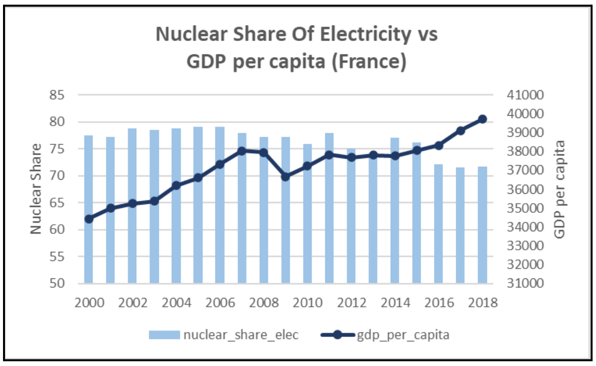


Figure 49: Nuclear Share of Electricity vs GDP per capita (Russia)



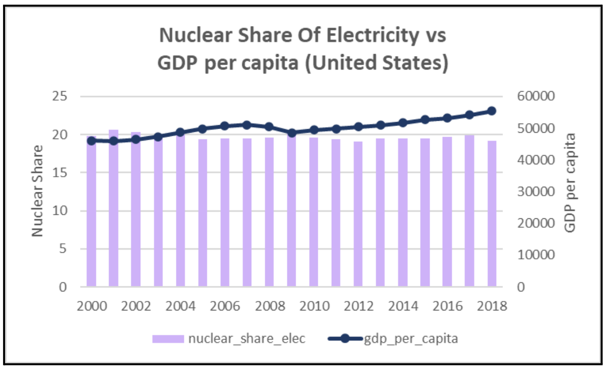


Figure 50: Nuclear Share of Electricity vs GDP per capita (France)

Figure 51: Nuclear Share of Electricity vs GDP per capita (United States)

Nuclear Energy and Its Impact on Efficiency of Electricity Generation

Efficiency measured in terms of output (electricity generation) over input (energy consumption) reveals that nuclear efficiency is highest followed by renewable efficiency and lastly fossil efficiency.

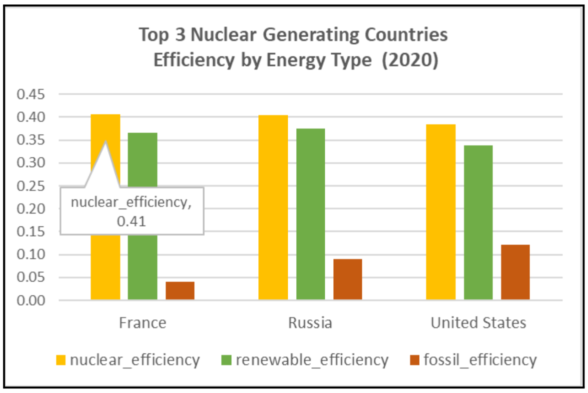


Figure 52: Top 3 Nuclear Generating Countries: Efficiency by energy type (2020)

Going Nuclear with Micro-Reactors

Recent technological developments on micro-nuclear reactors have made nuclear energy a realisable dream for Singapore. Microreactors have 3 main advantages.

Firstly, they are small and easily transportable. This allows reduction of Exclusion Area (EA) and Emergency Planning Zone (EPZ) which is favourable for Singapore due to its land constraints. Secondly, easy installation and removal. Microreactors contain few components and hence require fewer maintenance and operators. Within these few components, safety systems also prevent the risk of core overheating or meltdown, mitigating safety concerns (Office of Nuclear Electricity, 2021).

Lastly, microreactors have a relatively high cost efficiency. The levelized cost of energy (LCOE) of microreactors provide an estimate the electricity generation costs of micro reactors, which are approximated to be as low as 14 cents per kWH which is comparable to diesel generator costs which are currently utilised by Singapore that range between 16 - 60 cents per kWH. Hence, going nuclear in Singapore would allow electricity prices to remain the same, or potentially even decrease (Testoni Et Al., 2021).

Conclusion

To conclude, Singapore's geographical constraints and hence high import reliance and little alternative energy options make a compelling case for Singapore to go nuclear. However, in order to reap the benefits of nuclear energy, Singapore needs to emphasise on strong cooperation among research institutions, industry and regulatory bodies to continually develop technologies to improve safety and reduce risks of usage of microreactors, in the hopes to utilise clean, efficient and safe nuclear energy to propel Singapore to achieve its decarbonisation goals and improve self sufficiency in terms of its energy needs.

8. Debunking Skepticism Surrounding Climate Change (Q15)

Question: Despite the increasing awareness of environmental issues, some remain skeptical about climate change being a problem. Using the data provided, build a convincing data narrative to illustrate climate change problems associated with emissions.

Our Approach

To debunk the skepticisms surrounding climate change, we adopted a step-by-step data driven approach to analyse the causal relationship between emission and the resulting climate change. Firstly, we established the link between carbon emission from fossil fuels towards greenhouse gas (GHG) emission. Subsequently, we evaluated the corresponding changes in global temperatures and its effect on polar ice caps and sea levels. And lastly, the detriments to society as a result of these climate change related changes.

Fossil Fuels in Greenhouse Gas Emissions

Fossil fuels predominantly constitute oil, coal and gas. By analysing, summing up and averaging these values then doing the same for total CO2, we can see from below (see Figure 55) that fossil fuels constitute a large proportion of CO2 emission.

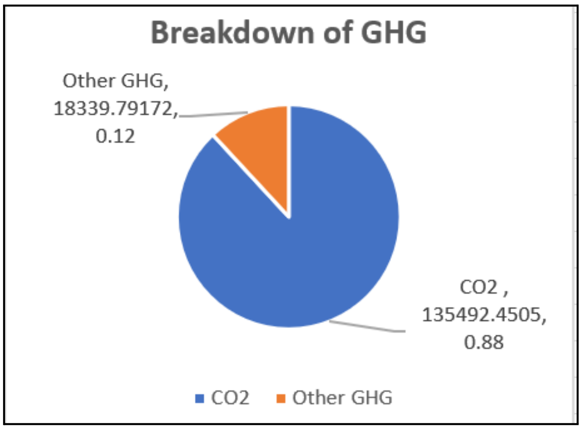


Figure 53: Breakdown of Greenhouse Gases

The figure on the right (see Figure 53) also shows that CO2 takes up a large proportion of greenhouse gases. By extension, fossil fuels contribute greatly to greenhouse gas emissions, consistently averaging about 80% over the years, evident from the time series plot on the right (see Figure 54).

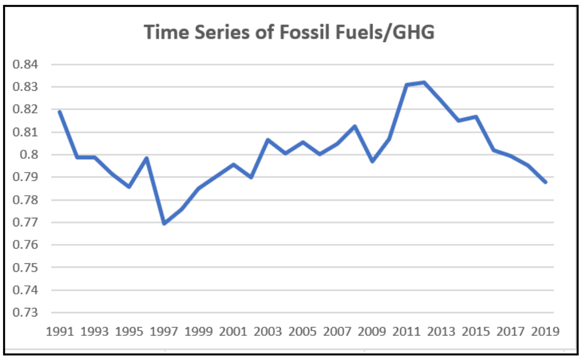


Figure 54: Percentage of Fossil Fuels to Greenhouse Gases of time

Furthermore, Figure 56 below clearly shows that total emissions of CO2 from fossil fuels, total CO2 emissions and total greenhouse gases emissions are all steadily increasing over the years, and this upward trend is certainly concerning with regards to climate change.

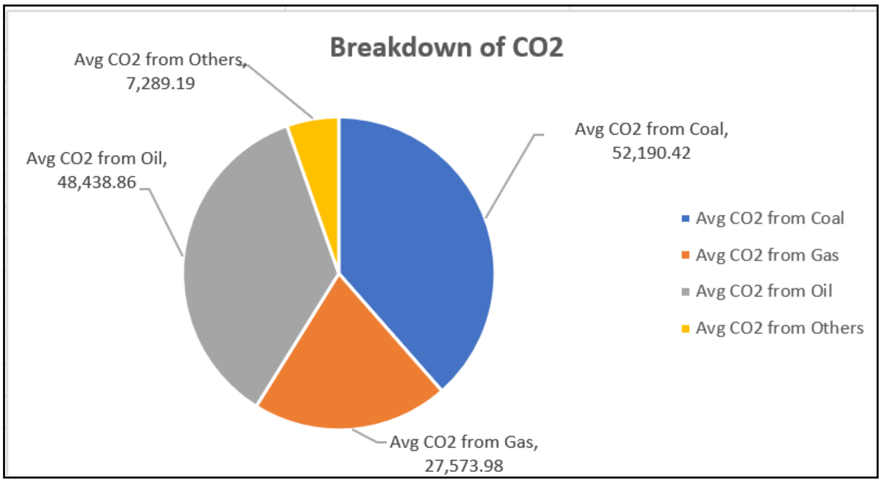


Figure 55: Breakdown of CO2 Emissions from Different Energy Consumptions

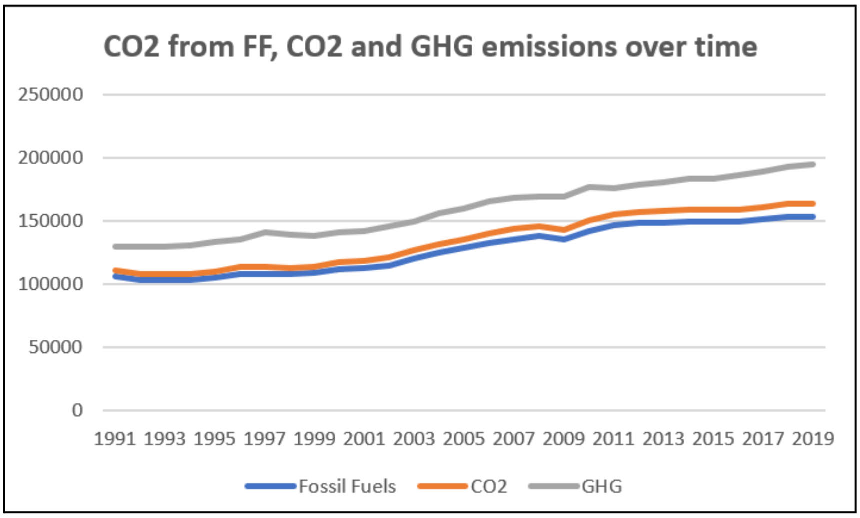


Figure 56: CO2 Emissions from Fossil Fuels, Total CO2 Emissions, Greenhouse Gas Emissions Over Time

Rising Temperatures from Greenhouse Gases

As greenhouse gas emissions increase, the average yearly land temperature is also undoubtedly on the rise in recent years, indicating correlation and perhaps a possibility of causation. This is shown in Figure 57 on the right.

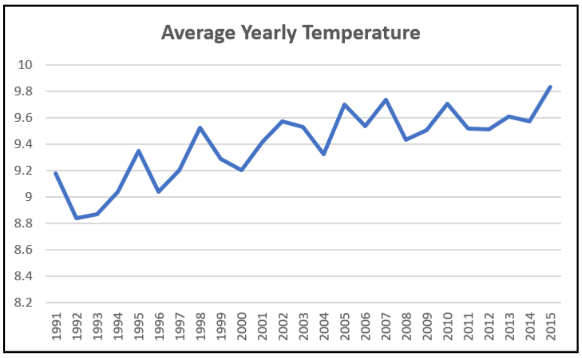


Figure 57: Average Yearly Temperature across the globe (2001 - 2015)

Melting Sea Ice & Rising Water Levels

As of 2018, the extent of sea ice in the northern and southern hemispheres has decreased significantly by 28.8% as a result of rising global temperatures (see Figure 58). With melting ice caps, sea levels have also risen by a huge margin as seen in Figure 59, with an estimate of 30mm increase since 2000 (Datahub.io, 2015).

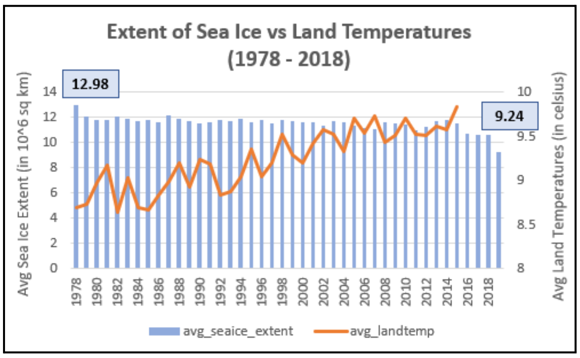


Figure 58: Extent of Sea Ice vs Land Temperatures since 1978

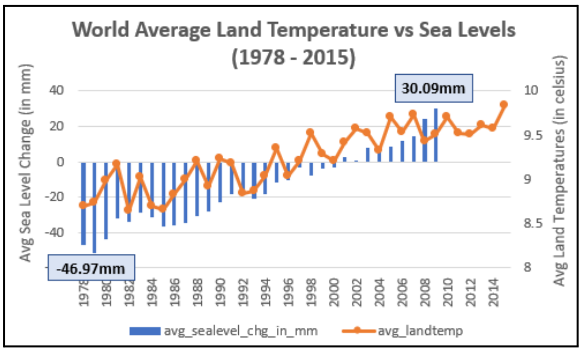


Figure 59: Sea Level Changes vs Land Temperatures since 1978

Societal Detriments

In order to paint a convincing narrative that climate change is indeed a problem, we will need to discuss the further implications it has or the threats it poses to the individual or society, for it to feel more relevant and closer to home.

As such, after understanding the associated physical changes brought about by high greenhouse gas emissions and climate change, such as changes in global temperatures and sea levels, we proceed to analyse the negative impacts climate change has on the societal level and point out the severity of such detriments in terms of socio-economic conditions. Only when climate change issues are current, severe and have close proximity to humans, will people start to realise the urgency and reality of climate change as a problem.

Risk to Low-Rise Regions

Rising sea levels poses a risk to populations living in low-rise regions and coastal areas. From Figure 60, we can observe that Asia and South America have an estimate of 10% of their population living 5 metres above sea levels and hence more prone to detrimental effects of rising sea levels (The World Bank, 2021).

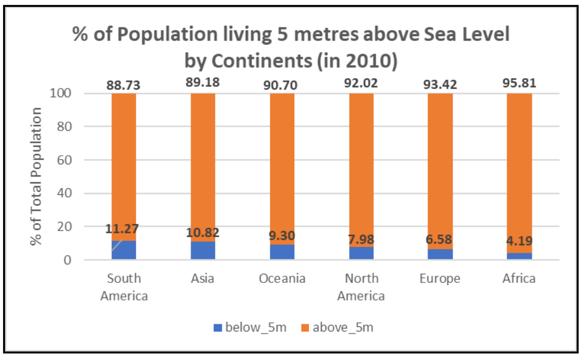


Figure 60: % of Population living 5 metres above sea level by continents (2010)

Climate Change Related Natural Disasters

Scoping into climate-change related natural disasters in Figure 61, we can observe that generally disasters have been occurring more frequently in recent years, with the bulk of disasters attributing to floods and storms (International Monetary Fund, 2020). We shall shift our focus towards the major events in our subsequent analysis and analyse the economic and societal impacts on a global scale.

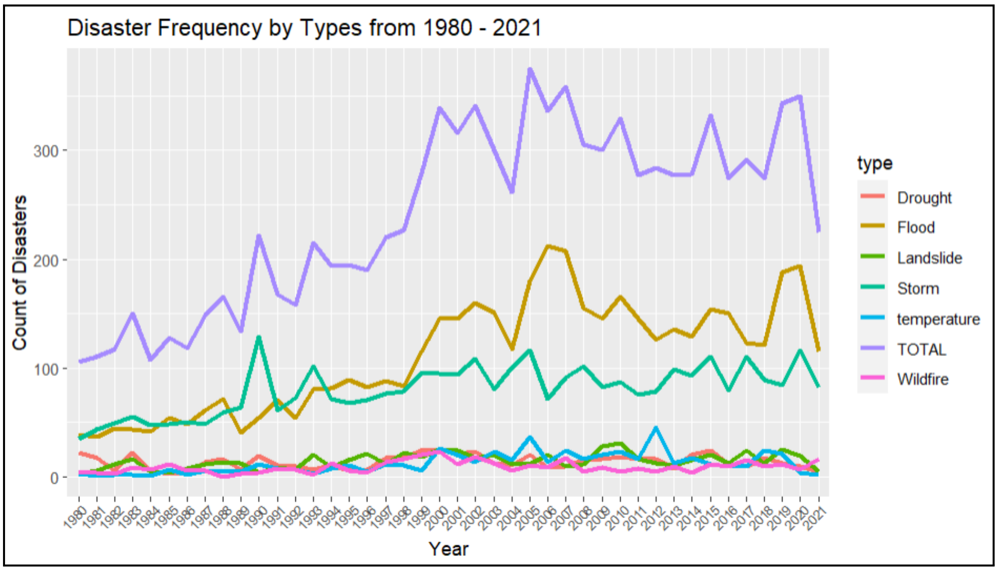


Figure 61: Climate Change Related Disaster Frequency (1980 - 2021)

Deaths and Economic Damages

Needless to say, natural disasters bring about radical consequences or aftermaths to the cities and populations struck. Death tolls can reach high numbers and the corresponding economic damages it poses on economics can be detrimental to a country's economic status. Therefore the extent of damage of natural disasters caused by climate change negatively implicates social and financial aspects of a country.

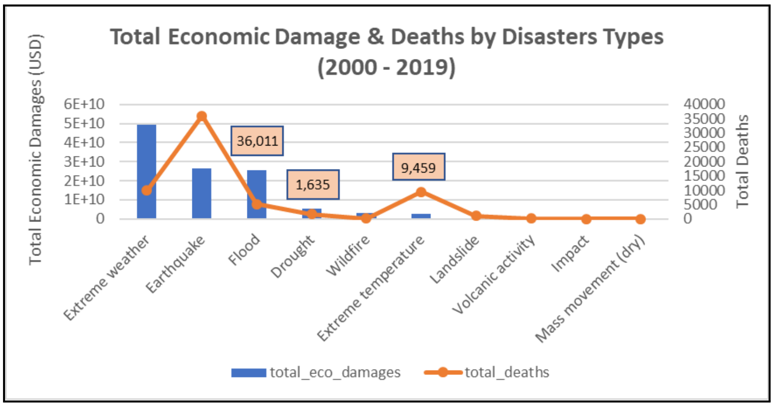


Figure 62: Total Economic Damages & Deaths by Disaster Types (2000 - 2019)

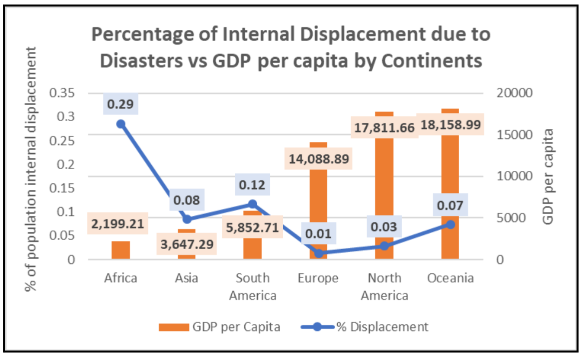


Figure 63: Percentage Internal Displacements due to Floods vs GDP per capita (2008 - 2021)

Flooding Internal Displacements

Extreme flooding may result in regions becoming inhabitable and populations may have to relocate for survivability, which disrupts economic growth. Based on Figure 63, we can observe that continents such as Africa and South America with lower GDP per capita experience more internal displacements (Internal Displacement Monitoring System, 2021). Climate change progression has worsened the flooding situations in these vulnerable regions and without adaptation measures, the severity continues to worsen (Kaoru Kakinuma, 2019).

Climate Change and Water-Borne Diseases

Another aspect of climate change is its impact on water-borne illnesses. The rise in temperature, increase in storm surges and precipitation uncertainty favour the survival, growth and spread of bacteria, supporting the outbreak of such water-borne diseases.

Furthermore, one of the many health consequences of flooding (which is also attributed to climate change as discussed above) apart from drowning and injuries is the outbreak of water-borne diseases. Floods contaminate sources of clean drinking water supply with sewage, chemicals and disease agents. For instance, the largest outbreak of cholera recorded in Kenya was in 1997, coinciding with the 1997 El Nino rains causing massive flooding. It had 17,200 cases and 555 deaths, and the situation did not improve but instead dragged on to 1998, with a total of 33,137 cases and 1,549 deaths (Okaka F. & Odhiambo B., 2018).

As climate change continues, the combination of high temperatures and flooding increases the possibility of pathogens being transported to and residing in recreational waters, and fosters their growth. Higher temperatures and altered precipitation patterns also promote the growth of harmful algal blooms which can contaminate fish and shellfish, the seafood that we consume (Physicians for Social Responsibility, n.d.). Over time, medical conditions or bacteria like Salmonella, Campylobacter and Legionnaires Disease start to develop and increase in prevalence, resulting in inevitable widespread health detriments to society, as well as economic disruptions as more will need to be spent on the healthcare industry to curb these illnesses.

Climate Change and Agricultural Production & Crop Yield

Climate change can have direct impacts on agricultural production and crop yield. "Higher growing season temperatures can significantly affect agricultural productivity, farm incomes and food security." (Battisti & Naylor, 2009) In seasonally arid and tropical regions, typically in the lower latitudes, temperatures may already be close to the optimal growing temperature for crops, such that slight increases can lead to heat stress on crops and water loss via evaporation, in turn being detrimental to crop production. Changes in climate could also result in the need to shift current farming practices to maintain productivity.

Extreme weather events like floods and droughts as discussed earlier will have similar, if not even more pronounced effects on agriculture. According to historical records, many of the negative anomalies in crop yield are attributed to climate variability, in particular precipitation extremes. (The Royal Society, 2010). Lobell & Burke (2008) report that variations in average precipitation by one standard deviation can result in up to a 10 percent change in production.

The world has been seeing an increase in agricultural land area being affected by drought since the 1960s, from about 5-10% to 15-25% (Li *et al*, 20009), further corroborating with our earlier findings in "Climate Change Related Disaster Frequency". Studies have also shown that there is a linear relationship between yield reduction rate (YRR) and prevalence of droughts indicated by the Palmer Drought Severity Index (PDSI), and it is estimated that drought-related yield reduction rates can go up to 50% by 2050 if climate change and the corresponding frequency of droughts keep up.

Similarly, heavy rainfall and floods can also lead to soil water logging, anaerobicity and reduced plant growth, and the rise in greenhouse gases is projected to link to an increase in intense rainfalls, according to research. There are many other climate change issues or disasters like extreme temperatures and tropical storms, and they each have their fair share in disrupting crop production and crop yields. One thing for sure is that climate change is undeniably detrimental to the agricultural industry, and by extension, the economy.

Conclusion

The main source of energy for most countries, if not the whole world, is fossil fuels, yet fossil fuels produce large amounts of carbon dioxide (almost all the carbon dioxide emitted is from fossil fuel consumption), which approximately equates to greenhouse gases since it constitutes the majority. Essentially, fossil fuels contribute greatly to greenhouse gas emissions and the upward trends of both are indicators of worsening climate change.

The most common and obvious impacts, or some might even argue indicators, of climate change are rising global temperatures, melting sea ice and rising sea levels. However, one might ask, “So what?” The slight increase in temperatures and minute changes in sea level seem trivial at first glance and hardly seem to be a problem we should be concerned about.

As such, we move onto the secondary consequences of climate change where we explore the health, economic and livelihood effects on the societal level. The severity and relevance of such consequences are more telling of how climate change is indeed a problem.

Climate change indirectly results in risks to populations living in low-rise regions, as it contributes to the over looming threats of natural disasters like floods and droughts, which in turn inevitably leads to death tolls, societal and economic damages. There are countless ways where climate change can affect our society, mostly negatively, like the outbreak of water-borne diseases and crop yield reduction in the agricultural industry, just to name a few.

To those who remain skeptical, if this is not sufficient evidence to convince that climate change is undoubtedly a problem close to home that requires urgent action, then what is?

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10. Appendix

10.1. mySQL Queries

Q1. How many countries are captured in [owid_energy_data]?

Output

country	iso_code
Afghanistan	AFG
Albania	ALB
Algeria	DZA
American Samoa	ASM
Angola	AGO
Antigua and Barbuda	ATG
Argentina	ARG
Armenia	ARM
Aruba	ABW
Australia	AUS

(217 row(s) returned)

Q2. Find the earliest and latest year in [owid_energy_data]. What are the countries having a record in <owid_energy_data> every year throughout the entire period (from the earliest year to the latest year)?

Output

MinYear	MaxYear	TotalRecordYear
1900	2021	122

country	countOfYears
Argentina	122
Australia	122
Austria	122
Bangladesh	122
Belgium	122
Bolivia	122
Brazil	122
Bulgaria	122

(44 row(s) returned)

Q3. Specific to Singapore, in which year does <fossil_share_energy> stop being the full source of energy (i.e., <100)? Accordingly, show the new sources of energy.

Output

year	country	low_carbon_share_energy	other_renewables_share_energy	renewables_share_energy	solar_share_energy
1986	Singapore	0.143	0.143	0.143	0
1987	Singapore	0.136	0.136	0.136	0
1988	Singapore	0.118	0.118	0.118	0
1989	Singapore	0.103	0.103	0.103	0
1990	Singapore	0.086	0.086	0.086	0
1991	Singapore	0.245	0.245	0.245	0
1992	Singapore	0.228	0.228	0.228	0
1993	Singapore	0.209	0.209	0.209	0
1994	Singapore	0.182	0.182	0.182	0
1995	Singapore	0.175	0.175	0.175	0

(35 row(s) returned)

Year 1986.
Fossil fuel consists of gas, coal and oil and hence all 4 types of energy are removed from consideration.
Low carbon includes other renewables and nuclear energy.
Renewables include other renewables (including biofuels), hydro, solar and wind energy. However, biofuels, hydro, wind and nuclear energy remained 0 throughout and are hence removed as well.

Q4. Compute the average <GDP> of each ASEAN country from 2000 to 2021 (inclusive of both years). Display the list of countries based on the descending average GDP value.

Output

country	avg_gdp
Indonesia	1970289338615.0527
Thailand	850644159074.579
Philippines	561245634399.8948
Malaysia	508048012556.8421
Vietnam	404540388126.5263
Singapore	277187081428.4737
Myanmar	189145793585.21054
Cambodia	36252651482.68421
Laos	26084002724.68421

(9 row(s) returned)

There are quite a number of records/rows with missing GDP values, we excluded those null rows and calculated average GDP using only existing GDP data. Brunei had missing gdp values for all records from 2000 to 2021, which is why it didn't appear in the final results.

Q5. (Without creating additional tables/collections) For each ASEAN country, from 2000 to 2021 (inclusive of both years), compute the 3-year moving average of <oil_consumption> (e.g., 1st: average oil consumption from 2000 to 2002, 2nd: average oil consumption from 2001 to 2003, etc.). Based on the 3-year moving averages, identify instances of negative changes (e.g., An instance of negative change is detected when 1st 3-yo average = 74.232, 2nd 3-yo average = 70.353). Based on the pair of 3-year averages, compute the corresponding 3-year moving averages in GDP.

Output

country	duration_3YMA	GDP_3YMA
Indonesia	2012 - 2014	2404351577135
Indonesia	2013 - 2015	2527840615714.3335
Indonesia	2014 - 2016	2653406947698.3335
Indonesia	2015 - 2017	2785879843874.3335
Indonesia	2017 - 2019	2999863669792.5
Indonesia	2018 - 2020	3075456084370
Malaysia	2007 - 2009	468794830234
Malaysia	2008 - 2010	489133234422.6667
Malaysia	2012 - 2014	605262962087.6666
Malaysia	2013 - 2015	636911028203.3334
Malaysia	2014 - 2016	669024648017.6666
Malaysia	2015 - 2017	702434988315.6666
Malaysia	2016 - 2018	736942736520.6666
Malaysia	2017 - 2019	756149085729
Malaysia	2018 - 2020	773658537411
Philippines	2000 - 2002	339520983115.3333
Philippines	2001 - 2003	355380670728.3333

(33 row(s) returned)

We calculated 3Y-MA based on available GDP values. For cases of missing GDP values we calculated the moving average as such (1st Year = 20, 2nd Year = 0, 3rd Year = 0, 3Y-MA = 20). Null GDP_3YMA indicates that there are no GDP values for periods with negative instances for oil_3YMA.

Q6. For each <energy_products> and <sub_products>, display the overall average of <value_ktoe> from [importsofenergyproducts] and [exportsofenergyproducts].
Output

energy_products	sub_products	import_overallavg	export_overallavg
Coal and Peat	Coal and Peat	239.1687499999973	0.9499999999999994
Crude Oil	Crude Oil	50975.97499999994	60.15000000000001
Crude Oil	Other Crude Oil	1755.1437499999975	1031.1312500000004
Petroleum Products	Fuel Oil	56357.30000000006	23343.762500000004
Petroleum Products	Gas/Diesel Oil	12571.96874999999	22540.906249999996
Petroleum Products	Gasoline	13715.549999999996	22908.562500000007
Petroleum Products	Jet Fuel Kerosene	2391.4312500000037	6116.337499999997
Petroleum Products	Naphtha	6430.506249999992	1184.6250000000014
Petroleum Products	Other Petroleum Products	2030.0437499999966	7785.743749999994

(9 row(s) returned)

Q7. For each combination of <energy_products> and <sub_products>, find the yearly difference in <value_ktoe> from [importsofenergyproducts] and [exportsofenergyproducts]. Identify those years where more than 4 instances of export value > import value can be detected.
Output

Yearly difference in <value_ktoe>:

year	energy_products	sub_products	yearly_diff
2005	Coal and Peat	Coal and Peat	-7.8999999999999995
2005	Crude Oil	Crude Oil	-58707.299999999996
2005	Crude Oil	Other Crude Oil	-602.8
2005	Petroleum Products	Fuel Oil	-13484.5
2005	Petroleum Products	Gas/Diesel Oil	11209.099999999999
2005	Petroleum Products	Gasoline	7563.5
2005	Petroleum Products	Jet Fuel Kerosene	4774.6
2005	Petroleum Products	Naphtha	-1624.8000000000002
2005	Petroleum Products	Other Petroleum Products	5882.9
2006	Coal and Peat	Coal and Peat	-3.8000000000000003
2006	Crude Oil	Crude Oil	-56536.4
2006	Crude Oil	Other Crude Oil	-867.0000000000001
2006	Petroleum Products	Fuel Oil	-17796.199999999997
2006	Petroleum Products	Gas/Diesel Oil	10956.199999999999
2006	Petroleum Products	Gasoline	7210.200000000001

(144 row(s) returned)

Identified years where more than 4 instances of export value > import value can be detected:

year
2014

(1 row(s) returned)

2014 is the only year where 5 instances of export value > import value can be detected.

Q8. In [householdelectricityconsumption], for each <region>, excluding “overall”, generate the yearly average <kwh_per_acc>.

Output

	region	year	avg(kwh_per_acc)
▶	Central Region	2005	537.9000244140625
	Central Region	2006	537.2999877929688
	Central Region	2007	538
	Central Region	2008	525.5999755859375
	Central Region	2009	543.5999755859375
	Central Region	2010	548.5
	Central Region	2011	530.7000122070312
	Central Region	2012	534.2000122070312
	Central Region	2013	536.4000244140625
	Central Region	2014	535.9000244140625
	Central Region	2015	538.0999755859375
	Central Region	2016	548.2999877929688

(85 row(s) returned)
We filtered <dwelling_type> = “Overall”, <month> = “Annual”, as well as <description> = “____ Region” (i.e. filter out all the different descriptions like Bishan, Bukit Merah, etc. and only take the rows where the description corresponds with the region like Central Region, North Region, etc.), because we assume the <kwh_per_acc> in those filtered rows refer to the yearly average of that region.

Q9. Who are the energy-saving stars? Compute the yearly average of <kwh_per_acc> in each region, excluding “overall”. Generate the moving 2-year average difference (i.e., year 1 average kwh_per_acc for the central region = 1223, year 2 = 1000, the moving 2-year average difference = -223). Display the top 3 regions with the most instances of negative 2-year averages.

Output

Yearly Average

	year	region	yearlyavg
	2005	Central Region	537.9000244140625
	2006	Central Region	537.2999877929688
	2007	Central Region	538
	2008	Central Region	525.5999755859375
	2009	Central Region	543.5999755859375
	2010	Central Region	548.5
	2011	Central Region	530.7000122070312
	2012	Central Region	534.2000122070312
	2013	Central Region	536.4000244140625
	2014	Central Region	535.9000244140625
▸	2015	Central Region	538.0999755859375
	2016	Central Region	548.2999877929688
	2017	Central Region	509.200012207031...

(85 row(s) returned)

2-Year Moving Averages

	region	moving2Ydurati...	moving2Yavg
▸	Central Region	2005-2006	-0.60003662109375
	Central Region	2007-2008	-12.4000244140625
	Central Region	2010-2011	-17.79998779296875
	Central Region	2013-2014	-0.5
	Central Region	2016-2017	-39.0999755859375
	Central Region	2017-2018	-17.5
	Central Region	2020-2021	-26.4000244140625
	East Region	2005-2006	-6
	East Region	2007-2008	-15.5
	East Region	2010-2011	-21.399993896484375
	East Region	2013-2014	-2.70001220703125
	East Region	2014-2015	-0.100006103515625
	East Region	2016-2017	-31.9000244140625
	East Region	2017-2018	-19.199981689453125

(42 row(s) returned)

	region	NoOfInstances
▸	North East Region	11
	West Region	9
	East Region	8
	Central Region	7
	North Region	7

(5 row(s) returned)

Energy-saving Stars are North East, West and East Regions based on the top 3 regions with the most instances of negative 2-year averages.

Q10. Are there any seasonal (quarterly) effects on energy consumption? Visualizations are typically required to eyeball the effects. For each region, in each year, compute the quarterly average in <kwh_per_acc>. Exclude "Overall" in <region>.

Note: 1st quarter = January, February, and March, 2nd quarter = April, May, and June, and so on.

Output

	year	Region	quarter	avg_kwh_per_acc	Scaled_avg_kwh
▸	2005	Central Region	1	481.53333536783856	**
	2005	Central Region	2	576.5999959309896	***
	2005	Central Region	3	553.1666666666666	**
	2005	Central Region	4	539.6666666666666	***
	2005	East Region	1	443.90000406901044	***
	2005	East Region	2	536.2999979654948	***
	2005	East Region	3	511.8333231608073	***
	2005	East Region	4	483.7666727701823	***
	2005	North East Region	1	397.2999979654948	************************
	2005	North East Region	2	472.3666585286458	***
	2005	North East Region	3	462.43332926432294	**
	2005	North East Region	4	436.26666259765625	***
	2005	North Region	1	375.76666259765625	*************
	2005	North Region	2	431.8999938964844	***

(330 row(s) returned)

Observation
From our plot, we can notice that generally within a year, energy consumption is lowest in the 1st quarter and greatest in the 2nd quarter, and as the quarters progresses from 2nd to 4th quarter, energy consumption decreases.

Q11. Consider [householdtowngasconsumption]. Are there any seasonal (quarterly) effects on town gas consumption? For each <sub_housing_type>, in each year, compute the quarterly average in <avg_mthly_hh_tg_consp_kwh>. Exclude "Overall" in <sub_housing_type>.

Output

sub_housing_type	year	quarter	avg_qtrly_hh_tg_consp_kwh
1 Room and 2 Room	2005	1	64.5666666666666
1 Room and 2 Room	2005	2	62.833333333333336
1 Room and 2 Room	2005	3	61.366666666666674
1 Room and 2 Room	2005	4	61.333333333333336
1 Room and 2 Room	2006	1	61.76666666666667
1 Room and 2 Room	2006	2	59.166666666666664
1 Room and 2 Room	2006	3	59.333333333333336
1 Room and 2 Room	2006	4	61.06666666666666
1 Room and 2 Room	2007	1	61.06666666666666
1 Room and 2 Room	2007	2	59.800000000000004
1 Room and 2 Room	2007	3	58.70000000000001
1 Room and 2 Room	2007	4	59.86666666666667
1 Room and 2 Room	2008	1	60.6

(396 row(s) returned)

Assumption

Assume that there are a total of 6 sub housing types consisting of 2 sub housing types of Private Housing (ie. Landed Properties, Private Apartments and Condominiums) and 4 sub housing types of Public Housing (ie. 1 room and 2 room, 3 room, 4 room, 5 room and executive)

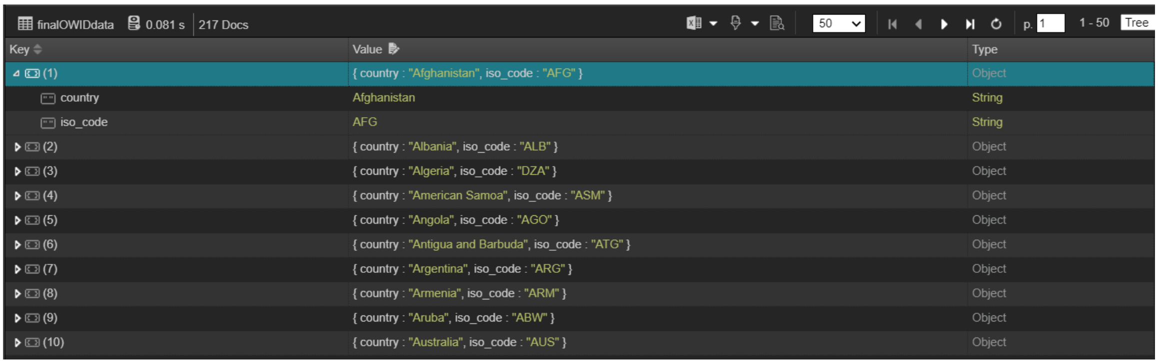
Observation

We can observe that within a year, town gas consumption is highest in the 1st quarter and generally decreases throughout the rest of the year through the 2nd to 4th quarter.

10.2. noSQL Queries

Q1. How many countries are captured in [owid_energy_data]?

Output



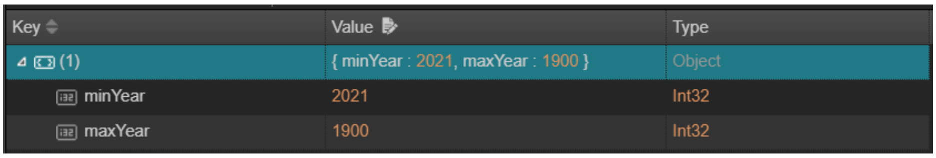
finalOWIDdata 0.081 s 217 Docs

Key	Value	Type
(1)	{ country : "Afghanistan", iso_code : "AFG" }	Object
country	Afghanistan	String
iso_code	AFG	String
(2)	{ country : "Albania", iso_code : "ALB" }	Object
(3)	{ country : "Algeria", iso_code : "DZA" }	Object
(4)	{ country : "American Samoa", iso_code : "ASM" }	Object
(5)	{ country : "Angola", iso_code : "AGO" }	Object
(6)	{ country : "Antigua and Barbuda", iso_code : "ATG" }	Object
(7)	{ country : "Argentina", iso_code : "ARG" }	Object
(8)	{ country : "Armenia", iso_code : "ARM" }	Object
(9)	{ country : "Aruba", iso_code : "ABW" }	Object
(10)	{ country : "Australia", iso_code : "AUS" }	Object

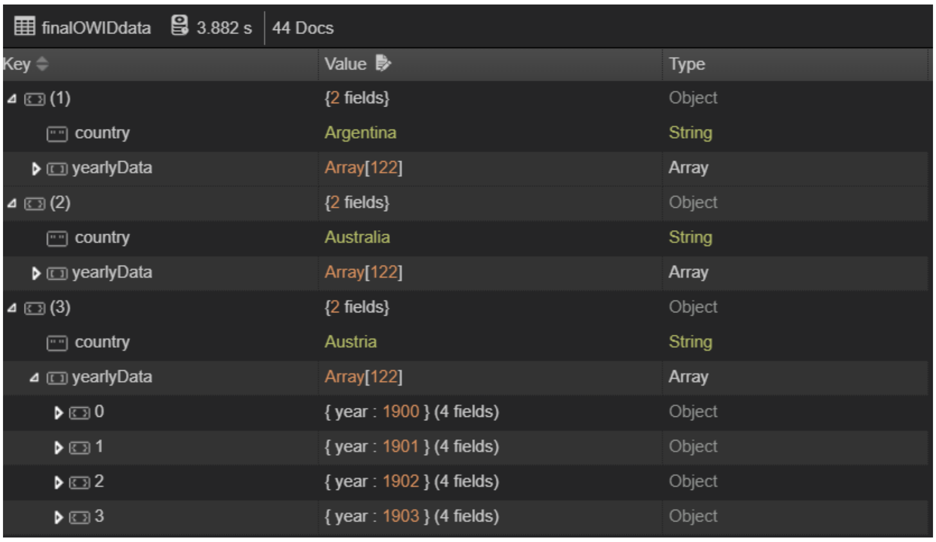
(217 row(s) returned)

Q2. Find the earliest and latest year in [owid_energy_data]. What are the countries having a record in <owid_energy_data> every year throughout the entire period (from the earliest year to the latest year)?

Output



Key	Value	Type
(1)	{ minYear : 2021, maxYear : 1900 }	Object
minYear	2021	Int32
maxYear	1900	Int32



finalOWIDdata 3.882 s 44 Docs

Key	Value	Type
(1)	{2 fields}	Object
country	Argentina	String
yearlyData	Array[122]	Array
(2)	{2 fields}	Object
country	Australia	String
yearlyData	Array[122]	Array
(3)	{2 fields}	Object
country	Austria	String
yearlyData	Array[122]	Array
0	{ year : 1900 } (4 fields)	Object
1	{ year : 1901 } (4 fields)	Object
2	{ year : 1902 } (4 fields)	Object
3	{ year : 1903 } (4 fields)	Object

(44 Doc(s) returned)

Q3. Specific to Singapore, in which year does <fossil_share_energy> stop being the full source of energy (i.e., <100)? Accordingly, show the new sources of energy.

Output

finalOWIDdata 0.049 s | 80 Docs

	_id	country	energy	energy_share	fossil_share	year
1	6373536016a1b2c13fd	Singapore	other_renewables	0.143	99.857	1986
2	6373536016a1b2c13fd	Singapore	renewables	0.143	99.857	1986
3	6373536016a1b2c13fd	Singapore	low_carbon	0.143	99.857	1986
4	6373536016a1b2c13fd	Singapore	other_renewables	0.136	99.864	1987
5	6373536016a1b2c13fd	Singapore	renewables	0.136	99.864	1987
6	6373536016a1b2c13fd	Singapore	low_carbon	0.136	99.864	1987
7	6373536016a1b2c13fd	Singapore	other_renewables	0.118	99.882	1988
8	6373536016a1b2c13fd	Singapore	low_carbon	0.118	99.882	1988
9	6373536016a1b2c13fd	Singapore	renewables	0.118	99.882	1988
10	6373536016a1b2c13fd	Singapore	low_carbon	0.103	99.897	1989

(80 doc(s) returned)

Year: 1986
We excluded other_renewables_exc_biofuels since there is no energy_share data as well as null values for energy_share.

Q4. Compute the average <GDP> of each ASEAN country from 2000 to 2021 (inclusive of both years). Display the list of countries based on the descending average GDP value.

Output

finalOWIDdata 0.023 s | 9 Docs

Key	Value
(1) Indonesia	{ avg_gdp : 1970289338615.0527 }
(2) Thailand	{ avg_gdp : 850644159074.579 }
(3) Philippines	{ avg_gdp : 561245634399.8948 }
(4) Malaysia	{ avg_gdp : 508048012556.8421 }
(5) Vietnam	{ avg_gdp : 404540388126.5263 }
(6) Singapore	{ avg_gdp : 277187081428.4737 }
(7) Myanmar	{ avg_gdp : 189145793585.21054 }
(8) Cambodia	{ avg_gdp : 36252651482.68421 }
(9) Laos	{ avg_gdp : 26084002724.68421 }

(9 doc(s) returned)

As mentioned earlier, noSQL disregards null GDP values during their calculation of average, hence we will notice that Brunei average GDP will be null since no values are available so we excluded it from our results.

Q5. (Without creating additional tables/collections) For each ASEAN country, from 2000 to 2021 (inclusive of both years), compute the 3-year moving average of <oil_consumption> (e.g., 1st: average oil consumption from 2000 to 2002, 2nd: average oil consumption from 2001 to 2003, etc.). Based on the 3-year moving averages, identify instances of negative changes (e.g., An instance of negative change is detected when 1st 3-yo average = 74.232, 2nd 3-yo average = 70.353). Based on the pair of 3-year averages, compute the corresponding 3-year moving averages in GDP.

Output

finalOWIDdata | 0.299 s | 33 Docs | 50

Key	Value
(1)	{ country : "Indonesia", period_3YMA : "2012-2014", gdp_3YMA : 2404351577135 }
(2)	{ country : "Indonesia", period_3YMA : "2013-2015", gdp_3YMA : 2527840615714.3335 }
(3)	{ country : "Indonesia", period_3YMA : "2014-2016", gdp_3YMA : 2653406947698.3335 }
(4)	{ country : "Indonesia", period_3YMA : "2015-2017", gdp_3YMA : 2785879843874.3335 }
(5)	{ country : "Indonesia", period_3YMA : "2017-2019", gdp_3YMA : 2999863669792.5 }
(6)	{ country : "Indonesia", period_3YMA : "2018-2020", gdp_3YMA : 3075456084370 }
(7)	{ country : "Malaysia", period_3YMA : "2007-2009", gdp_3YMA : 468794830234 }
(8)	{ country : "Malaysia", period_3YMA : "2008-2010", gdp_3YMA : 489133234422.6667 }
(9)	{ country : "Malaysia", period_3YMA : "2012-2014", gdp_3YMA : 605262962087.6666 }
(10)	{ country : "Malaysia", period_3YMA : "2013-2015", gdp_3YMA : 636911028203.3334 }

(33 Docs returned)

We removed years where there are null GDP values since this would indicate missing data for GDP. Furthermore, our calculation of 3Y MA is based on existing values, so for missing values indicated as null, noSQL automatically disregards it during its calculation. Calculation of 3Y MA is as such (1st Year = 20, 2nd Year = 0, 3rd Year = 0, 3Y-MA = 20).

Q6. For each <energy_products> and <sub_products>, display the overall average of <value_ktoe> from [importsofenergyproducts] and [exportsofenergyproducts].

Output

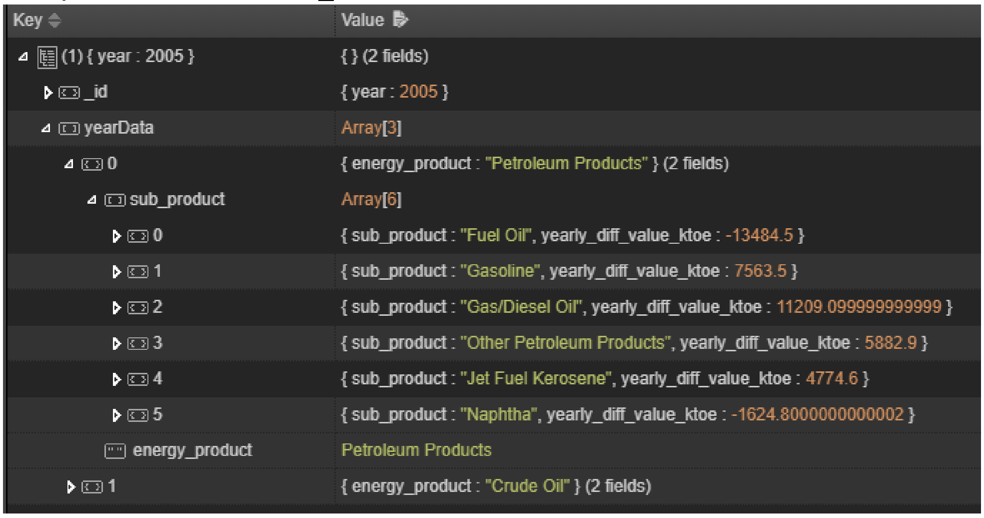
finalSGYearlyData | 0.014 s | 9 Docs

Key	Value
(1) { name : "Coal and Peat", sub_products : "Coal and Pe	{ overall_avg_exports_ktoe : 0.95, overall_avg_imports_ktoe : 239.16875 }
(2) { name : "Petroleum Products", sub_products : "Other F	{ overall_avg_exports_ktoe : 7785.74375, overall_avg_imports_ktoe : 2030.04375 }
(3) { name : "Petroleum Products", sub_products : "Naphth	{ overall_avg_exports_ktoe : 1184.625, overall_avg_imports_ktoe : 6430.50625 }
(4) { name : "Petroleum Products", sub_products : "Fuel Oi	{ overall_avg_exports_ktoe : 23343.7625, overall_avg_imports_ktoe : 56357.3 }
(5) { name : "Petroleum Products", sub_products : "Jet Fue	{ overall_avg_exports_ktoe : 6116.3375, overall_avg_imports_ktoe : 2391.43125 }
(6) { name : "Petroleum Products", sub_products : "Gas/Di	{ overall_avg_exports_ktoe : 22540.90625, overall_avg_imports_ktoe : 12571.96875 }
(7) { name : "Petroleum Products", sub_products : "Gasolir	{ overall_avg_exports_ktoe : 22908.5625, overall_avg_imports_ktoe : 13715.55 }
(8) { name : "Crude Oil", sub_products : "Crude Oil" }	{ overall_avg_exports_ktoe : 60.15, overall_avg_imports_ktoe : 50975.975 }
(9) { name : "Crude Oil", sub_products : "Other Crude Oil" }	{ overall_avg_exports_ktoe : 1031.13125, overall_avg_imports_ktoe : 1755.14375 }

(9 row(s) returned)

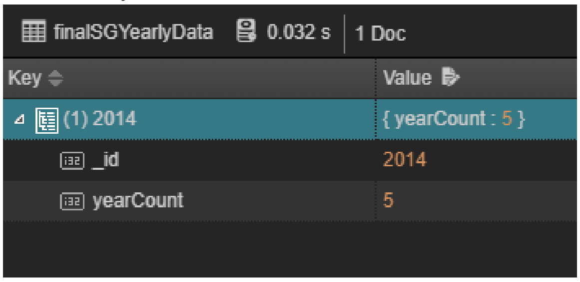
Q7. For each combination of <energy_products> and <sub_products>, find the yearly difference in <value_ktoe> from [importsofenergyproducts] and [exportsofenergyproducts]. Identify those years where more than 4 instances of export value > import value can be detected.
Output

Yearly difference in <value_ktoe>:



(16 Docs returned)

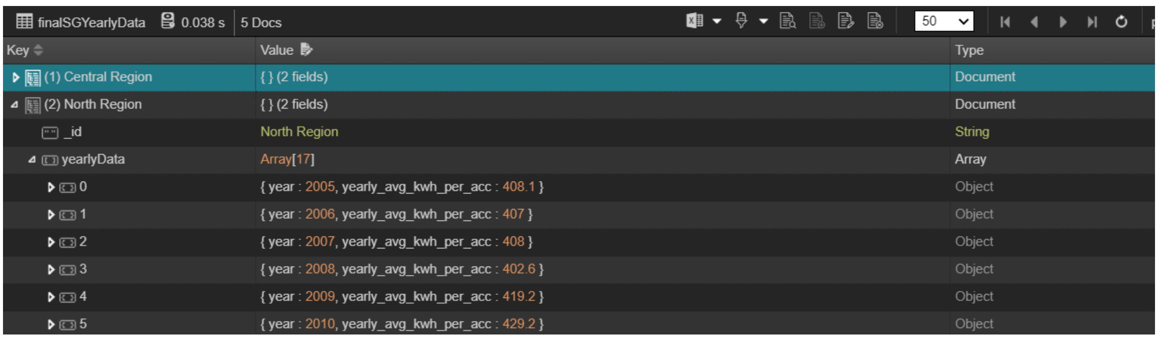
Identified years where more than 4 instances of export value > import value can be detected:



2014 is the only year where 5 instances of export value > import value can be detected.

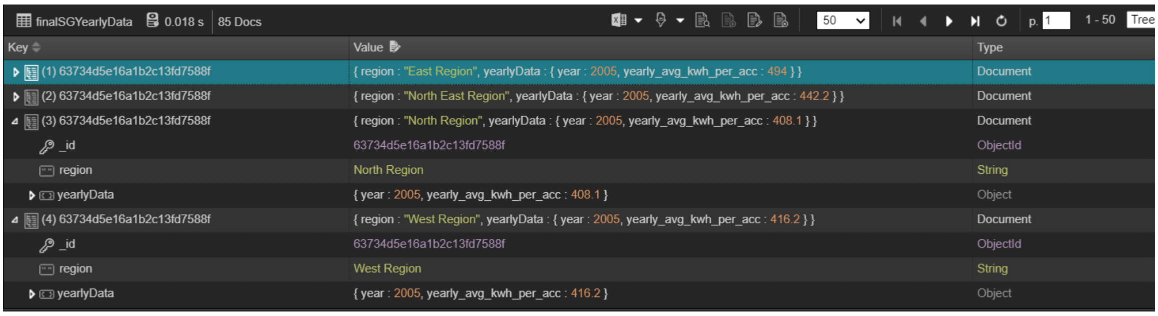
(1 Doc(s) returned)

Q8. In [householdelectricityconsumption], for each <region>, excluding "overall", generate the yearly average <kwh_per_acc>.
Output



(5 doc(s) returned)

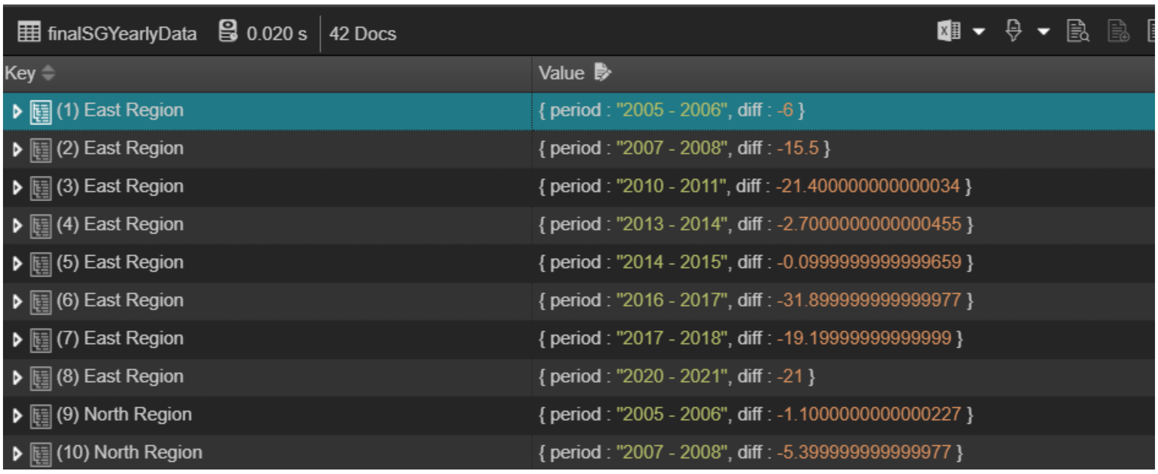
Q9. Who are the energy-saving stars? Compute the yearly average of <kwh_per_acc> in each region, excluding "overall". Generate the moving 2-year average difference (i.e., year 1 average kwh_per_acc for the central region = 1223, year 2 = 1000, the moving 2-year average difference = -223). Display the top 3 regions with the most instances of negative 2-year averages.
Output



finalSGYearlyData 0.018 s 85 Docs

Key	Value	Type
(1) 63734d5e16a1b2c13fd7588f	{ region : "East Region", yearlyData : { year : 2005, yearly_avg_kwh_per_acc : 494 } }	Document
(2) 63734d5e16a1b2c13fd7588f	{ region : "North East Region", yearlyData : { year : 2005, yearly_avg_kwh_per_acc : 442.2 } }	Document
(3) 63734d5e16a1b2c13fd7588f	{ region : "North Region", yearlyData : { year : 2005, yearly_avg_kwh_per_acc : 408.1 } }	Document
_id	63734d5e16a1b2c13fd7588f	ObjectId
region	North Region	String
yearlyData	{ year : 2005, yearly_avg_kwh_per_acc : 408.1 }	Object
(4) 63734d5e16a1b2c13fd7588f	{ region : "West Region", yearlyData : { year : 2005, yearly_avg_kwh_per_acc : 416.2 } }	Document
_id	63734d5e16a1b2c13fd7588f	ObjectId
region	West Region	String
yearlyData	{ year : 2005, yearly_avg_kwh_per_acc : 416.2 }	Object

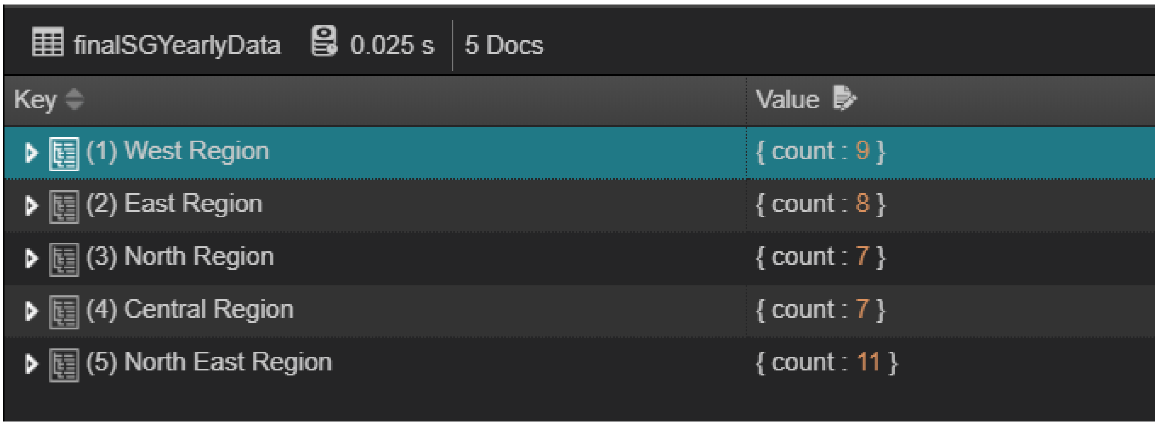
(85 row(s) returned)



finalSGYearlyData 0.020 s 42 Docs

Key	Value
(1) East Region	{ period : "2005 - 2006", diff : -6 }
(2) East Region	{ period : "2007 - 2008", diff : -15.5 }
(3) East Region	{ period : "2010 - 2011", diff : -21.400000000000034 }
(4) East Region	{ period : "2013 - 2014", diff : -2.7000000000000455 }
(5) East Region	{ period : "2014 - 2015", diff : -0.0999999999999659 }
(6) East Region	{ period : "2016 - 2017", diff : -31.899999999999977 }
(7) East Region	{ period : "2017 - 2018", diff : -19.19999999999999 }
(8) East Region	{ period : "2020 - 2021", diff : -21 }
(9) North Region	{ period : "2005 - 2006", diff : -1.1000000000000227 }
(10) North Region	{ period : "2007 - 2008", diff : -5.399999999999977 }

(42 row(s) returned)



finalSGYearlyData 0.025 s 5 Docs

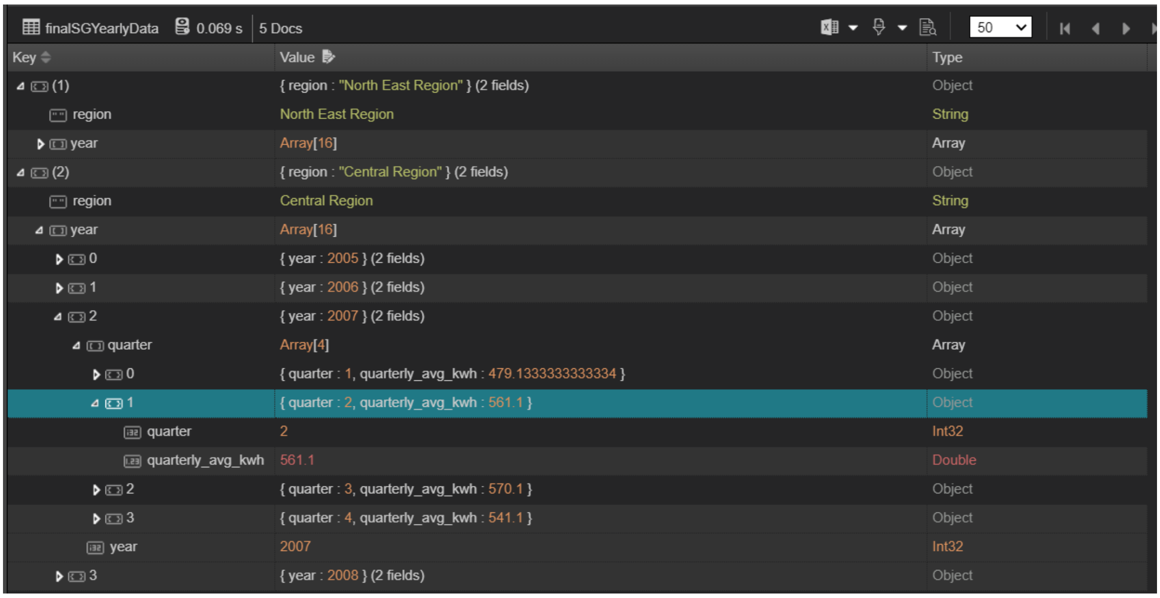
Key	Value
(1) West Region	{ count : 9 }
(2) East Region	{ count : 8 }
(3) North Region	{ count : 7 }
(4) Central Region	{ count : 7 }
(5) North East Region	{ count : 11 }

(5 row(s) returned)

Q10. Are there any seasonal (quarterly) effects on energy consumption? Visualizations are typically required to eyeball the effects. For each region, in each year, compute the quarterly average in <kwh_per_acc>. Exclude “Overall” in <region>.

Note: 1st quarter = January, February, and March, 2nd quarter = April, May, and June, and so on.

Output



finalSGYearlyData 0.069 s 5 Docs 50

Key	Value	Type
(1)	{ region : "North East Region" } (2 fields)	Object
region	North East Region	String
year	Array[16]	Array
(2)	{ region : "Central Region" } (2 fields)	Object
region	Central Region	String
year	Array[16]	Array
0	{ year : 2005 } (2 fields)	Object
1	{ year : 2006 } (2 fields)	Object
2	{ year : 2007 } (2 fields)	Object
quarter	Array[4]	Array
0	{ quarter : 1, quarterly_avg_kwh : 479.1333333333334 }	Object
1	{ quarter : 2, quarterly_avg_kwh : 561.1 }	Object
quarter	2	Int32
quarterly_avg_kwh	561.1	Double
2	{ quarter : 3, quarterly_avg_kwh : 570.1 }	Object
3	{ quarter : 4, quarterly_avg_kwh : 541.1 }	Object
year	2007	Int32
3	{ year : 2008 } (2 fields)	Object

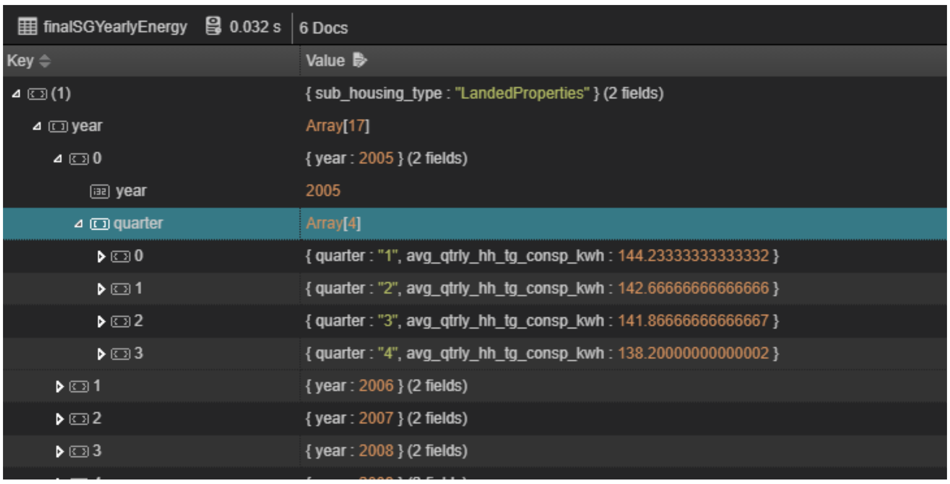
(5 Docs returned)

<u>Observation</u>

Based on each region and their respective years, the trend we can observe is that 1st quarter is the lowest and 2nd quarter is the highest, and progressing from 2nd to 4th quarter, the energy consumption decreases.

Q11. Consider [householdtowngasconsumption]. Are there any seasonal (quarterly) effects on town gas consumption? For each <sub_housing_type>, in each year, compute the quarterly average in <avg_mthly_hh_tg_consp_kwh>. Exclude “Overall” in <sub_housing_type>.

Output



finalSGYearlyEnergy 0.032 s 6 Docs

Key	Value
(1)	{ sub_housing_type : "LandedProperties" } (2 fields)
year	Array[17]
0	{ year : 2005 } (2 fields)
year	2005
quarter	Array[4]
0	{ quarter : "1", avg_qtrly_hh_tg_consp_kwh : 144.23333333333332 }
1	{ quarter : "2", avg_qtrly_hh_tg_consp_kwh : 142.66666666666666 }
2	{ quarter : "3", avg_qtrly_hh_tg_consp_kwh : 141.86666666666667 }
3	{ quarter : "4", avg_qtrly_hh_tg_consp_kwh : 138.20000000000002 }
1	{ year : 2006 } (2 fields)
2	{ year : 2007 } (2 fields)
3	{ year : 2008 } (2 fields)

(6 row(s) returned)

Assumption
Assume that there are a total of 6 sub housing types consisting of 2 sub housing types of Private Housing (ie. Landed Properties, Private Apartments and Condominiums) and 4 sub housing types of Public Housing (ie. 1 room and 2 room, 3 room, 4 room, 5 room and executive)

Observation
We can observe that within a year, town gas consumption is highest in the 1st quarter and generally decreases throughout the rest of the year through the 2nd to 4th quarter.

10.3. noSQL Database Structure

Figure 10.3.1. Structure of finalYearlyEnergyData

```
finalSGYearlyData{[
    {
        "year": 2017,

        // Array of monthly household Consumption
        "monthlyhouseholdConsumption":[

            {"month": 1,

            // Array of household categories containing energy consumption
            "household_category":[
                {
                    "household_type": "1-room",
                    "housing_type": "public" // optional
                    "avg_mthly_hh_tg_consp_kwh": 23, // Overall for 1 room

                    // Array of Regional electricity data
                    "regional_elect_data":[
                        {"Region": "East", "region_kwh_per_acc":14},
                        {"Region": "West", "region_kwh_per_acc":10}
                    ]
                }
            ]}
        ],
        // Array of Yearly Imports/ Exports
        "energy_products":[
            {
                "name": "Petroleum Products",

                // Array of Sub-products
                "sub_products": [
                    {
                        "name": "Fuel Oil",
                        "import_value_ktoe": 23,
                        "export_value_ktoe": 4
                    },
                    {
                        "name": "Petroleum",
                        "import_value_ktoe": 10,
                        "export_value_ktoe": 0
                    }
                ]
            }
        ]
    }
]}
```

Figure 10.3.2. Structure of finalOWIDdata

```
finalOWIDdata{[
    {
        "country": "Singapore",
        //
        yearlyData:[
            {
                year: 2000,

                // Country Details
                "countryDetails": {
                    "population": 1,000,000,
                    "gdp": 3,000,000,
                    "iso_code": "AWG"
                },

                // Energy Data Details
                "countryEnergyData":{
                    "primary_energy_source": 104,
                    "greenhouseGasEmission": 1000,
                    "carbon_intensity_elec": 1000,

                    "energy_cons_change_pct":10,
                    "energy_cons_change_twh":10,
                    "energy_per_capita":10,
                    "energy_per_gdp":10,

                    "per_capita_electricity": 63,
                    "electricity_demand": 100,
                    "electricity_generation": 1000,

                    "net_elec_imports": 100,
                    "net_elec_imports_share_demand": 100
                }
                // Array of Energy Products
                "listOfEnergyData":[
                    {
                        "energy": "oil", // other-renewable excl biofuel
                        "energy_Types": [
                            {type: "consumption",
                              energyData: {
                                "consumption": 10,
                                "cons_change_twh": 10,
                                "cons_change_pct": 10
                            }},
                            {type: "production"},
                            {type: "energy"},
                            {type: "share"},
                            {type: "electricity"},
                         ]

                    },
                    {
                        "energy": "wind"
                    }
                ]
            }
        ]
    }
]}
```

10.4. Task Allocation Form

Seminar 5 Group 5

S/N	Tasks	Member In-charge
1	*[relational database] Planning Database Implementation*	*All*
2	*[relational database] mySQL Database Implementation*	*All*
3	*[relational database] mySQL Data Cleaning*	*All*
4	*[relational database] SQL development (specific to query 1, 7, 11, 14)*	*Denise*
5	*[relational database] SQL development (specific to query 2, 5, 10, 13, 15)*	*Eugene*
6	*[relational database] SQL development (specific to query 3, 6, 9, 12)*	*Shermaine*
7	*[relational database] SQL development (specific to query 4, 8, 15)*	*Tommy*
8	*[non-relational database] Planning Database Implementation*	*All*
9	*[non-relational database] noSQL Database Implementation*	*Eugene*
10	*[non-relational database] noSQL development (specific to query 1, 7, 11, 14)*	*Denise*
11	*[non-relational database] noSQL development (specific to query 2, 5, 10, 13)*	*Eugene*
12	*[non-relational database] noSQL development (specific to query 3, 6, 9, 12)*	*Shermaine*
13	*[non-relational database] noSQL development (specific to query 4, 8, 15)*	*Tommy*
14	*[Open-ended Questions] Concept development (specific to Question 12)*	*Shermaine*
15	*[Open-ended Questions] Concept development (specific to Question 13)*	*Eugene*
16	*[Open-ended Questions] Concept development (specific to Question 14)*	*Denise*
17	*[Open-ended Questions] Concept development (specific to Question 15)*	*Tommy & Eugene*