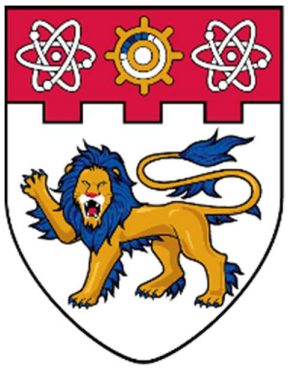


NANYANG TECHNOLOGICAL UNIVERSITY
SINGAPORE

BC2402: Designing and Developing Databases
Project Proposal

THE GREEN WORLD PROJECT

Seminar 5 Group 2

NAME	MATRICULATION NUMBER
Angie Wong Mei Chi	U2121896E
Bryan Lim Kai Wen	U2121763H
Chalamalasetti Sree Vaishnavi	U2122784J
Guo Chenrui	U2120138F
Keith Heng Jinsheng	U2121807C

Discussion on data driven insights

Question 12

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.

Hint: The formal technique to identify comparable references is "matching" in econometrics (i.e., propensity score matching, see https://en.wikipedia.org/wiki/Propensity_score_matching). For this question, you may consider countries with somewhat comparable GDP and/or population).
Note: Manufacturing economies used more energy than service economies as more energy is required to manufacture goods than provide service

To ensure an objective comparison, we have identified 2 countries similar to Singapore in terms of the following category respectively: population size, Gross Domestic Product (GDP) and GDP per capita. With time intervals of 10 years starting from 1965, we have listed the top 10 countries with the closest population, GDP and GDP per capita to Singapore in each period (Appendix B).

By counting the overall number of times each country appears in each time interval for each individual category, we have identified the following countries to be similar to Singapore.

- For population size, it would be Lebanon [4] and Costa Rica [4]
- For GDP, it would be Peru [3] and Kazakhstan [3]
- For GDP per capita, it would be Ireland [5] and the United States (USA) [3]

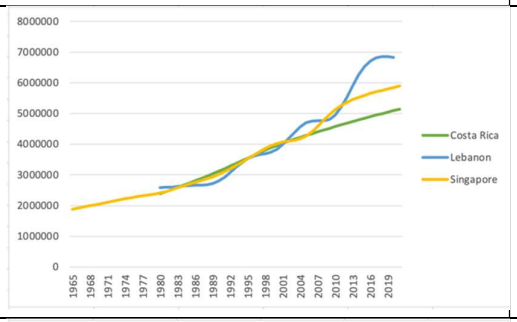
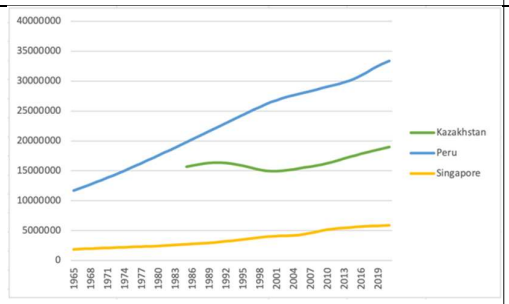
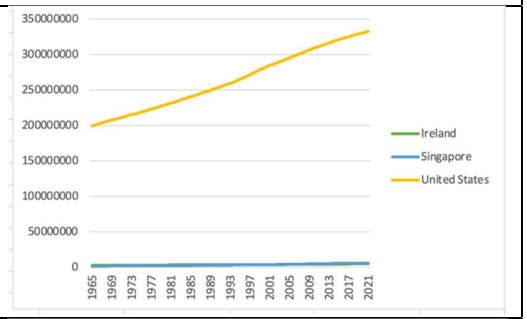
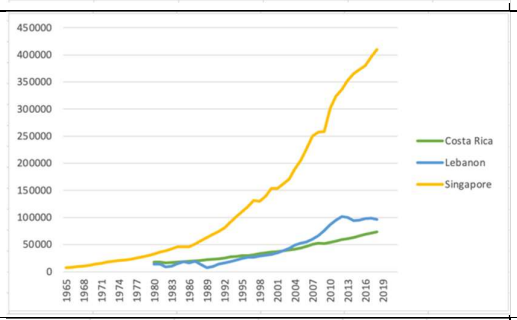
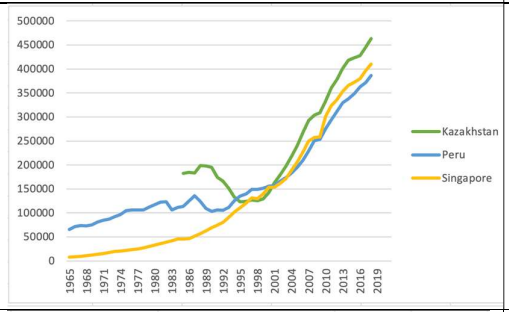
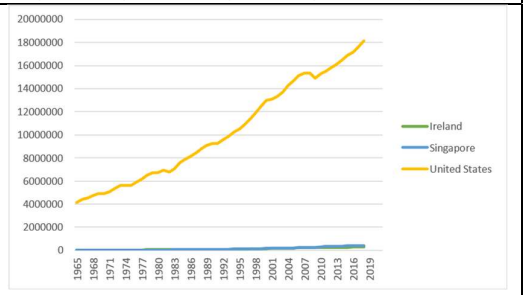
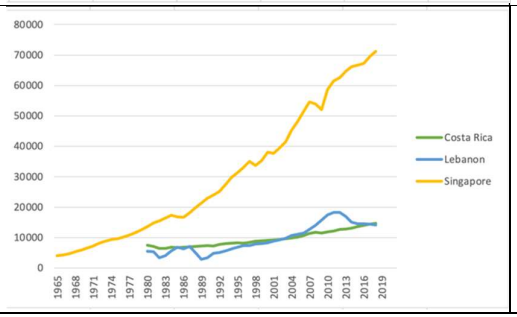
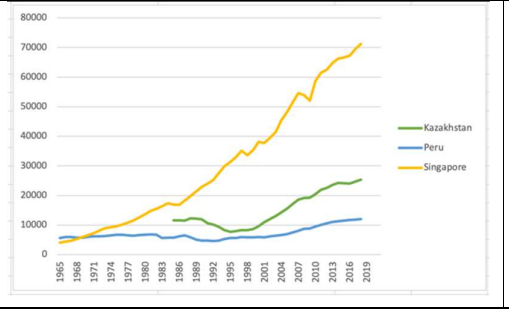
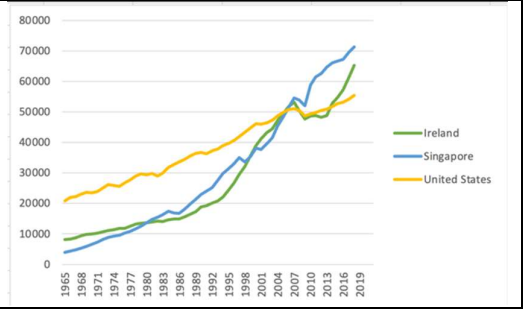
When comparing countries similar in population to Singapore, we can see that Singapore's energy per capita is rising while energy per GDP is decreasing. For energy per capita, the trend can be explained by Singapore's rapid development compared to the other two countries, which can still be considered developing countries. Singapore's drastic increase in GDP and primary energy consumption shows the rapid development that Singapore has undergone. Singapore's rapid growth in GDP compared to primary energy consumption also explains why Singapore's energy per GDP has significantly decreased compared to Costa Rica. However, from the 1980s onwards, it can be seen that Singapore's decrease in energy per GDP is smaller than Lebanon's. Instead of the cause being a shift from manufacturing to a service economy, Lebanon's decrease in energy per GDP is mainly due to poor economic performance during the 2006 Lebanon War.

For countries similar in GDP to Singapore, we can see that Singapore's energy per capita is rising drastically compared to Peru and Kazakhstan. Whereas for energy per GDP, Kazakhstan initially had the highest values, but towards the end of the period, Singapore had the highest value. This observation would be because Kazakhstan suffered from the dissolution of the Soviet Union during the mid-1990s. This resulted in a drop in energy and GDP, with the decrease in energy being more. For energy per capita, Singapore increased the most due to its population being much smaller than Peru and Kazakhstan. Despite having a higher energy per GDP, Singapore's energy per GDP has been steadily declining at a rate higher than Peru's and Kazakhstan's. With an expanding economy, the fall in

Singapore's energy per GDP showcases a shift from energy-intensive manufacturing industries to service-oriented ones that further fuels economic growth

Lastly, for countries similar in GDP per capita to Singapore, we can see that Singapore's energy per GDP and energy per capita are both higher than USA and Ireland. Initially, the USA had the highest energy per capita amongst the three countries. However, Singapore surpassed United States' energy per capita by a considerable amount after 1990. Singapore surpassing the USA is likely due to our small population, which is more than 60 times smaller than that of the United States. In the context where Singapore increases its energy consumption, the same increase in energy consumption in the USA would be distributed by 60 times that of Singapore. This fact contributes to relatively more minor growth in USA's energy per capita. Comparing Ireland and Singapore, both countries have similar populations and GDPs, but Ireland has smaller primary energy consumption. This difference explains why Ireland has lower energy per GDP and energy per capita.

Overall from 1965 to 2019, Singapore showed enormous growth in energy per capita compared to other countries listed, while other countries' energy per capita remained relatively stagnant throughout the years, as shown in Figure 1.3. The growth could be due to Singapore's small population and transformation into a first-world country, which does not apply to other countries. As for energy per GDP, it is noted that Singapore has the highest value at the end of the period. The enormous growth in energy per capita is a possible sign of concern for Singapore as it uses more energy for each person and relies heavily on fossil fuels as shown in Figure 1.2. As increased energy consumption from fossil fuels leads to more negative impacts on the environment due to more carbon emissions, Singapore has to ensure that it finds ways to limit the negative consequences.

	Similar in **Population**	Similar in **GDP**	Similar in **GDP Per capita**
Population			
GDP			
GDP Per capita			

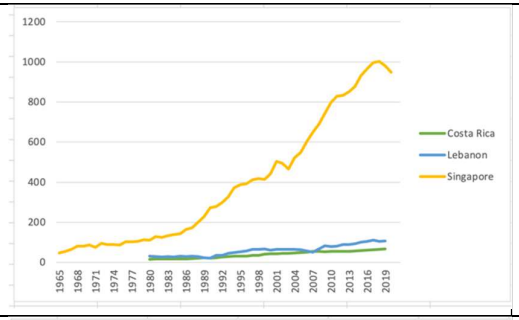
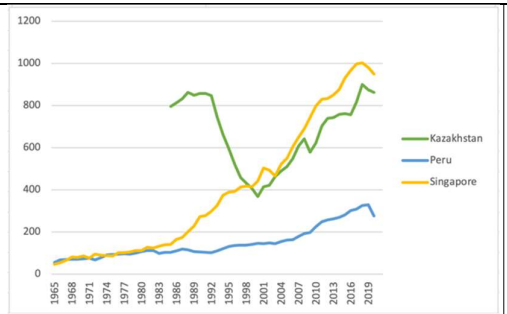
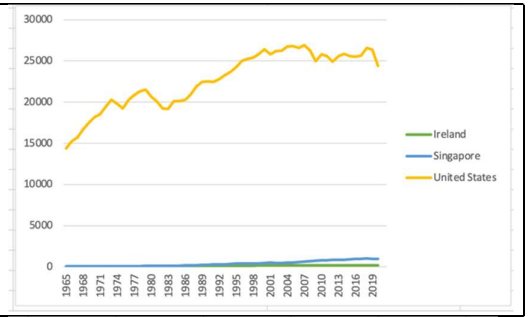
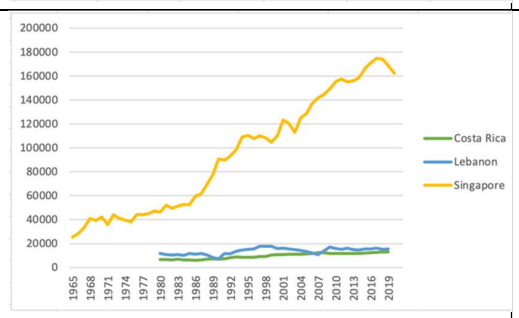
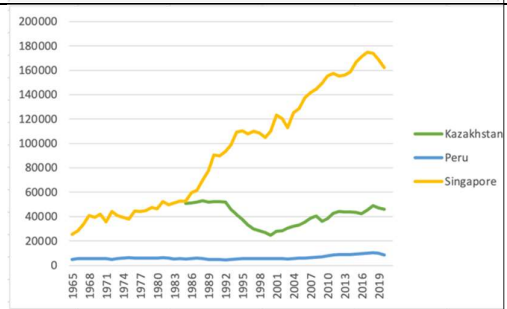
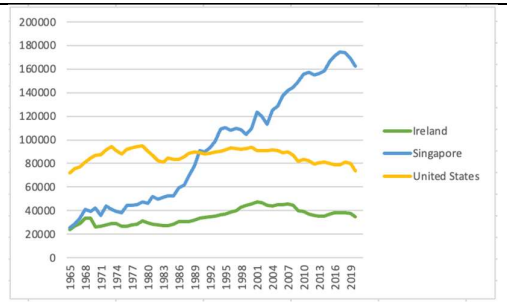
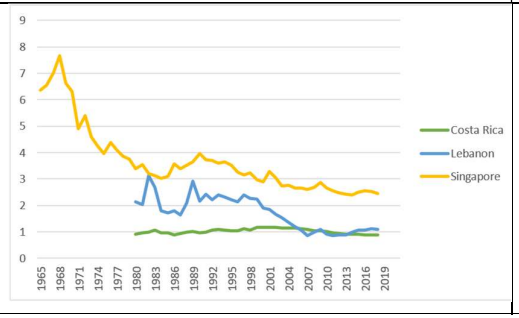
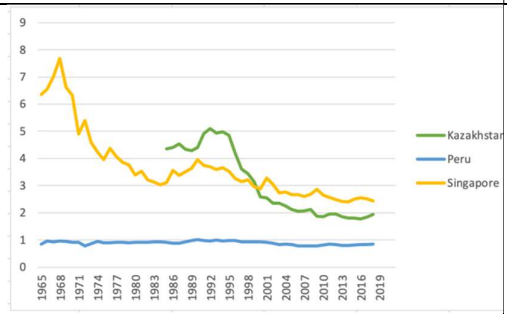
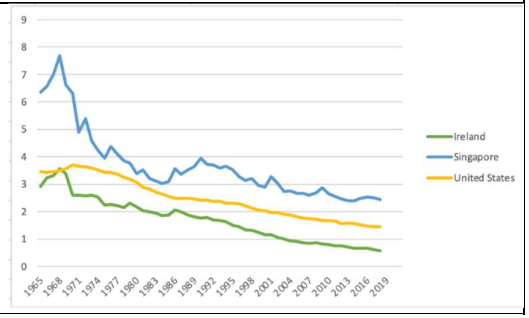
Primary Energy Consumption			
Energy Per capita			
Energy Per GDP			

Figure 1.1

For analysis of various types of energies used by each country, we used energy_per_capita and share_energy. The energy consumption was broken down into coal, natural gas, oil, other renewable energy, biofuel, hydro energy, solar energy and wind energy. Lebanon and Costa Rica were excluded as the variables mentioned above were not found for these two countries.

From Figure 1.2, the two primary energy sources for Singapore would be Oil and Natural Gas. We can see that Singapore is using more natural gas and less oil over the years. The reason for the change is because natural gas is the cleanest form of fossil fuels (Cabotaje, K. G. ,2022)

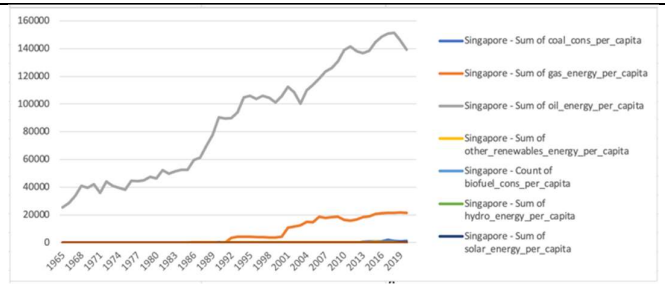
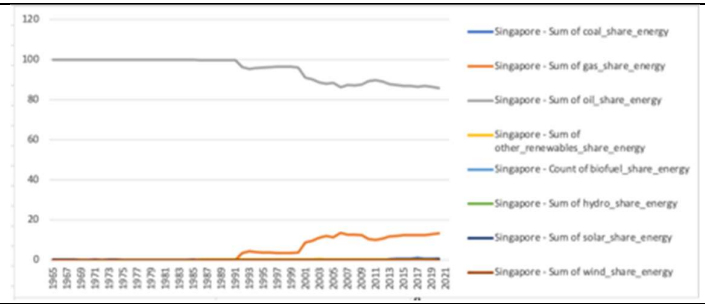
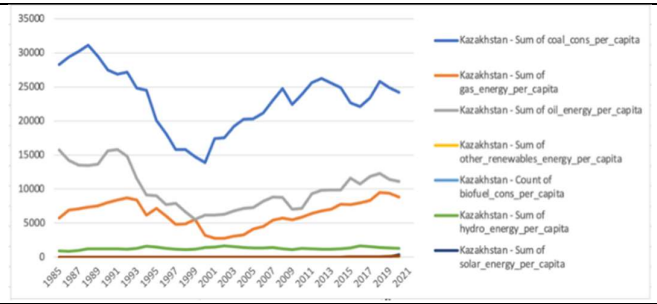
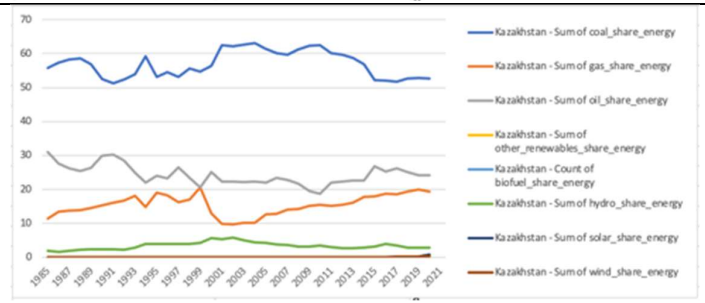
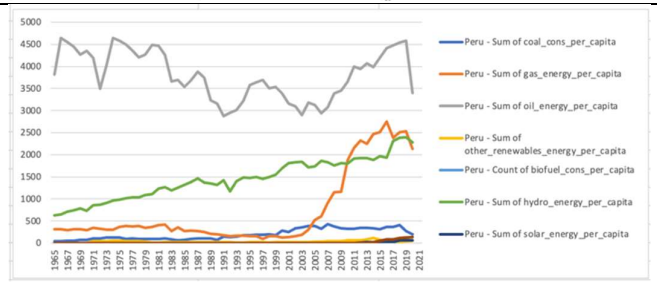
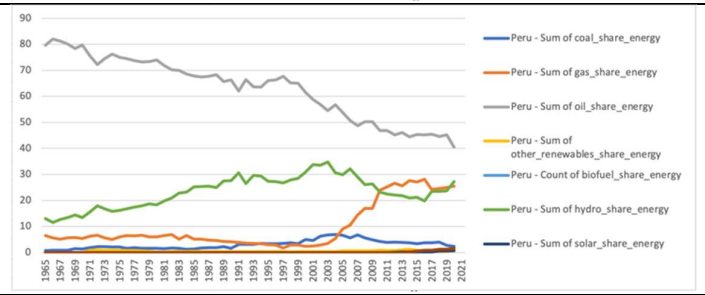
We can also see that Singapore's energy_per_capita is significantly higher than the other countries. The other countries also use three to four energy sources as compared to Singapore’s usage of two.
Kazakhstan's primary energy sources are Coal, Natural Gas and Oil.
Peru's primary energy sources are Coal, Natural Gas and Hydro Energy.
Ireland's primary energy sources are Natural Gas, Oil, and Wind (replacing coal in recent years)
USA’s primary energy sources are Coal, Natural Gas and Oil.
The reason why Singapore only uses two energy sources is that Singapore has limited natural resources, and most of the energy is primarily imported from Malaysia and Indonesia (EMA, 2022).

In addition, Singapore and Kazakhstan both primarily rely on fossil fuel sources. The other countries seem to be looking to switch to other forms of clean energy or have already been using them.

As Singapore is already established as a developed country, it can look to follow in the footsteps of Ireland and the USA. The two countries are switching to renewable forms of energy. Their switch is due to fossil fuels producing greenhouse gases, which have a negative impact on the environment. The change is especially important for Singapore as it is noted that Singapore has a high energy per capita, and this high energy is supplied by fossil fuels.

However it also has to be noted that Singapore has very limited natural resources which makes it hard to rely on renewable sources of energy to power the country
As such, this discussion leaves the question, "Why and how should Singapore change to cleaner forms of energy?", which will be discussed in the later questions.

Note: Coal, natural gas and oil are fossil fuels

	Energy_per_capita	Share_Energy
Singapore		
Kazakhstan (similar in GDP)		
Peru (similar in GDP)		

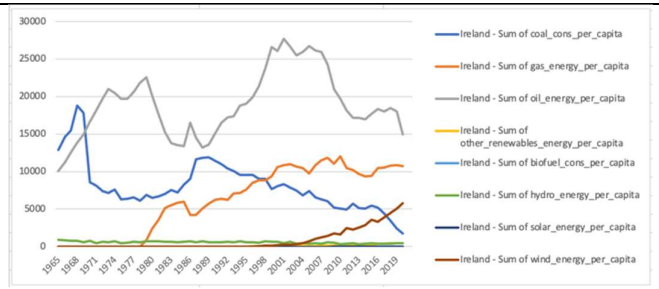
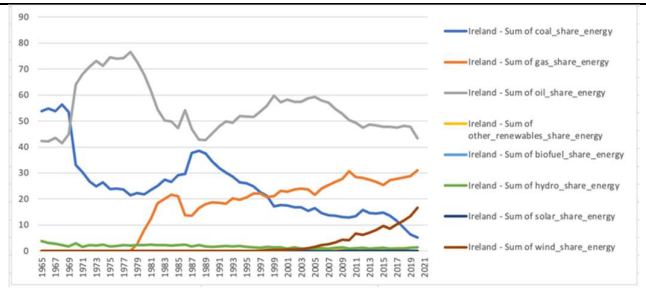
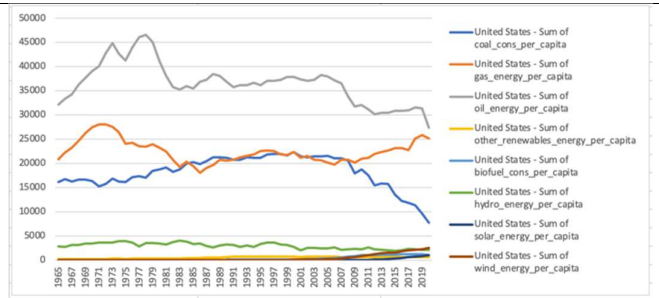
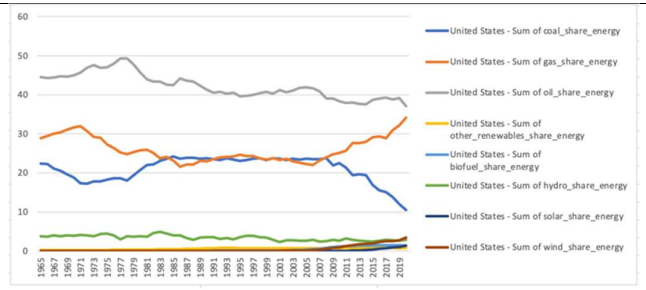
Ireland (similar in GDP Per capita)		
USA (Similar in GDP Per capita)		

Figure 1.2

Question 13

Can renewable energy adequately power continued economic growth?

Renewable energy refers to energy derived from natural sources that are replenished at a higher rate than they are consumed (United Nations, n.d.). They include solar energy, wind energy, geothermal energy, hydropower, ocean energy, and bioenergy. Following this definition, as radioactive fuel takes a very long time to replenish itself, nuclear energy will be considered a non-renewable energy source (National Geographic Society, n.d.).

For this question, "adequately power" can be interpreted as eliminating the use of fossil fuels and other non-renewable sources, and utilising only renewable energy sources to meet the growing energy demands for economic progress.

We will be measuring the economic growth and use of renewable energy using the following metrics:

- Economic growth:
    - GDP (change visualised on line charts)
- Renewable energy:
    - renewables_share_energy (Share of primary energy consumption from renewables)
    - renewables_electricity (Electricity generation from renewables, measured in terawatt-hours)

Because we are exploring the feasibility of renewable energy powering economic growth, we have chosen to analyse countries with a high share of primary energy consumption from renewables in recent times. We will use the top 4 highest renewables_share_energy* countries from each income bracket: High Income, Upper Middle Income and Lower Middle Income**.

The table below shows the countries we have selected for analysis.

High Income	**Upper Middle Income**	**Lower Middle Income*** **
Iceland (82.835)	Brazil (46.054)	Sri Lanka (26.122)
Norway (71.128)	Peru (35.138)	Vietnam (24.254)
Sweden (48.346)	Ecuador (35.111)	Philippines (18.061)
New Zealand (38.04)	Colombia (33.758)	Pakistan (12.893)

*The countries are sorted based on their maximum renewables_share_energy from 2000 and later, as this ensures recency and also goes back far enough to include countries currently with decreasing renewables_share_energy, which will add to the comprehensiveness of our research.

**The results from the query are compared against the classification of the countries based on national income brackets to find the 4 highest countries for each bracket. This classification is taken from the World Bank website (The World Bank, n.d.).

***There are no low-income countries observed with a significant renewables_share_energy from the data available, so the lower middle income category is segregated out and used as a proxy for "lower income" countries.

This question will be approached from 2 perspectives:

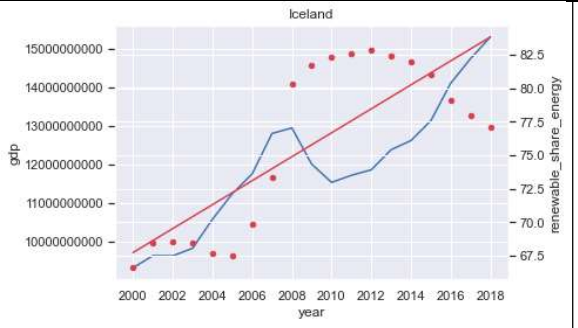
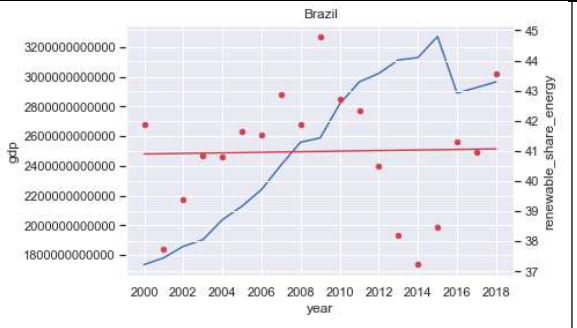
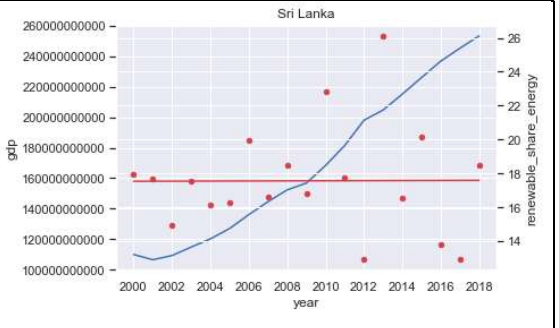
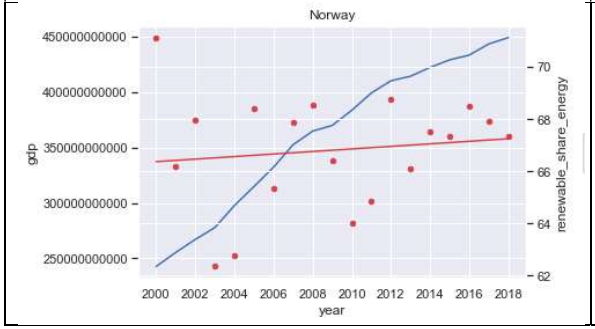
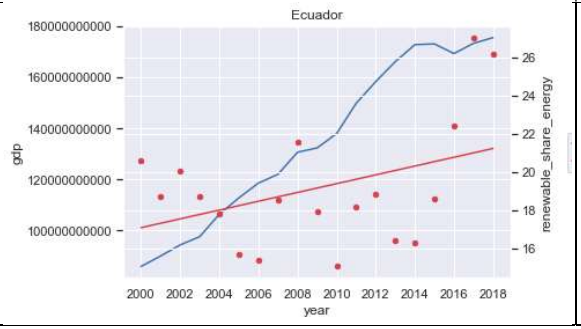
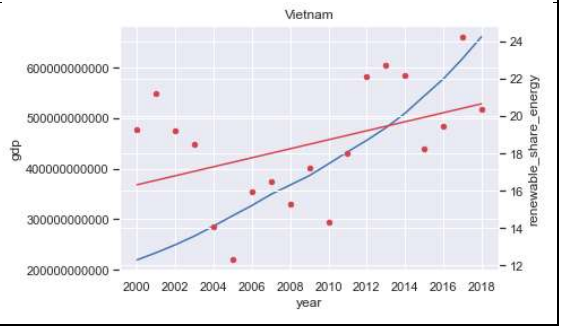
- Perspective 1: Observing the relationship between GDP growth and renewables_share_energy growth to determine if it positively or negatively impacts GDP, and whether the supply of energy from renewables can meet energy demands and therefore be adequate to sustain economic growth.
- Perspective 2: Observing the consistency of electricity generation from renewables (renewables_electricity) to determine if renewables is a stable source to be relied upon for economic growth.

Perspective 1

We conducted an analysis of GDP growth for countries most highly powered by renewable energy (renewables_share_energy), which are faceted by low, middle, high income. If any impairment of GDP growth is shown to be caused by a high or growing renewables_share_energy over the long term, then we can conclude that renewables are unable to fuel economic growth. Furthermore, if the short term renewables_share_energy shows a downwards trend, or is highly volatile over time, it is likely that renewables are not sufficient to meet the sudden spikes in energy demands for economic growth, as countries consume more non-renewables to meet the demands.

Visualisation 1: Plot of best fit line of renewables_share_energy over GDP for each country from 2000 to 2018 (most countries do not have GDP values beyond 2018). The best fit line shows the long term changes of renewables_share_energy.

Legend:

High Income	Upper Middle Income	Lower Middle Income
		
		

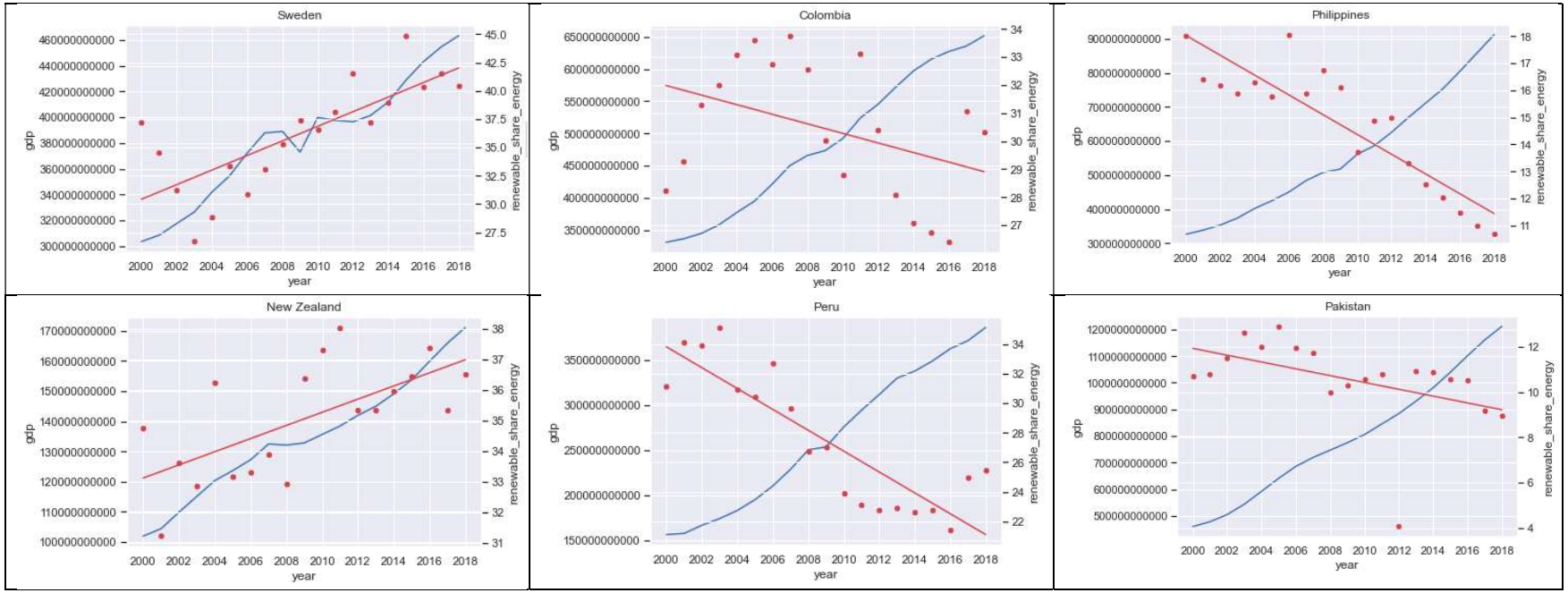


Figure 2.1

From Figure 2.1, focusing on countries with a high or growing renewables_share_energy that are more reliant on renewable sources of energy, we find that GDP is generally upward trending as well. These trends can be seen in Ecuador and Vietnam (growing trend of renewables_share_energy), and Iceland, Norway, Sweden, New Zealand (both high and growing trend of renewables_share_energy). Any decrease in GDP for these countries are found to be independent of the rise in renewables_share_energy. For example, in Iceland, while a stunted GDP growth from 2008 to 2012 coincided with their highest renewables_share_energy, it was instead attributed to a financial crisis that was caused by the collapse of Icelandic banks, which arose as a result of deregulation and poor decision making of business Vikings (Bergmann, 2014).

The positive correlation between renewables_share_energy and GDP for countries more reliant on renewables and the lack of direct causation between high renewables_share_energy and impairment to GDP growth shows that renewables are capable of powering economic growth.

Visualisation 2: Plot of renewables_share_energy for each country from 2000 to 2020. This shows the short term changes of renewables_share_energy. The countries in this case are grouped according to their income bracket (high, higher middle and lower middle).

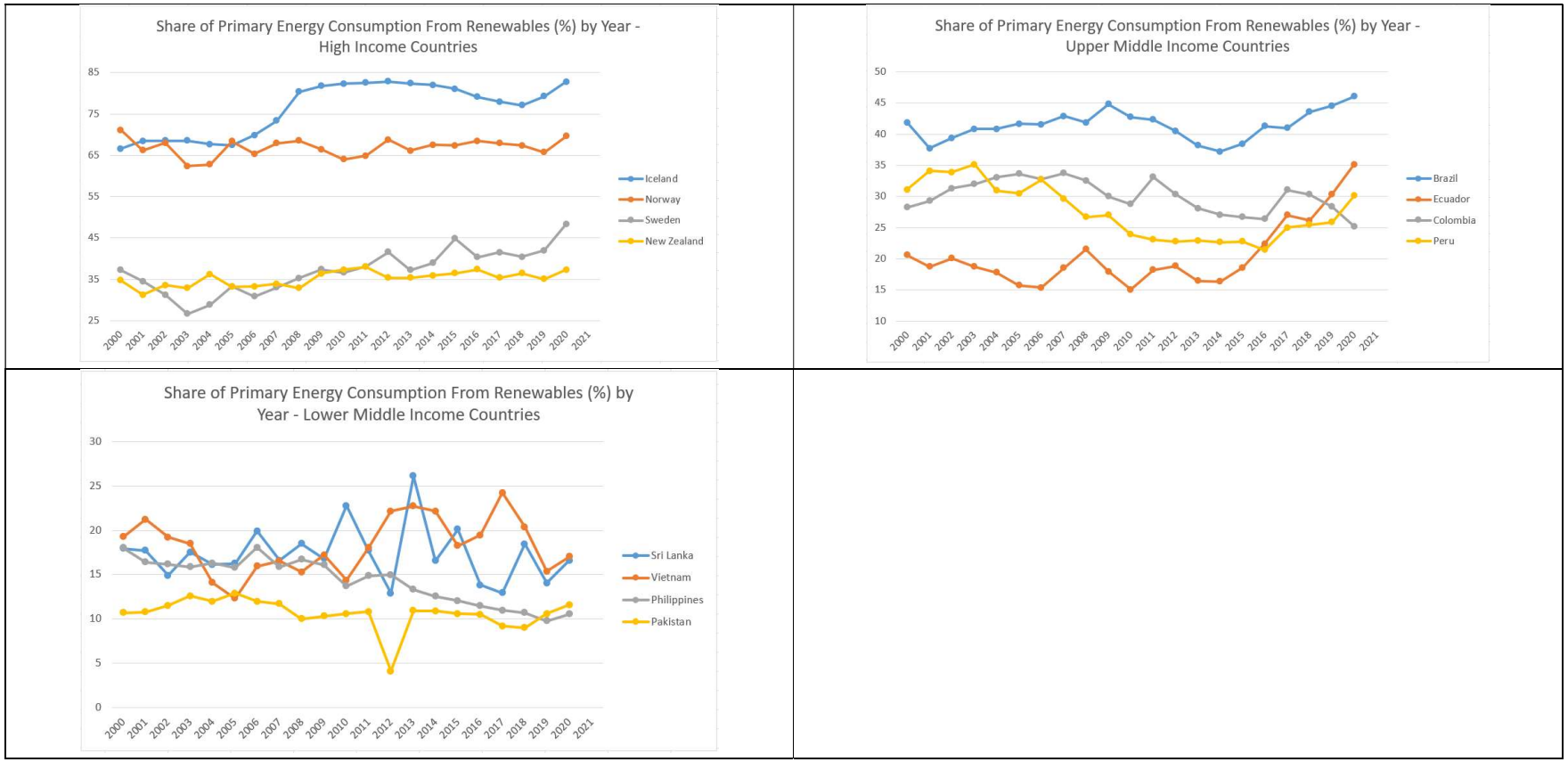


Figure 2.2

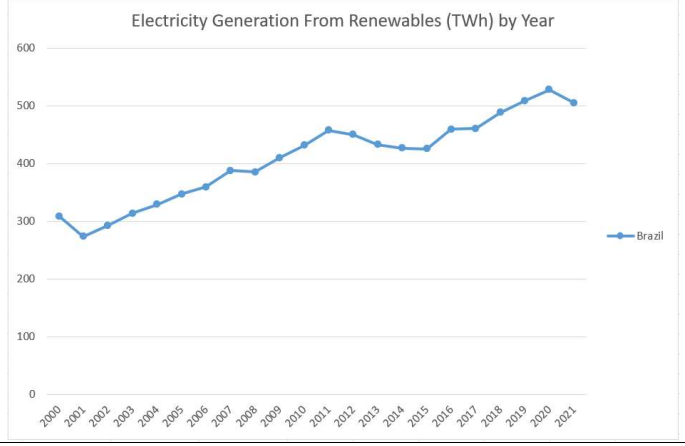
From Figure 2.2, it is observed that many countries experience moderate to strong fluctuations in the share of energy consumption from renewables, and this is especially prevalent among lower income countries (Sri Lanka, Vietnam, Brazil and Colombia). Some countries even show a consistent decreasing trend, particularly Philippines and Colombia. This suggests that energy supply from renewables alone cannot cope with both short term and long term rises in energy demand from the people and the economy.

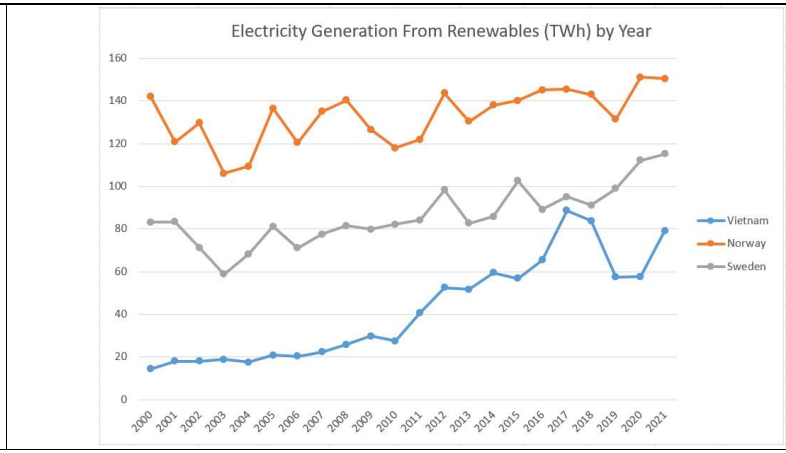
Moreover, one reason for the decreasing share of energy consumption from renewables could be prevailing state policies that favour non-renewables, as they are more readily available than developing expensive utility-scale renewable energy infrastructure (Barasa & Thurber, 2022). This points to the infeasibility of renewables as an economical source of energy, making it less suitable to adequately power economic growth, especially for lower income countries. This also explains the low maximum renewables_share_elec in lower income countries (~25%).

Perspective 2

If the electricity generation from renewables (renewables_electricity) is consistent over the years and does not fluctuate (i.e., fall sharply), then this shows that renewable energy is a stable source that can be relied on.

Visualisation: Plot of electricity generation from renewables (renewables_electricity) against year for each country. For these plots, the countries are grouped together based on their ranges of renewables_electricity so that the changes over time are more easily observable.





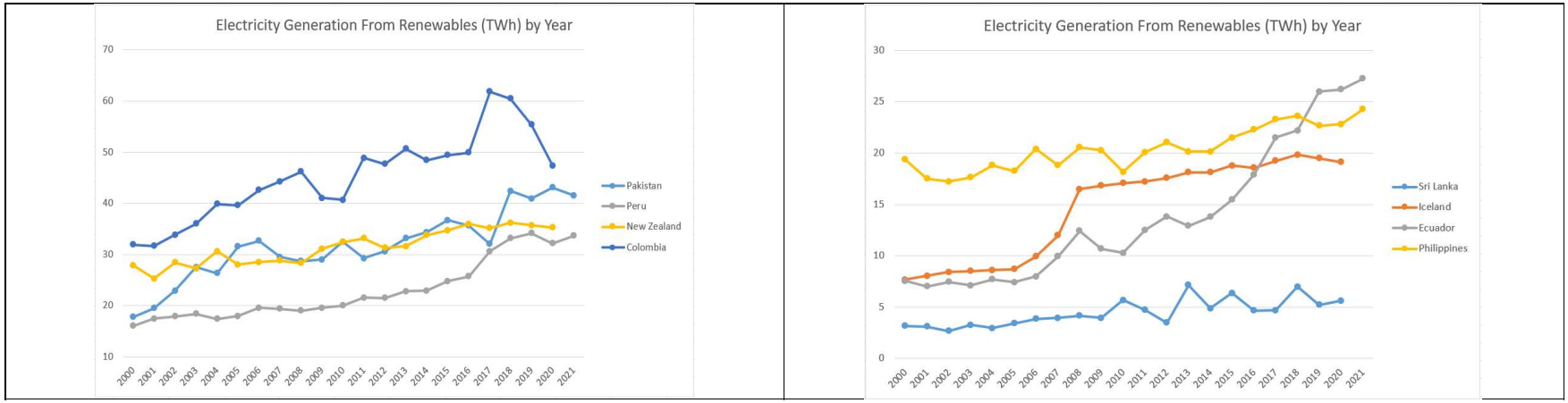


Figure 2.3

In general, the plots show that very few countries can maintain a constant or a consistently growing trend of electricity generation from renewables. Even for Peru, Ecuador and Iceland, which show the most consistent growth of the 12 countries, there are occasional dips observable. The countries with the most fluctuations come from all income brackets, from Norway and Sweden in the high income bracket, to Vietnam in the lower middle income bracket. Factors resulting in these inconsistencies include environmental (changing wind and sunlight patterns, insufficient precipitation and irregular river discharge) and even political (water conflicts between river nations).

We can conclude from these observations that with the exceptions of a few countries, electricity generation from renewables is generally inconsistent across countries of all income levels and as such renewables are not a very secure source to rely on to meet energy needs.

Conclusion

Overall, renewable energy is capable of powering economic growth only as far as being a complement to other energy sources, as they are found to be inconsistent in generation, and are unable to cope with short- and long-term spikes in energy demand. The discrepancy in its consistency in countries across different income brackets points to the inability of lower income countries to fully take advantage of renewable energy. Its low uptake and pace of growth in lower income countries also suggests huge financial and technological barriers to its development.

With climate awareness, state investments in renewable energy projects, and research into making renewable energy generation more stable, these drawbacks can be mitigated allowing renewable energy to be more adequate in meeting the demands of a growing economy.

Question 14

Say micro-nuclear reactors (see https://energypost.eu/micro- nuclear-reactors-up-to-20mw-portable-safer/) 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.

Singapore's Sustainability Goals

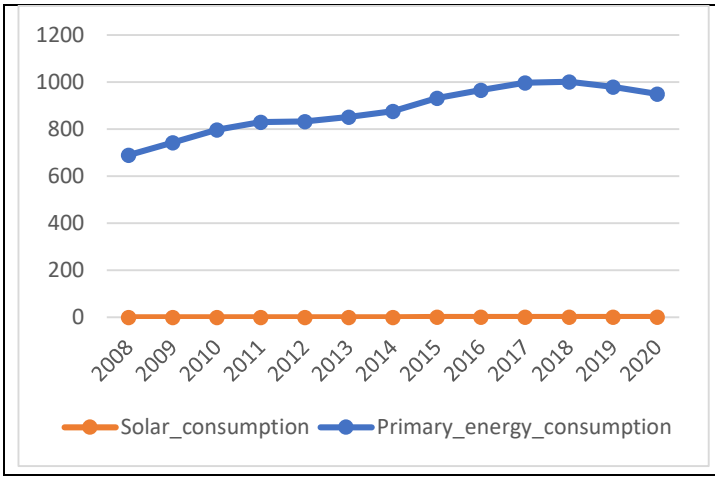
In Singapore's latest revision of its sustainability plan, PM Lawrence Wone announced that Singapore will aim to achieve net-zero emissions by 2050 (Wong, 2022). Accordingly, Singapore will try to reduce greenhouse gas emissions to 65MtCO2e by 2030 (Fogarty, 2022).

Singapore's Strategy

In order to achieve net-zero emissions by 2050, Singapore's priority is transiting from the use of fossil fuels to clean energy sources. To do this, Singapore is relying on increased use of solar energy and emerging low-carbon solutions, which mainly refers to hydrogen power (EMA, 2022)

However, solar energy is unlikely to replace fossil fuels as a substantial source of energy. Even if Singapore hits its 2030 solar energy target of 3% electricity demand via solar energy, this is a miniscule portion of the overall goal of net-zero emissions. Furthermore, our limited land space implies that it will be increasingly difficult to scale solar energy as a source of power (MSE, 2019).

Therefore, Singapore is mainly relying on the use of emerging low-carbon solutions such as hydrogen to achieve this transition. According to Singapore's national hydrogen strategy, Singapore aims to increase hydrogen energy deployment to meet 50% of our 2050 projected electricity demand (MTI, 2022).



From the dataset, we can observe that although primary energy consumption is increasing, the solar energy consumption accounts for a insignificant proportion of Singapore's energy consumption.

	solar_cons_change_pct	solar_share_energy	year
	92.053	0.001	2010
	57.586	0.002	2011
	66.302	0.003	2012
	52.272	0.004	2013
	114.802	0.008	2014
	78.538	0.013	2015
	80.505	0.023	2016
	37.942	0.031	2017
	9.436	0.034	2018
	43.458	0.049	2019
	51.077	0.077	2020

Although there is a positive increase in solar energy yearly with a high average of 86% across the years, this is unable to match the rising primary energy consumption and accounts for small portion energy 0.08%. Hence solar energy alone is insufficient to meet Singapore's sustainability goals.

However, hydrogen power has its challenges as well. Singapore does not currently possess the large-scale facilities for mass hydrogen production or high-pressure fuel tanks needed for large-scale hydrogen storage. Given the limited land space in Singapore this poses as a barrier for expansion in hydrogen energy.

Need for Other Clean Sources of Energy

Even if Singapore can achieve its hydrogen and solar power goals by 2050, it is still far from achieving net-zero emissions. Furthermore, these energy sources come with unique challenges. Thus, Singapore cannot just rely on these two sources of energy and needs to diversify its clean energy options to truly achieve its net zero emissions target.

The Opportunity: Micro-nuclear Reactors

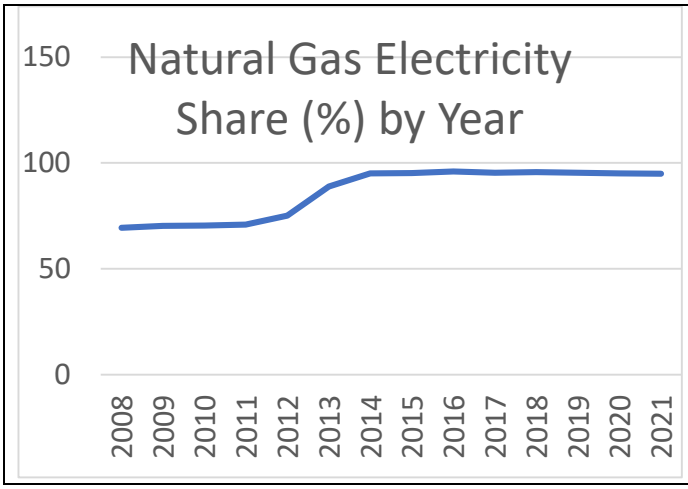
Micro-nuclear reactors are smaller and a less powerful version of existing power plants that can fit in the back of a 40-foot truck and generate up to 20MW, 3.5% of what is generated from the smallest power plant in USA. They utilise low-enriched uranium fuel and passive cooling using hot pipes to improve the safety of these reactors, albeit not full proof (Nunez, 2021).

Benefits of Micro-nuclear Reactors

Despite generating lesser power, the compact size allows micro-nuclear reactors to provide zero-carbon power in remote settings even for countries with small land sizes such as Singapore (Nunez,2021). Currently, Singapore generates 0 power from nuclear plants. Despite being a zero-carbon alternative, the major issues that Singapore has faced with nuclear plants is the small land area and high urban density (Igini,2022). This can be solved through micro-nuclear reactors due to their compact sizes, ideal for small and populated cities as well as densely built-up areas like Singapore.

Additionally, 95% of Singapore's energy today is generated from natural gas, primarily imported from Malaysia and Indonesia (EMA, 2022). With that said, micro-nuclear reactors are not only an efficient way of energy generation, but also a chance for further energy diversification. This reduces the energy dependence of Singapore on its immediate

neighbours, which brings about more geopolitical power and stability, allowing it to diversify energy sources.



From the data, there has been an increasing and extremely high reliance on imported natural gas for Singapore's electricity production. This goes against Singapore's goal of energy diversification and independence.

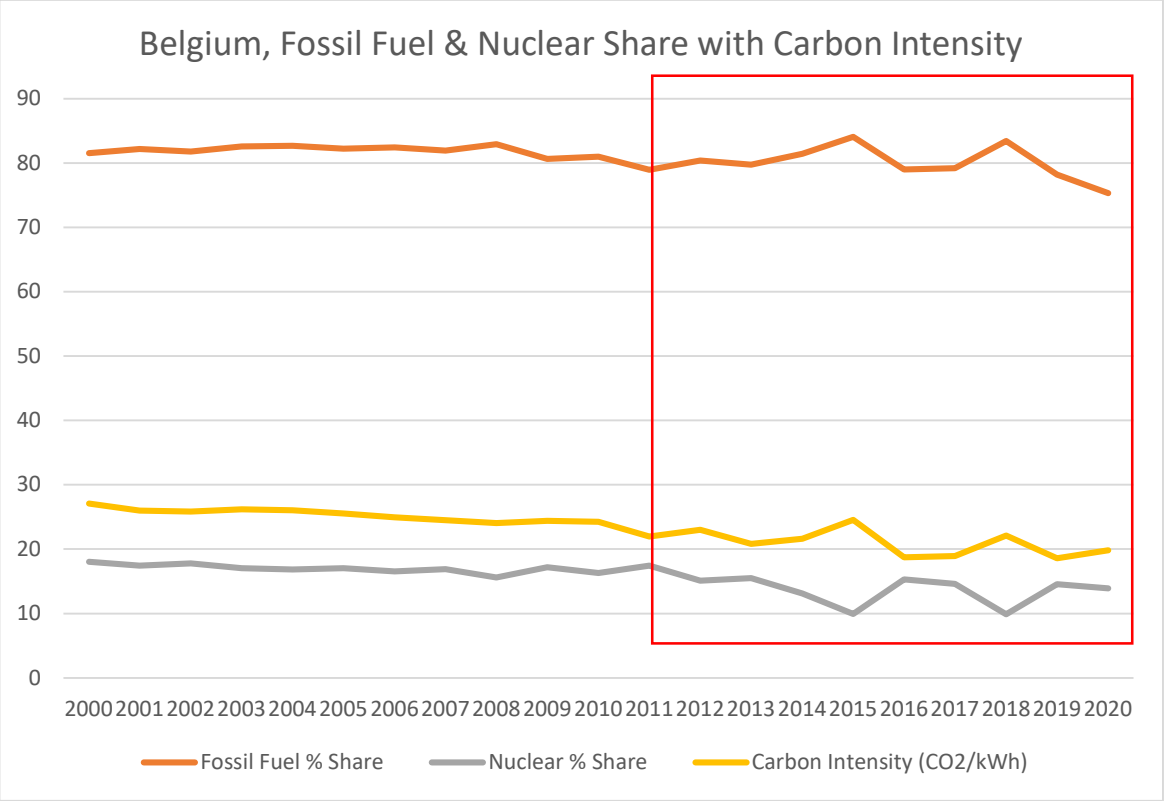
Furthermore, Singapore is committed to achieving net zero emission by 2050 as mentioned earlier. Despite not producing direct carbon dioxide emissions, nuclear power reactors still generate substantial amounts of energy (EIA, 2022). For instance, only 20 micro-reactors would potentially generate the same amount of energy as the 396MW Tuaspring combined cycle power station (YTL PowerSeraya, 2022). This provides a golden opportunity for Singapore to fuel its growing economy while remaining accountable to its environmental conservation goals.

Existing Efficacy of Nuclear Power

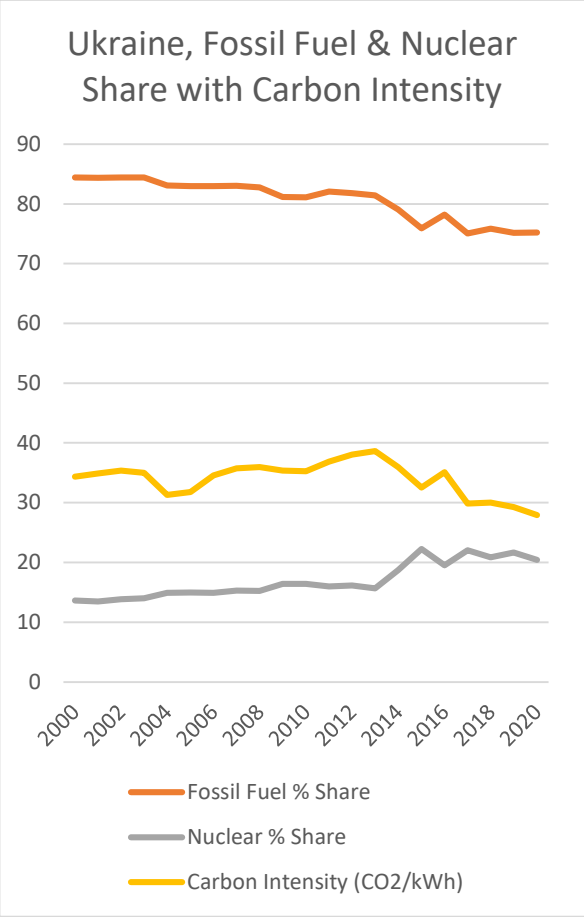
From the data, we are able to analyse how utilising nuclear energy over fossil fuels has impacted countries' greenhouse emissions. For this, we need to pick countries which fulfil certain criteria:

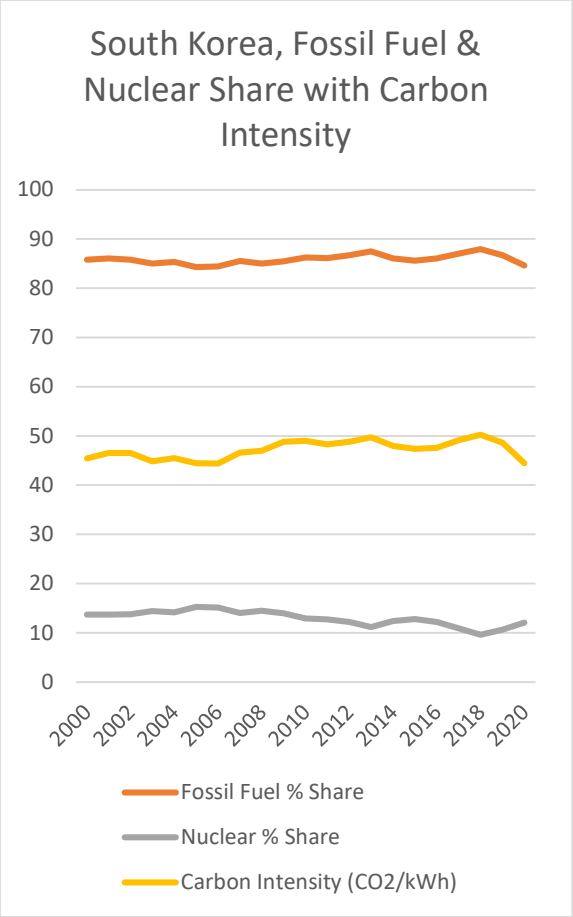
1. Fossil fuel and nuclear energy together, on average over 20 years, make up more than 95% of primary energy consumption over a span of 20 years.
2. Nuclear energy, on average over 20 years, was more than 10% of primary energy consumption
3. Carbon intensity (CO_2 generated per kWh) used as an indicator of greenhouse gases emitted.

For points 1 and 2, this is to ensure that any effects observed are mostly due to the relationship between these two energy types as they are the predominant energy sources in the country. For points 3, carbon intensity makes for an apt indicator as it shows how 'clean' a country's energy production is. In comparison, greenhouse gas by itself is a fickle indicator as it may increase or decrease due to varying economic performance and not relating to sustainability efforts. The countries that met these criteria were Belgium, South Korea and Ukraine.



As seen above for Belgium, we plotted fossil fuel (% share of primary energy consumption), nuclear share (% share of primary energy consumption) and carbon intensity (CO2/kWh) with time. Since fossil fuel and nuclear share are the 2 main types of energy sources in these 3 countries, fossil fuel share and nuclear share 'mirror' each other – an increase in one leads to a decrease in the other and vice versa. Generally, an increase in nuclear share (which decreases fossil fuel share) leads to a decrease in carbon intensity. Conversely, a decrease in nuclear share has leads to an increase in carbon intensity. This affirms the theoretical notion that nuclear share (as a low-emissions energy source) can reduce greenhouse gas emissions when used in replacement of fossil fuels. The carbon-reducing impact of nuclear energy is especially obvious in years where fluctuations are more pronounced, such as between 2013 to 2020.





Similarly, the same observation that using nuclear power in place of fossil fuel share leads to reduced carbon emissions can be observed in the case of Ukraine and South Korea. An increase in nuclear share (with a corresponding decrease in fossil fuel share) leads to a decrease in carbon intensity, and vice-versa. Thus, the adoption of nuclear energy as a cleaner source of energy is backed by existing data.

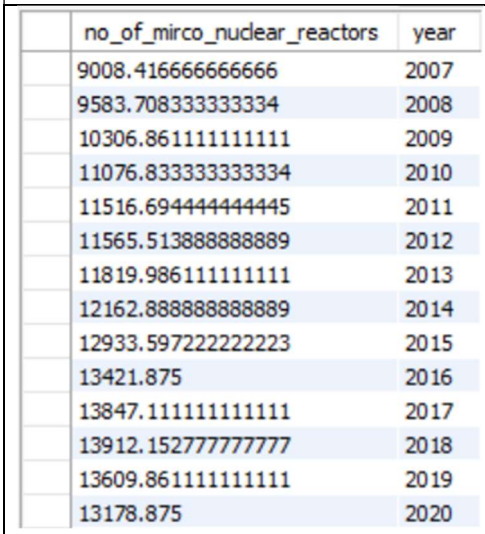
Singapore's Stance on Nuclear Power

Despite not utilising nuclear power in the past, due to recent significant developments like micro-nuclear reactors the Energy Market Authority (EMA) identified nuclear energy as a potential power source for Singapore as the country races to decarbonise and achieve its target of reaching net-zero "by or around mid-century" (MTI, 2022). This untapped potential in the past opens new windows for Singapore with the EMA hoping to utilise nuclear energy to power 10% of Singapore by 2050.(CNA, 2022).

Based on this information, we need to identify two main things to identify whether it is practically feasible to employ nuclear energy in Singapore:

1) The number of microreactors needed to provide 10% of Singapore: this is based on the aim mentioned above that Singapore aims to reach by 2050 in nuclear power
2) The land area the microreactors occupy: this is needed to examine whether the microreactors needed are small enough to fit in a limited land area like Singapore.

This helps target the barrier that Singapore faced in the past in deploying nuclear power because of limited land size

SQL output	Explanation behind calculation
	Formula: $\frac{primary\ energy\ consumption}{energy\ provided\ by\ 1\ micro-nuclear\ reactor}$ Assumption: primary energy consumption is used as it measures the total energy demand of the country. Other variables like energy_per_capita are subsets of primary energy consumption hence will be unable to capture the whole energy demand of Singapore As primary_energy_consumption is in Terawatts-hour and energy provided by a micro-nuclear reactor is in Megawatts, to balance the units: 1) We multiplied primary_energy_consumption by 10^6 to convert it to megawatts-hour 2) We multiplied energy provided by a micro nuclear reactor by 3600 to convert it to megawatts-hour

Land Area Calculation

Since one micro-reactor fits into a standard 40ft shipping container, we can make a rough estimate of how much land area is needed to supply 10% of primary energy consumption using micro reactors. Using the latest year, 2020, as the basis of this calculation, we will get the following:

$$40\ ft\ shipping\ container = 40ft\ (Length)\ \times\ 8ft\ (Width)\ \times\ 8ft.6in\ (Height)$$
$$= 12.19m\ (Length)\ \times\ 2.44m\ (Width)\ \times\ 2.89m\ (Height)$$

$$Area\ of\ 40ft\ shipping\ container = 12.19m\ \times\ 2.44m$$
$$=\ 29.7436\ m^2$$

$$Total\ Area\ for\ all\ micro\ reactors = 13179\ \times\ 29.743$$
$$\approx\ 391982.997m^2$$
$$\approx 0.392km^2$$

Assumptions in Calculation:

1. **Micro-reactors are built on flat land without vertical stacking.** It is assumed that the micro-reactors are built on separate flat land instead of being combined

with existing architecture such as in the internal space of buildings. Additionally, it is assumed that these micro-reactors cannot be vertically stacked to reduce space. Given that micro-reactors are still largely in a primitive development phase where safety cannot be fully ensured, these are reasonable assumptions. In any case, we want to find the 'worst-case' scenario to know how much land space, at maximum, will such a method employ.

2. **Micro-reactors fit into a standard 40ft shipping container.** While micro-reactors in the phase of development, most researchers are confident that it will be able to fit into a 40ft shipping container or on the back of a truck. Thus, this is a reasonable assumption to make.

Comparison with Singapore Land Area

To put into perspective the land area needed for the micro-reactors, various areas and their corresponding land size are shown:

Area/Region	Land Size (km^2)	District/Neighbourhood	Land Size (km^2)
Singapore	728.6	Ang Mo Kio	13.94
Central Region	132.7	Jurong East	17.83
East Region	93.1	Pasir Ris	15.02
North Region	134.5	Pioneer	12.1
North-East Region	103.9	Tampines	20.89
West Region	201.3	Yishun	21.24

Insights from the Data

Based on the query, we require an average of 13500 micro nuclear reactors in recent years. The land area needed for these reactors is: 0.392km^2. Given that Singapore has a land area of 728.6km^2 ,the land area needed for the nuclear reactors is negligible. They can be stored in areas such as Jurong island which has a land area of 36km^2. Given that employing micro nuclear reactors are environmentally and economically feasible according to the question, our calculations show that the land area needed is negligible hence opening a window of possibility for Singapore to go nuclear. However, we still need to investigate concerns of safety of these reactors before deriving at a conclusion.

Concerns on Safety

While the micronuclear reactors have made progress in terms of safety with a low likelihood of an accident, given the small land space even a minor accident can have a devastating impact (CNA, 2022). Nuclear energy produces nuclear waste that remain radioactive and dangerous to human health even for thousands of years in case of accidents (EIA, n.d.). The devastating impacts were seen in accidents like the Fukushima Daachi and Chernobyl accident. Similarly micronuclear reactors produce dangerous long-lived radioactive waste that needs to be dumped safely in a suitable land. Hence it is of vital importance to further reduce the likelihood of an accident occurring.

Amount of Radioactive Nuclear Waste

Radioactive waste is life threatening hence we require a gauge on the amount to help identify whether there is sufficient safe storage space to dispose this waste. Based on research, the generation of electricity from a typical 1,000-megawatt nuclear power station, $3m^3$of vitrified high-level waste per year, given that the used fuel is recycled (World Nuclear Organisation, n.d.).

Amount of radioactive nuclear waste produced per year: 13500 x 20/1000 x 3= $810m^3$

Conclusion

From our calculations, given that the land size occupied is negligible and the usefulness of nuclear in meeting Singapore's sustainability goals, Singapore should go nuclear. That being said the safety of micro-nuclear reactors should be further improved. We also require more research to identify which exact areas can be utilised to store the micronuclear reactors before providing a definite answer. Furthermore, we require research on a possible area to dump long-lived radioactive waste as calculated above and how large of a container it needs, given the safety hazard that it poses, a common issue which even bigger countries such as USA and Russia are facing (BBC, 2020).

Overall, nuclear energy is a viable and beneficial option for Singapore.

Question 15

Despite the increasing awareness of environmental issues, some remain sceptical about climate change being a problem (see https://www.bbc.com/news/science-environment-62225696). Using the data provided in this project and the individual assignment (as well as any other publicly available data, if your team shall desire), build a convincing data narrative to illustrate climate change problems associated with emissions.

Notes: When additional datasets are considered, your team must provide the formal references/sources to retrieve the original datasets.
Evaluation will be performed with attention to the coherence of your team's narrative. A coherent data narrative can be achieved using a focused dataset. A rich, diversified dataset can muddle the narrative if the data is not meaningfully integrated.

1. Climate Change is a Man-made Phenomenon

With Earth's everchanging climate, there has been increased focus on the cause of climate change and questions raised about whether we should be concerned about such phenomenon. Amongst them, there exist theories that climate change is a natural phenomenon that occurs independently of human's impact on the environment. The information below serves to challenge these sceptics' views regarding the cause of climate change, and to prove that climate change is the result of human activities.

1.1 Rapid Increase in Greenhouse Gases

Prior to the Industrial Revolution between 1760 to 1840, the greenhouse emission has been low, and this was maintained until mid-20th century.(Ritchie, 2020) In comparison to the 6 billion tonnes of greenhouse gasses produced in 1950, the amount had more than quintupled in 1990, reaching 30 billion tonnes of emissions as shown in Figure 4.1.

Emissions have continued to grow rapidly with a gradually steeper increase in greenhouse gas emissions each year; we now emit over 50 billion tonnes each year. Despite global efforts such as the Kyoto Protocol and The Paris Agreement, the continued rise in emissions reflects our indifference towards the impact of greenhouse gas emissions: climate change. We will be exploring some of the climate problems to illustrate the severity of climate change and prove that it is indeed a top priority for all of Earth's inhabitants.

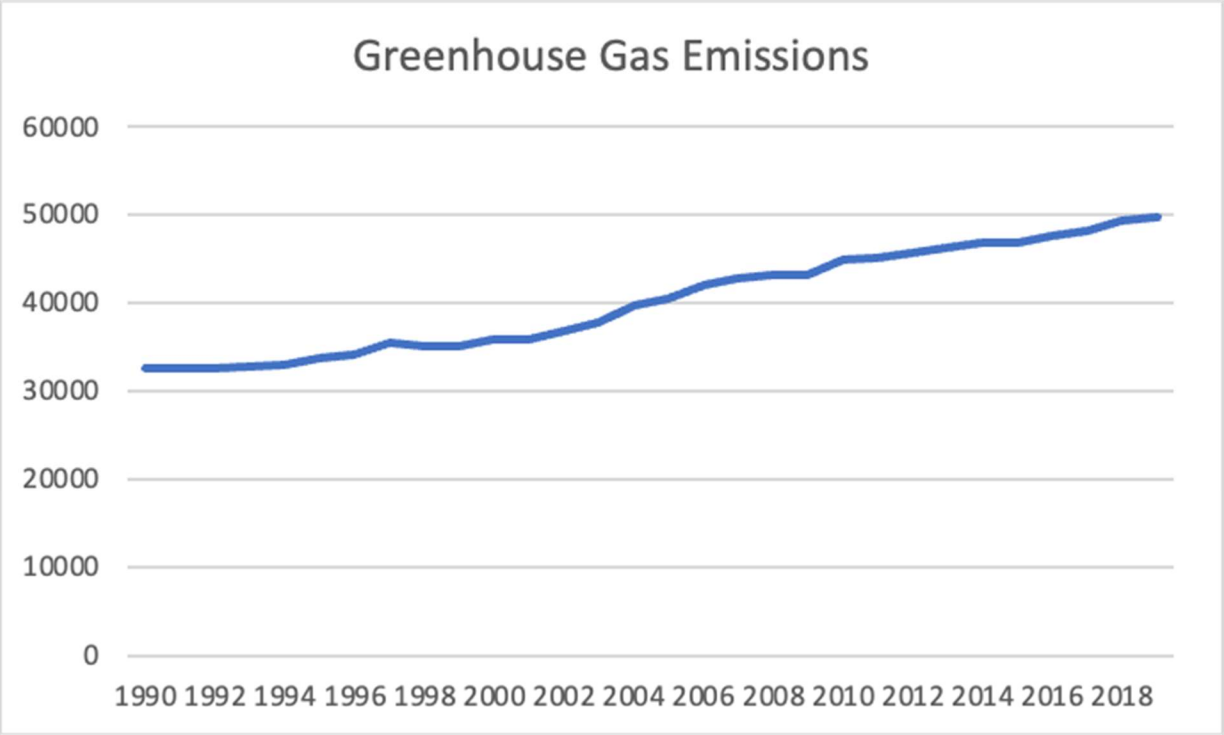


Figure 4.1 (OWID Greenhouse Gas Dataset)
Dataset Source: https://ourworldindata.org/co2-emissions#

1.2 Climate Problem 1: Rising Land Temperature

Despite on-going efforts to reduce greenhouse gases, there is an undeniable trend of constant increase in the land temperature**,** with the average land temperature reaching an all-time high at 9.57°C in 2014 and 9.83°C in the following year as shown in Figure 4.2.

Evidently, the effects of high emissions have long-lasting consequences, in the form of gradually warmer temperatures that continuously beat previous temperature records. Seeing the constant rise in global temperatures, it is expected for land temperatures to rise by as much as 1.4°C in 2050, which is far greater than the 1°C increase in temperatures since 1880. (Lindsey & Scott, 2022)

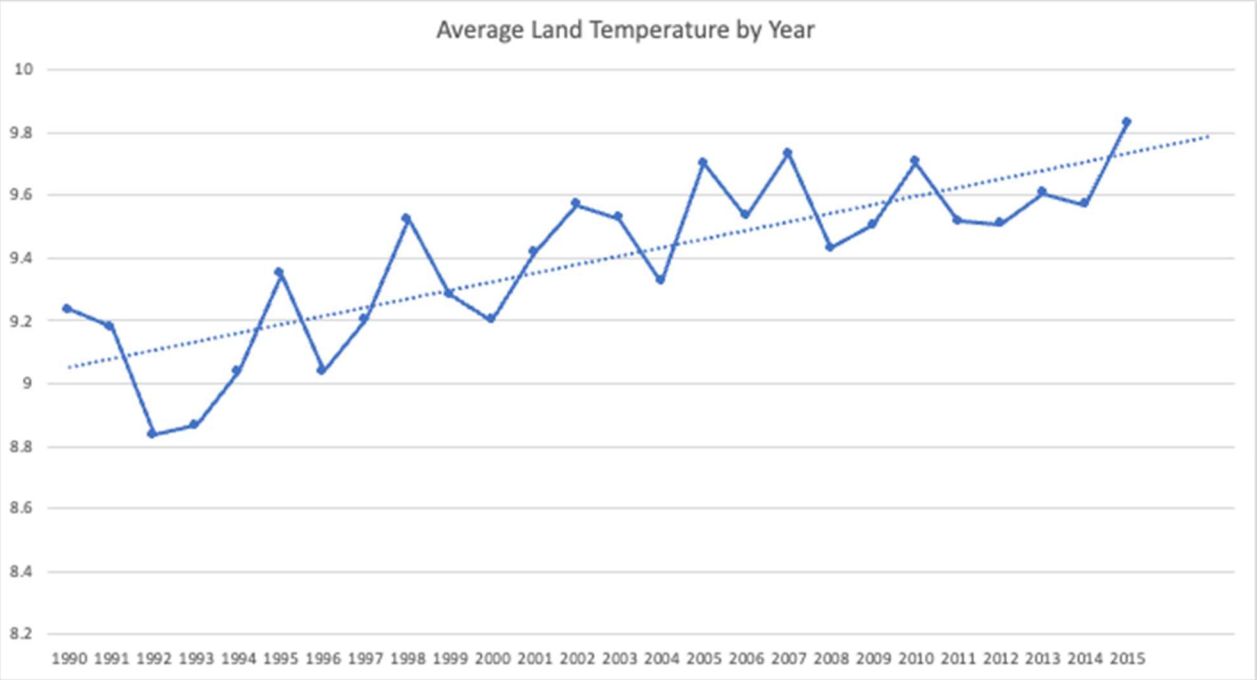


Figure 4.2
Dataset Source: https://www.fao.org/documents/card/en/c/cb9051en

1.3 Climate Problem 2: Receding Glaciers and Decreasing Ice Extent

Glaciers are large, thick masses of ice that form on land when fallen snow gets compressed into ice. Not surprisingly, glaciers have been receding globally in conjunction with rising temperatures. This can be shown via the rapidly decreasing glacier mass balance.

Glacier mass balance can be thought of as the ‘health of a glacier’. Simply, it indicates whether a glacier is on overall, gaining or losing more mass. A negative glacier balance means that it is losing more mass – from factors such as rising temperatures – then they are gaining from snow or ice (Davis, 2020). Subsequently, this affects whether the glacier grows or melts.

As observed in Figure 4.3, the negative mass balance has closed to tripled from 1990 to 2018. The accelerating rate at which our glaciers are melting is a serious consequence of rising global temperatures due to heightened emissions. It further contributes to other phenomena such as rising sea levels, coastal erosion and increased incidence of hurricanes or typhoons (WWF, 2022).

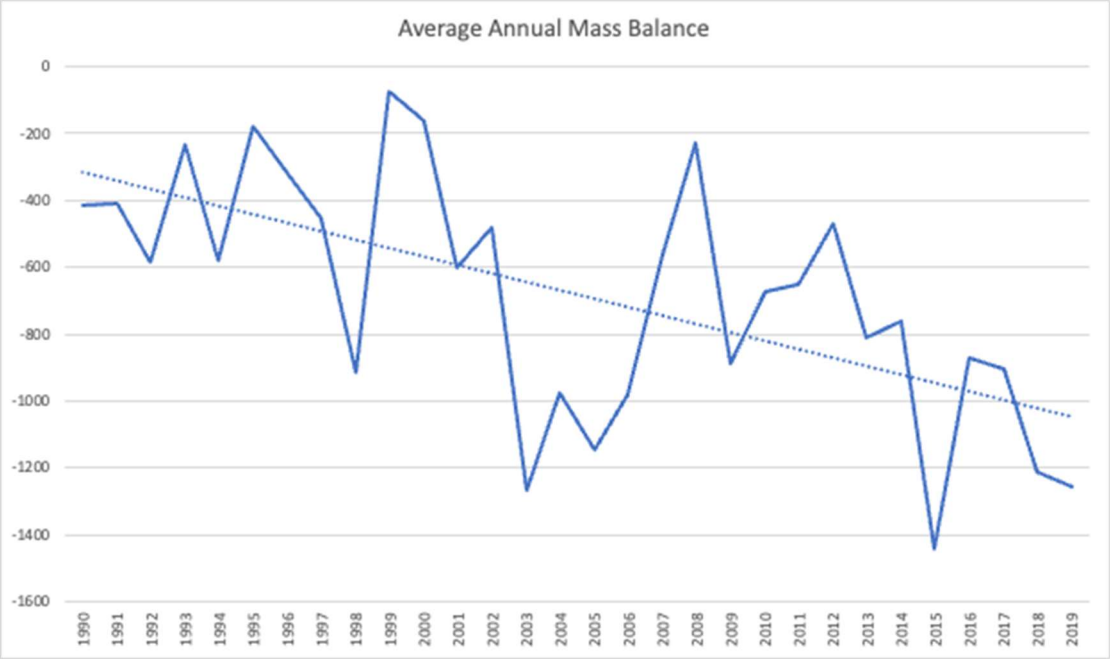


Figure 4.3

Dataset Source: https://cds.climate.copernicus.eu/cdsapp#!/dataset/insitu-glaciers-elevation-mass?tab=overview

Ice extent is the area of ocean where at least 15% of the surface being frozen (Lindsey & Scott, 2022). The average ice extent of South hemisphere dipped in the years 2006 and 2011, and in the years 2007 and 2012 for North Hemisphere.

Despite the increase in ice extent in the South Hemisphere after the year 2000, this increase is accompanied by the decrease in ice extent in the North Hemisphere. Therefore, there is an overall decline in the Total Average Ice Extent for both hemispheres since the year 1990, more notably in the North Hemisphere (Figure 4.3). This reduction in the amount of sea ice is an indicator of warmer air and water temperatures, and an example of the consequences of emissions on our environment.

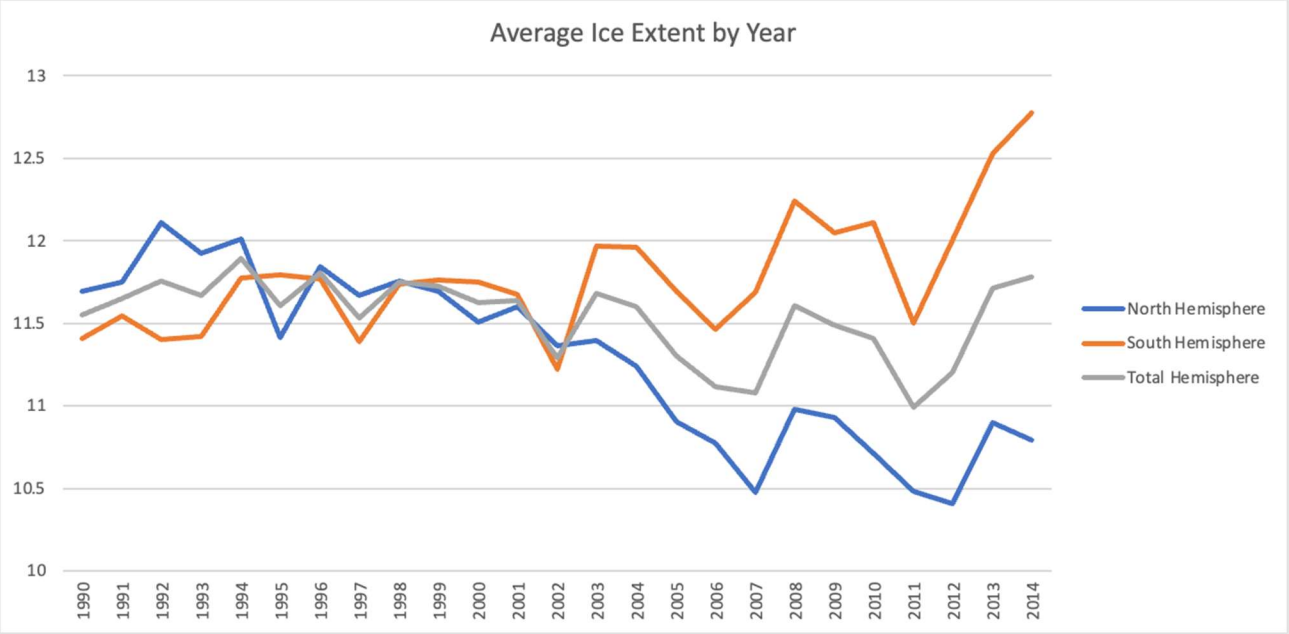


Figure 4.4

Source: https://www.kaggle.com/datasets/nsidcorg/daily-sea-ice-extent-data

1.4 Climate Problem 3: Rapid Increase in Sea Levels

With the expansion of water bodies due to rising temperatures, melting of glaciers and loss of ice extent, it is no wonder that our sea levels are rising each year. With reference to Figure 4.5, taking the mean of all Global Mean Sea Level (GMSL) between 1993 and 2019 as the benchmark, we can see that from the year 1993, sea levels have been rising.

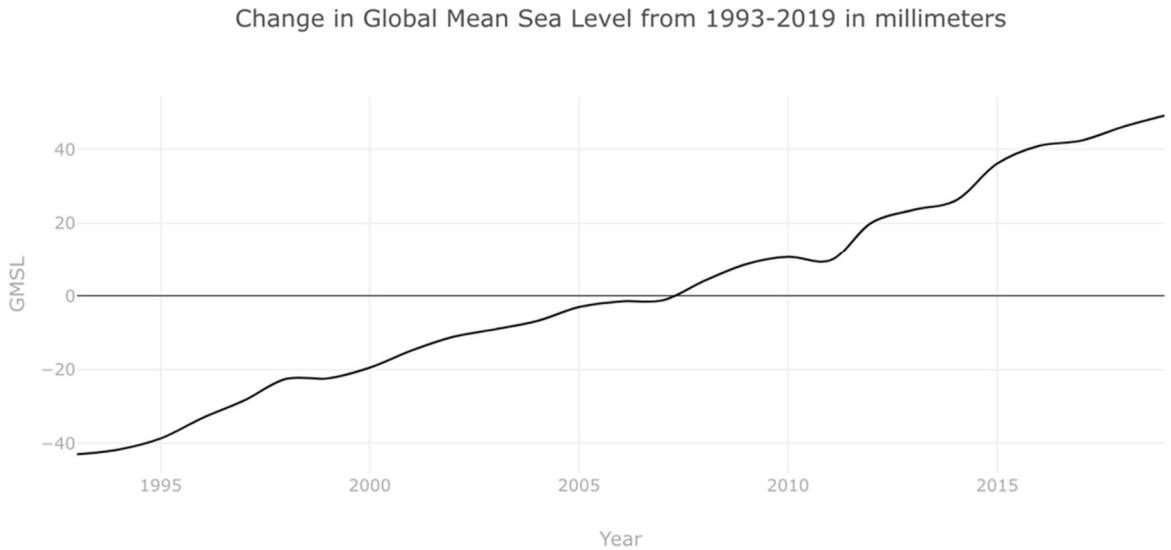


Figure 4.5

Dataset Source: https://research.csiro.au/slrwavescoast/sea-level/measurements-and-data/sea-level-data/

2. Consequences of Climate Change

Despite establishing that climate change is a man-made phenomenon, some may still question if there is a need to be concerned about such changes. To many, the effects of climate change may seem distant and have little to no impact on their daily life.

However, frequent weather events showcases the direct impact climate change has on our population. In addition to threatening the safety of populations, the losses incurred during frequent weather disasters are detrimental to the economy. Lastly, there is also an issue of migration of tropical diseases that threatens human health. These consequences of climate change will be further explored below.

2.1 Population Safety: Frequent Natural Disasters

In contrast to the early 1900s, there has been an exponential increase in the occurrence of natural disasters as shown in Figure 4.6. These natural disasters include droughts, earthquakes, extreme temperatures, extreme weathers (hurricane, tropical cyclones, etc), floods, landslides, dry mass movements, volcanic activities and wildfires. The severity of these events can be reflected through the high death tolls recorded in some events, for example the Haiti earthquake (2010) with death toll of over 220,000, where 2 in every 100 people died in Haiti that year.

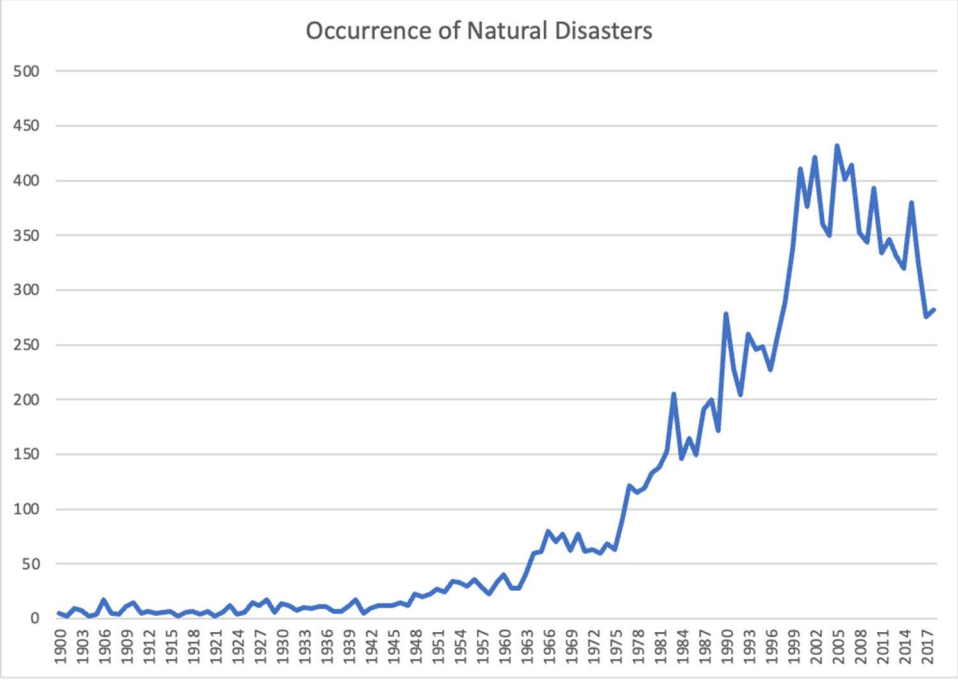


Figure 4.6 (Dataset from Natural Disaster Data)
Dataset Source: https://www.kaggle.com/datasets/dataenergy/natural-disaster-data/code?resource=download

2.2 Economic Loss: Damages from Natural Disasters

Besides threatening the safety of human populations, natural disasters destroy tangible assets for example, buildings and equipment. Increased frequency of natural disasters therefore increases the cost incurred to fix damaged capital. As shown in Figure 4.7, the total economic damages due to natural disasters have been rising exponentially after mid 1900s, approximately the same timing where the occurrence of natural disaster has been rising as well. Additionally, the damage of capital affects business in located in the affected region. Damaged buildings and equipment may lead to reduced production and revenue, further increasing the toll on the economy post-event. (Small Business Natural Disaster Preparedness and Resilience Inquiry (2022), n.d.)

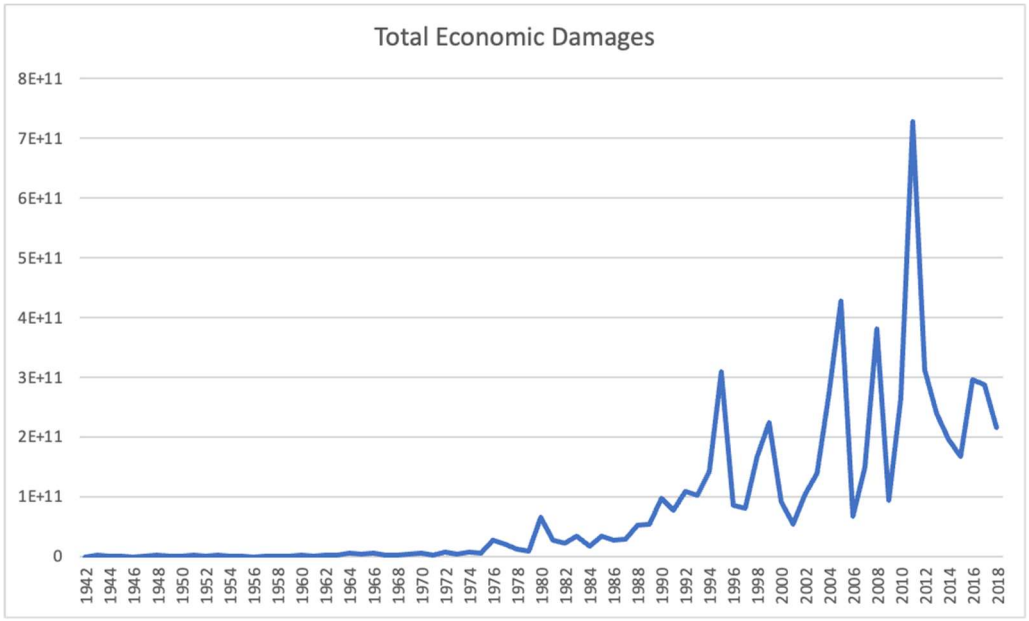


Figure 4.7 (Dataset from Natural Disaster Data)
Dataset Source: https://www.kaggle.com/datasets/dataenergy/natural-disaster-data/code?resource=download

Another economical implication of natural disasters is the burden on insurance companies. Although insurance companies play a crucial role in providing immediate financial support to overcome the impact of natural disasters, the burden of high damages can cost insurance companies to incur debt when the amount of insured losses exceeds the premium they collected. (Cho, 2022)

In order to prevent losses, insurance companies are incentivised to increase the price of premiums offered, making insurance less affordable for the middle and lower classes. A prime example of such cases would be Florida, where insurance rate has more than doubled in 5 years, yet insurance firms are still making losses. This is mainly due to the rising risk of hurricane with the occurrence of Hurricanes Matthew(2016), Irma(2017) and Micheal (2018) and increased flooding in recent years. (S. Hamid, 2022)

2.3 Population Health: Rise of Tropical Diseases

With climate change, the rise in temperature and rainfalls has also expanded the range of mosquitoes, leading to the spread of vector-borne diseases such as Dengue, Malaria and many more. Increased occurrence of storms, floods and rising sea levels have also led to outbreaks of other tropical diseases such as Lassa Fever and Cholera. (Prillaman, 2022)

As shown in Figure 4.8, the occurrence of tropical diseases and malaria has been rapidly increasing since early 1990s. Though there was a drop in occurrence between 2010 and 2015, we see that there is a rising trend of such infectious diseases after 2015.

As such, climate change directly threatens the well-being of human population, making them vulnerable to deadly diseases that not only causes severe pain, but also lead to long-term disabilities and death of more than 170,000 people each year. (The Impact of Neglected Tropical Diseases, 2022)

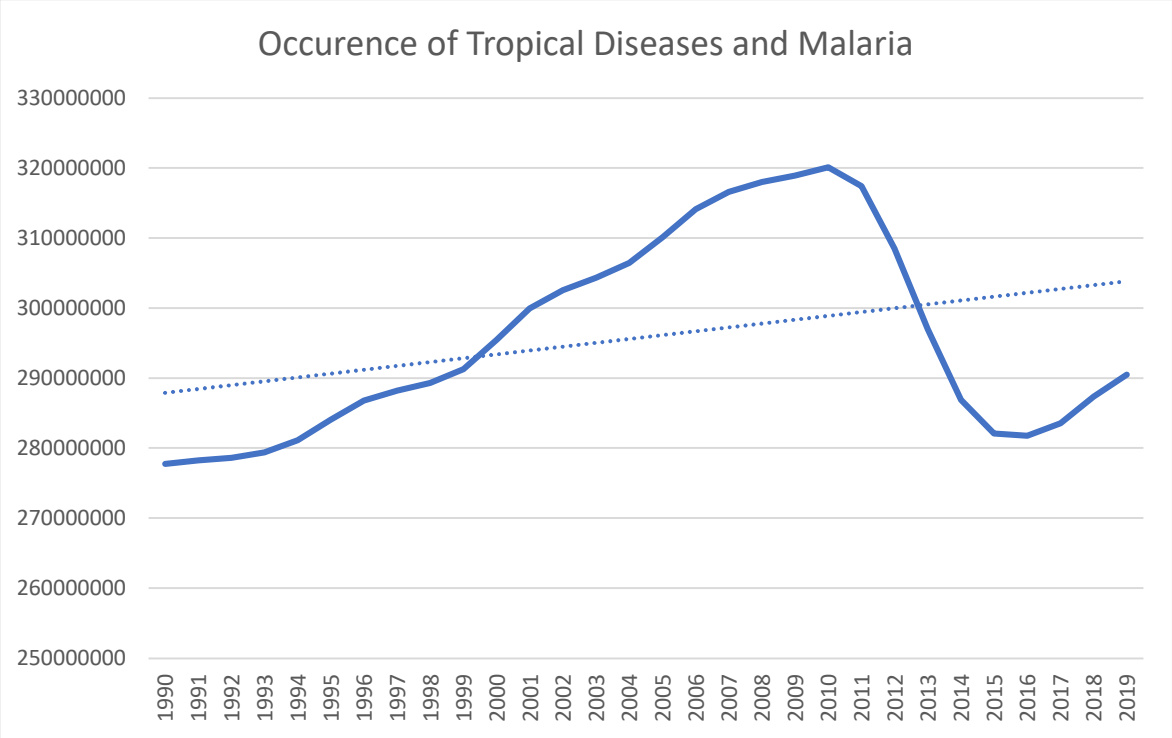


Figure 4.8
Dataset Source: https://vizhub.healthdata.org/gbd-results/

3. Appeal for Urgency in Addressing Climate Change

Climate change is no longer a matter of “if” but “when”. By responding to the scepticism regarding the causes of climate change and showcasing the severe impact it has on our safety, wealth and health, we hope to change the perspective sceptics have towards climate change.

Although there has been efforts such as the Climate Movement, the Kyoto Protocol and the Paris Agreement, simply reducing the increase in rate of emission is not enough to minimise the impact of climate change. More regulations and sustained efforts must be done before we see a plateau in climate problems such as rising temperatures, rising sea levels and melting glaciers.

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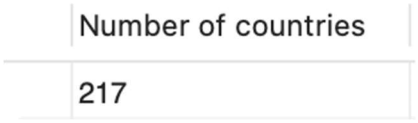
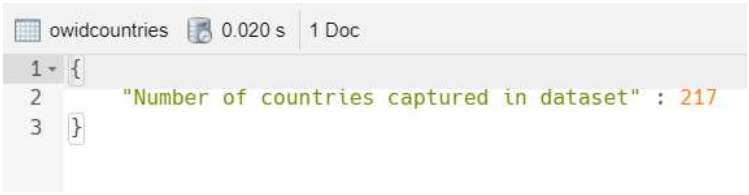
Appendix

Appendix A – 11 queries

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

   Note: Be careful! The devil is in the details.

mySQL	 [1 row returned]
mongoDB	 [1 doc returned]

2. 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)?

   Note: The output must provide evidence that the countries have the same number of records.

mySQL

country	earliest_year	latest_year	year_count
Argentina	1900	2021	122
Australia	1900	2021	122
Austria	1900	2021	122
Bangladesh	1900	2021	122
Belgium	1900	2021	122
Bolivia	1900	2021	122
Brazil	1900	2021	122
Bulgaria	1900	2021	122
Burundi	1900	2021	122
Canada	1900	2021	122
Chile	1900	2021	122
China	1900	2021	122
Denmark	1900	2021	122

[44 rows returned]

mongoDB

owidcountries 0.022 s 1 Doc

```
{
    "minyear" : 1900,
    "maxyear" : 2021,
    "count" : 122
}
```

[1 doc returned]

owidcountries 0.053 s 44 Docs

	_id	count
1	Argentina	122
2	Australia	122
3	Austria	122
4	Bangladesh	122
5	Belgium	122
6	Bolivia	122
7	Brazil	122
8	Bulgaria	122
9	Burundi	122
10	Canada	122
11	Chile	122
12	China	122
13	Denmark	122
14	Ecuador	122
15	Egypt	122
16	France	122
17	Germany	122
18	Greece	122

[44 docs returned]

3. 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.

mySQL

country	year	fossil_share_ener...	biofuel_share_ener...	hydro_share_ener...	nuclear_share_energy	other_renewables_share_ene...	solar_share_energy	wind_share_ener...
Singapore	1986	99.857	0.0	0.0	0.0	0.143	0.0	0.0
Singapore	1987	99.864	0.0	0.0	0.0	0.136	0.0	0.0
Singapore	1988	99.882	0.0	0.0	0.0	0.118	0.0	0.0
Singapore	1989	99.897	0.0	0.0	0.0	0.103	0.0	0.0
Singapore	1990	99.914	0.0	0.0	0.0	0.086	0.0	0.0
Singapore	1991	99.755	0.0	0.0	0.0	0.245	0.0	0.0
Singapore	1992	99.772	0.0	0.0	0.0	0.228	0.0	0.0
Singapore	1993	99.791	0.0	0.0	0.0	0.209	0.0	0.0
Singapore	1994	99.818	0.0	0.0	0.0	0.182	0.0	0.0
Singapore	1995	99.825	0.0	0.0	0.0	0.175	0.0	0.0
Singapore	1996	99.827	0.0	0.0	0.0	0.173	0.0	0.0
Singapore	1997	99.835	0.0	0.0	0.0	0.165	0.0	0.0
Singapore	1998	99.837	0.0	0.0	0.0	0.163	0.0	0.0

[35 rows returned]

mongoDB

owidcountries 0.019 s 35 Docs

	country	year	fossil_share_energy	other_renewables_share_energy	solar_share_energy
1	Singapore	1986	99.857	0.143	
2	Singapore	1987	99.864	0.136	
3	Singapore	1988	99.882	0.118	
4	Singapore	1989	99.897	0.103	
5	Singapore	1990	99.914	0.086	
6	Singapore	1991	99.755	0.245	
7	Singapore	1992	99.772	0.228	
8	Singapore	1993	99.791	0.209	
9	Singapore	1994	99.818	0.182	
10	Singapore	1995	99.825	0.175	
11	Singapore	1996	99.827	0.173	
12	Singapore	1997	99.835	0.165	
13	Singapore	1998	99.837	0.163	
14	Singapore	1999	99.836	0.164	

[35 docs returned]

4. 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.

mySQL

country	Average GDP from 2000 to 2021
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
Brunei	NULL

[10 rows returned]

mongoDB

owidcountries 0.022 s 10 Docs

	_id	AverageGDP
1	Indonesia	1,970,289,338,615.0527 (2.0T)
2	Thailand	850,644,159,074.579 (0.85T)
3	Philippines	561,245,634,399.8948 (0.56T)
4	Malaysia	508,048,012,556.8421 (0.51T)
5	Vietnam	404,540,388,126.5263 (0.40T)
6	Singapore	277,187,081,428.4737 (0.28T)
7	Myanmar	189,145,793,585.2105 (0.19T)
8	Cambodia	36,252,651,482.6842 (36.3G)
9	Laos	26,084,002,724.6842 (26.1G)
10	Brunei	null

[10 docs returned]

5. (Without creating additional tables/collections)
   (a) 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.).
   (b) 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).
   (c) Based on the pair of 3-year averages, compute the corresponding 3-year moving averages in GDP.

mySQL

Brunei
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp avera...
2000		NULL	NULL		NULL
2001		NULL	NULL		NULL
2002		NULL	NULL		NULL
2003		NULL	NULL		NULL
2004		NULL	NULL		NULL
2005		NULL	NULL		NULL
2006		NULL	NULL		NULL
2007		NULL	NULL		NULL
2008		NULL	NULL		NULL
2009		NULL	NULL		NULL
2010		NULL	NULL		NULL
2011		NULL	NULL		NULL
2012		NULL	NULL		NULL
2013		NULL	NULL		NULL

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp avera...

[0 rows returned]

Cambodia
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp average
2000		NULL	NULL	20441457984.0	21508449010
2001		NULL	NULL	21596243896.0	22643754827.333332
2002		NULL	NULL	22487645150.0	24014806555.333332
2003		NULL	NULL	23847375436.0	26002586475.666668
2004		NULL	NULL	25709399080.0	28316005563.666668
2005		NULL	NULL	28450984911.0	30798080313.666668
2006		NULL	NULL	30787632700.0	32833262438
2007		NULL	NULL	33155623330.0	34065190129.333332
2008		NULL	NULL	34556531284.0	34676191098
2009		NULL	NULL	34483415774.0	35359208438.666664
2010		NULL	NULL	34988626236.0	36961012285

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp avera...

[0 rows returned]

Indonesia
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	653.849	671.9	33.16466666666656	1138300077496.0	1189256969627.6667
2001	675.667	685.4696666666667	13.569666666666762	1185220856628.0	1246427350064.3333
2002	686.184	707.402	21.932333333333304	1244249974759.0	1311967051499.3333
2003	694.558	723.7013333333333	16.299333333333266	1309811218806.0	1386332019340.6667
2004	741.464	725.761	2.059666666666658	1381839960933.0	1468122687887.3333
2005	735.082	726.334	0.5729999999999791	1467344878283.0	1561372553218.6667
2006	700.737	729.0416666666666	2.7076666666666824	1555183224446.0	1670079325938.3333
2007	743.183	748.0706666666666	19.028999999999996	1661589556927.0	1780463094030
2008	743.205	768.7733333333334	20.7026666666668	1793465196442.0	1898554856418.6667
2009	757.824	813.759	44.98566666666659	1886334528721.0	2017447380522.6667
2010	805.291	869.06	55.30099999999993	2015864844093.0	2148581325268.6667

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2013	914.234	887.841	-25.372333333333245	2406465801759.0	2527840615714.3335
2014	901.679	857.4336666666667	-30.407333333333327	2526852566687.0	2653406947698.3335
2015	847.61	848.5586666666667	-8.875	2650203478697.0	2785879843874.3335
2018	894.721	808.0439999999999	-74.88900000000012	3075456084370.0	3075456084370
2019	879.024	764.7055	-43.33849999999984		NULL
2020	650.387	650.387	-114.31850000000009		NULL

[6 rows returned]

Laos
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp average
2000		NULL	NULL	12209285533.0	13029138112
2001		NULL	NULL	13005703046.0	13907282508.333334
2002		NULL	NULL	13872425757.0	14905638777.666666
2003		NULL	NULL	14843718722.0	16017700480.333334
2004		NULL	NULL	16000771854.0	16795454123
2005		NULL	NULL	17208610865.0	18280134286
2006		NULL	NULL	17176979650.0	19947583976.333332
2007		NULL	NULL	20454812343.0	22238871570.333332
2008		NULL	NULL	22210959936.0	24153273319.333332
2009		NULL	NULL	24050842432.0	26251379007.333332
2010		NULL	NULL	26198017590.0	28486638196.666668

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp avera...

[0 rows returned]

Malaysia
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	272.335	291.3066666666666	15.694666666666649	305415976532.0	314326657427.3333
2001	284.072	312.10566666666665	20.799000000000035	309255226206.0	329135999882.3333
2002	317.513	330.9636666666667	18.85800000000006	328308769544.0	351482970979
2003	334.732	338.6806666666667	7.7169999999999845	349844003897.0	374682934439
2004	340.646	344.3906666666667	5.7099999999999795	376296139496.0	399137030306.3333
2005	340.664	355.9086666666667	11.518000000000029	397908659924.0	424757242551
2006	351.862	362.31033333333335	6.401666666666642	423206291499.0	451626413256.3333
2007	375.2	364.266	1.9556666666666729	453156776230.0	468794830234
2008	359.869	358.86833333333334	-5.39766666666668	478516172040.0	489133234422.6667
2009	357.729	366.95533333333333	8.086999999999989	474711542432.0	511417278197
2010	359.007	381.65333333333336	14.698000000000036	514171988796.0	544910462202.6667

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2008	359.869	358.86833333333334	-5.39766666666668	478516172040.0	489133234422.6667
2013	427.925	418.00333333333333	-1.5596666666667147	602189178661.0	636911028203.3334
2015	397.144	420.0263333333333	-3.0920000000000414	670135292796.0	702434988315.6666
2017	419.665	427.84	-0.10133333333340033	738639634047.0	756149085729
2018	420.889	415.47599999999994	-12.364000000000033	773658537411.0	773658537411
2019	442.966	412.7695	-2.7064999999999486		NULL
2020	382.573	382.573	-30.196500000000015		NULL

[7 rows returned]

Myanmar
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp average
2000		NULL	NULL	84093543261.0	92620037854.33333
2001		NULL	NULL	92175081533.0	102516002638.66667
2002		NULL	NULL	101591488769.0	114162846563.33333
2003		NULL	NULL	113781437614.0	127645389113.66667
2004		NULL	NULL	127115613307.0	142394445057.33334
2005		NULL	NULL	142039116420.0	158063693487.33334
2006		NULL	NULL	158028605445.0	169888288275
2007		NULL	NULL	174123358597.0	178309263620.66666
2008		NULL	NULL	177512900783.0	183509516783
2009		NULL	NULL	183291531482.0	190124908426.33334
2010		NULL	NULL	189724118084.0	199642813219.33334

[21 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_differen...	gdp	3-year gdp avera...

[0 rows returned]

Philippines
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	198.609	194.45433333333335	-9.304666666666662	326462616360.0	339520983115.3333
2001	197.51	190.35500000000002	-4.099333333333334	338531939692.0	355380670728.3333
2002	187.244	188.42466666666667	-1.9303333333333512	353568393294.0	376582601319
2003	186.311	185.39499999999998	-3.029666666666685	374041679199.0	400276583075
2004	191.719	176.70933333333335	-8.685666666666634	402137731464.0	425701480481
2005	178.155	168.30866666666665	-8.400666666666694	424650338562.0	452927712537
2006	160.254	162.04	-6.268666666666661	450316371417.0	480654772912.3333
2007	166.517	163.83666666666666	1.7936666666666667	483816427632.0	503081803567
2008	159.349	166.067	2.2333333333333485	507831519688.0	528955010328.6667
2009	165.635	167.52966666666666	1.4626666666666495	517597463381.0	555164818551
2010	173.217	168.794	1.2643333333333544	561436047917.0	591186404459.6666

[22 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	198.609	194.45433333333335	-9.304666666666662	326462616360.0	339520983115.3333
2001	197.51	190.35500000000002	-4.099333333333334	338531939692.0	355380670728.3333
2002	187.244	188.42466666666667	-1.9303333333333512	353568393294.0	376582601319
2003	186.311	185.39499999999998	-3.029666666666685	374041679199.0	400276583075
2004	191.719	176.70933333333335	-8.685666666666634	402137731464.0	425701480481
2005	178.155	168.30866666666665	-8.400666666666694	424650338562.0	452927712537
2006	160.254	162.04	-6.268666666666661	450316371417.0	480654772912.3333
2018	248.362	236.59366666666665	-13.058333333333366	912443450835.0	912443450835
2019	253.542	230.7095	-5.884166666666658		NULL
2020	207.877	207.877	-22.832499999999982		NULL

[10 rows returned]

Singapore
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	425.658	443.0816666666667	15.424000000000035	153483300990.0	156382416286.66666
2001	458.021	439.26133333333337	-3.8203333333333376	153706145452.0	162227342545.33334
2002	445.566	439.663	0.4016666666666424	161957802418.0	174133808291.66666
2003	414.197	453.0593333333333	13.396333333333303	171018079766.0	188771632016.33334
2004	459.226	488.74899999999997	35.68966666666665	189425542691.0	207298202093.66666
2005	485.755	524.2416666666667	35.49266666666671	205871273592.0	227485626125.33334
2006	521.266	562.8073333333333	38.56566666666663	226597789998.0	244621948368.66666
2007	565.704	605.3366666666667	42.5293333333334	249987814786.0	255277852611.33334
2008	601.452	654.2826666666666	48.94599999999991	257280240322.0	272373778241.33334
2009	648.854	702.0236666666666	47.740999999999985	258565502726.0	294473647422
2010	712.542	732.8953333333334	30.871666666666783	301275591676.0	320321284447.3333

[22 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2001	458.021	439.26133333333337	-3.8203333333333376	153706145452.0	162227342545.33334
2018	871.029	844.2633333333333	-15.466000000000008	410139845598.0	410139845598
2019	846.733	830.8805	-13.382833333333338		NULL
2020	815.028	815.028	-15.852499999999964		NULL

[4 rows returned]

Thailand
(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	413.542	424.7556666666667	3.8000000000000114	595846881139.0	618095367986.6666
2001	406.582	454.5796666666667	29.824000000000012	612467355322.0	648821857347
2002	454.143	503.50766666666664	48.92799999999994	645971867499.0	686892521207.6666
2003	503.014	537.6996666666668	34.19200000000012	688026349220.0	722334454446.6666
2004	553.366	551.9683333333334	14.268666666666604	726679346904.0	754554765925
2005	556.719	551.6513333333334	-0.3170000000000073	752297667216.0	786353329944.6666
2006	545.82	544.2510000000001	-7.400333333333265	784687283655.0	812568585842
2007	552.415	548.3473333333333	4.0963333333331775	822075038963.0	824349903506.3334
2008	534.518	556.225	7.877666666666755	830943434908.0	842326179565.6666
2009	558.109	578.283	22.057999999999993	820031236648.0	857952129285.6666
2010	576.048	601.929	23.645999999999958	876003867141.0	898392142290

[22 rows returned]
(c)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2005	556.719	551.6513333333334	-0.3170000000000073	752297667216.0	786353329944.6666
2006	545.82	544.2510000000001	-7.400333333333265	784687283655.0	812568585842
2018	725.795	706.0923333333334	-19.95399999999995	1124031904190.0	1124031904190
2019	729.096	696.241	-9.8513333333334		NULL
2020	663.386	663.386	-32.85500000000002		NULL

[5 rows returned]

Vietnam

(a) and (b)

year	oil_consumpti...	3-year oil_consumption aver...	moving_difference	gdp	3-year gdp average
2000	99.257	108.35033333333332	8.775333333333322	219648871274.0	234403191450.33334
2001	107.607	117.27666666666666	8.926333333333332	233951164570.0	250162434461.66666
2002	118.187	131.47533333333334	14.198666666666682	249609538507.0	267726222844.66666
2003	126.036	141.073	9.597666666666669	266926600308.0	286930103889.3333
2004	150.203	147.15133333333333	6.078333333333319	286642529719.0	307080721153.6667
2005	146.98	150.68933333333334	3.538000000000011	307221181641.0	328008035399.3333
2006	144.271	158.38733333333332	7.697999999999979	327378452101.0	348234372272
2007	160.817	167.48166666666668	9.094333333333367	349424472456.0	367888669762.3333
2008	170.074	175.7486666666667	8.267000000000024	367900192259.0	387965639433.6667
2009	171.554	186.342	10.593333333333305	386341344572.0	409841522851
2010	185.618	197.87266666666665	11.530666666666633	409655381470.0	433160715193.3333

[22 rows returned]

(c)

2020	271.463	271.463	-17.596499999999992		NULL

[1 row returned]

mongoDB

(a) and (b) (first 6 aggregation stages only)

owidcountries 0.026 s 214 Docs 500

	_id	country	year	oil_consumption	gdp	oil_mvg_avg	gdp_mov_avg	pre_oil_mvg_avg	mov_avg_oil_diff
53	63	Indonesia	2010	805.291	2,015,864,844,093 (2.0T)	869.06	2,148,581,325,268.6667 (2.1T)	813.759	55.301
54	63	Indonesia	2011	878.162	2,150,142,768,754 (2.2T)	905.3743	2,278,781,644,490.6665 (2.3T)	869.06	36.3143
55	63	Indonesia	2012	923.727	2,279,736,362,959 (2.3T)	913.2133	2,404,351,577,135 (2.4T)	905.3743	7.839
56	63	Indonesia	2013	914.234	2,406,465,801,759 (2.4T)	887.841	2,527,840,615,714.3335 (2.5T)	913.2133	-25.3723
57	63	Indonesia	2014	901.679	2,526,852,566,687 (2.5T)	857.4337	2,653,406,947,698.3335 (2.7T)	887.841	-30.4073
58	63	Indonesia	2015	847.61	2,650,203,478,697 (2.7T)	848.5587	2,785,879,843,874.3335 (2.8T)	857.4337	-8.875
59	63	Indonesia	2016	823.012	2,783,164,797,711 (2.8T)	864.2623	2,927,630,712,432 (2.9T)	848.5587	15.7037
60	63	Indonesia	2017	875.054	2,924,271,255,215 (2.9T)	882.933	2,999,863,669,792.5 (3.0T)	864.2623	18.6707
61	63	Indonesia	2018	894.721	3,075,456,084,370 (3.1T)	808.044	3,075,456,084,370 (3.1T)	882.933	-74.889
62	63	Indonesia	2019	879.024	null	764.7055	null	808.044	-43.3385
63	63	Indonesia	2020	650.387	null	650.387	null	764.7055	-114.3185
64	63	Laos	2000	null	12,209,285,533 (12.2G)	null	13,029,138,112 (13.0G)	null	null

[214 docs returned]

(c) (all aggregation stages)

owidcountries 0.022 s 33 Docs 500

	_id	country	year	oil_consumption	gdp	oil_mvg_avg	gdp_mov_avg	pre_oil_mvg_avg	mov_avg_oil_diff
1	63	Indonesia	2013	914.234	2,406,465,801,759 (2.4T)	887.841	2,527,840,615,714.3335 (2.5T)	913.2133	-25.3723
2	63	Indonesia	2014	901.679	2,526,852,566,687 (2.5T)	857.4337	2,653,406,947,698.3335 (2.7T)	887.841	-30.4073
3	63	Indonesia	2015	847.61	2,650,203,478,697 (2.7T)	848.5587	2,785,879,843,874.3335 (2.8T)	857.4337	-8.875
4	63	Indonesia	2018	894.721	3,075,456,084,370 (3.1T)	808.044	3,075,456,084,370 (3.1T)	882.933	-74.889
5	63	Indonesia	2019	879.024	null	764.7055	null	808.044	-43.3385
6	63	Indonesia	2020	650.387	null	650.387	null	764.7055	-114.3185
7	63	Malaysia	2008	359.869	478,516,172,040 (0.48T)	358.8683	489,133,234,422.6667 (0.49T)	364.266	-5.3977
8	63	Malaysia	2013	427.925	602,189,178,661 (0.60T)	418.0033	636,911,028,203.3334 (0.64T)	419.563	-1.5597
9	63	Malaysia	2015	397.144	670,135,292,796 (0.67T)	420.0263	702,434,988,315.6666 (0.70T)	423.1183	-3.092
10	63	Malaysia	2017	419.665	738,639,634,047 (0.74T)	427.84	756,149,085,729 (0.76T)	427.9413	-0.1013
11	63	Malaysia	2018	420.889	773,658,537,411 (0.77T)	415.476	773,658,537,411 (0.77T)	427.84	-12.364
12	63	Malaysia	2019	442.966	null	412.7695	null	415.476	-2.7065

[33 docs returned]

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

mySQL

	energy_products	sub_products	avg(value_ktoe)
▶	Coal and Peat	Coal and Peat	120.05937499999999
	Crude Oil	Crude Oil	25518.062499999996
	Crude Oil	Other Crude Oil	1393.1374999999998
	Petroleum Products	Fuel Oil	39850.53125
	Petroleum Products	Gas/Diesel Oil	17556.437500000004
	Petroleum Products	Gasoline	18312.056250000005
	Petroleum Products	Jet Fuel Kerosene	4253.884375
	Petroleum Products	Naphtha	3807.5656249999997
	Petroleum Products	Other Petroleum Products	4907.893750000001
	Natural Gas (NG)	Pipeline NG	6940.34375
	Natural Gas (NG)	Liquefied NG	1246.2625
	Other Energy Pro...	Other Energy Products	35.925

[12 rows returned]

mongoDB

filteredimport 0.010 s 12 Docs

	energy_products	sub_products	total_avg
1	Coal and Peat	Coal and Peat	120.0594
2	Crude Oil	Crude Oil	25,518.0625 (25.5K)
3	Crude Oil	Other Crude Oil	1,393.1375 (1.4K)
4	Natural Gas (NG)	Liquefied NG	1,246.2625 (1.2K)
5	Natural Gas (NG)	Pipeline NG	6,940.3438 (6.9K)
6	Other Energy Products	Other Energy Products	35.925
7	Petroleum Products	Fuel Oil	39,850.5313 (39.9K)
8	Petroleum Products	Gas/Diesel Oil	17,556.4375 (17.6K)
9	Petroleum Products	Gasoline	18,312.0563 (18.3K)
10	Petroleum Products	Jet Fuel Kerosene	4,253.8844 (4.3K)
11	Petroleum Products	Naphtha	3,807.5656 (3.8K)
12	Petroleum Products	Other Petroleum Products	4,907.8938 (4.9K)

[12 docs returned]

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

mySQL

(a)

year	energy_products	sub_products	difference
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
2005	Natural Gas (NG)	Pipeline NG	NULL
2005	Natural Gas (NG)	Liquefied NG	NULL
2005	Other Energy Pro…	Other Energy Products	NULL

[192 rows returned]

(b)

year	difference
2014	5

[1 row returned]

mongoDB

(a) (first 4 aggregation stages only)

filteredimport 0.015 s 192 Docs

	energy_products	sub_products	year	difference
1	Coal and Peat	Coal and Peat	2005	-7.9
2	Crude Oil	Crude Oil	2005	-58,707.3
3	Crude Oil	Other Crude Oil	2005	-602.8
4	Petroleum Products	Fuel Oil	2005	-13,484.5
5	Petroleum Products	Gas/Diesel Oil	2005	11,209.1 (11.2K)
6	Petroleum Products	Gasoline	2005	7,563.5 (7.6K)
7	Petroleum Products	Jet Fuel Kerosene	2005	4,774.6 (4.8K)
8	Petroleum Products	Naphtha	2005	-1,624.8
9	Petroleum Products	Other Petroleum Products	2005	5,882.9 (5.9K)
10	Natural Gas (NG)	Pipeline NG	2005	-5,571.1
11	Natural Gas (NG)	Liquefied NG	2005	0
12	Other Energy Products	Other Energy Products	2005	0
13	Coal and Peat	Coal and Peat	2006	-3.8
14	Crude Oil	Crude Oil	2006	-56,536.4
15	Crude Oil	Other Crude Oil	2006	-867
16	Petroleum Products	Fuel Oil	2006	-17,796.2

[192 docs returned]

(b) (all aggregation stages)

filteredimport 0.012 s 1 Doc

	_id	count
1	2014	5

[1 doc returned]

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

mySQL

Region	year	yearly_average
Central Region	2005	670.2252042007
East Region	2005	530.1846590909092
North East Region	2005	525.7578616352197
North Region	2005	576.3765407554675
West Region	2005	480.0438802083332
Central Region	2006	680.1069914040105
East Region	2006	517.7507575757572
North East Region	2006	529.01713836478
North Region	2006	567.887301587301
West Region	2006	477.2054687500001
Central Region	2007	674.1132653061223

[85 rows returned]

mongoDB

filtered_hec 0.063 s 85 Docs

	_id		avg_kwh
	year	region	
1	2005	Central Region	670.2252
2	2005	East Region	530.1847
3	2005	North East Region	525.7579
4	2005	North Region	576.3765
5	2005	West Region	480.0439
6	2006	Central Region	680.107
7	2006	East Region	517.7508
8	2006	North East Region	529.0171
9	2006	North Region	567.8873
10	2006	West Region	477.2055
11	2007	Central Region	674.1133
12	2007	East Region	510.6617

[85 docs returned]

9. Who are the energy-saving stars?

   a) Compute the yearly average of <kwh_per_acc> in each region, excluding “overall”. (Done in question 8).
   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).

   b) Display the top 3 regions with the most instances of negative 2-year averages.

mySQL

(a)

Region	year	average	previous_average	moving_difference
Central Region	2005	670.2252042007	NULL	NULL
Central Region	2006	680.1069914040105	670.2252042007	9.881787203310523
Central Region	2007	674.1132653061223	680.1069914040105	-5.993726097888157
Central Region	2008	672.2845804988648	674.1132653061223	-1.8286848072575594
Central Region	2009	679.6440726035167	672.2845804988648	7.359492104651963
Central Region	2010	691.8918196839592	679.6440726035167	12.247747080442423
Central Region	2011	660.8094178082176	691.8918196839592	-31.08240187574154
Central Region	2012	660.0434459072707	660.8094178082176	-0.7659719009469654
Central Region	2013	658.0441395082904	660.0434459072707	-1.9993063989802522
Central Region	2014	650.6985083189908	658.0441395082904	-7.345631189299638
Central Region	2015	644.8741102181405	650.6985083189908	-5.824398100850317

[85 rows returned]

(b)

Region	negative 2-year averages
East Region	11
Central Region	10
West Region	10

[3 rows returned]

mongoDB

(a) (first 4 aggregation stages only)

filtered_hec 0.062 s 85 Docs

	_id		avg_kwh	prev_year_avg_kv	mvg_diff
	year	region			
1	2005	Central Region	670.2252	null	null
2	2006	Central Region	680.107	670.2252	9.8818
3	2007	Central Region	674.1133	680.107	-5.9937
4	2008	Central Region	672.2846	674.1133	-1.8287
5	2009	Central Region	679.6441	672.2846	7.3595
6	2010	Central Region	691.8918	679.6441	12.2477
7	2011	Central Region	660.8094	691.8918	-31.0824
8	2012	Central Region	660.0434	660.8094	-0.766
9	2013	Central Region	658.0441	660.0434	-1.9993
10	2014	Central Region	650.6985	658.0441	-7.3456
11	2015	Central Region	644.8741	650.6985	-5.8244
12	2016	Central Region	653.3505	644.8741	8.4763

[85 rows returned]

(b) (all aggregation stages)

filtered_hec 0.078 s 3 Docs

	_id	count
1	East Region	11
2	West Region	10
3	Central Region	10

[3 rows returned]

10. 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.

mySQL

Region	year	first_quarter	second_quarter	third_quarter	fourth_quarter
Central Region	2005	604.1358974358975	721.738694638695	687.0657342657345	667.9498829039808
Central Region	2006	619.723148148148	728.9979452054795	698.4880459770116	672.5520454545457
Central Region	2007	591.7594104308389	701.7766439909293	718.3582766439905	684.5587301587306
Central Region	2008	615.6253968253968	710.9734693877556	684.4648526077101	678.0746031746038
Central Region	2009	606.7126984126986	698.5510204081633	718.2777272727275	695.1224489795915
Central Region	2010	643.7496598639453	730.246712018141	671.7500000000005	721.8879429324202
Central Region	2011	591.0038812785392	691.6251141552513	706.9821917808227	653.6264840182652
Central Region	2012	609.0598173515982	681.0775229357799	691.8528735632183	658.4974885844746
Central Region	2013	599.6205479452055	695.2631578947368	695.6168949771694	641.6862385321101
Central Region	2014	578.5720823798623	684.163990825688	685.2843678160917	655.0282758620684
Central Region	2015	563.3572413793105	659.8983870967741	681.5765517241374	674.4945205479454
Central Region	2016	607.3452054794523	710.4732876712326	654.7958904109595	640.7298165137605

[85 rows returned]

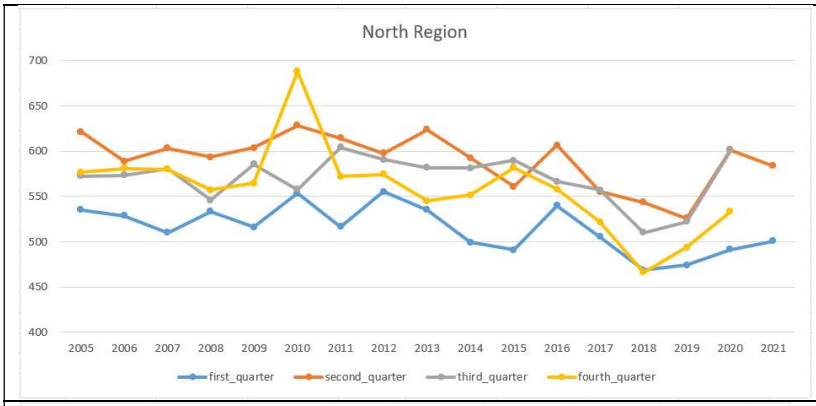
mongoDB

filtered_hec 0.172 s 330 Docs

	Region	Year	Quarter	Quarterly_Ave
1	Central Region	2005	1	604.1359
2	Central Region	2005	2	721.7387
3	Central Region	2005	3	687.0657
4	Central Region	2005	4	667.9499
5	Central Region	2006	1	619.7231
6	Central Region	2006	2	728.9979
7	Central Region	2006	3	698.488
8	Central Region	2006	4	672.552
9	Central Region	2007	1	591.7594
10	Central Region	2007	2	701.7766
11	Central Region	2007	3	718.3583
12	Central Region	2007	4	684.5587
13	Central Region	2008	1	615.6254
14	Central Region	2008	2	710.9735
15	Central Region	2008	3	684.4649
16	Central Region	2008	4	678.0746

[330 docs returned]

*Note: We have 4 quarters each year except for 2021 (2 quarters). There are 5 regions. So we expect a total of 85*4 – 2*5 = 330 docs.


North Region
700
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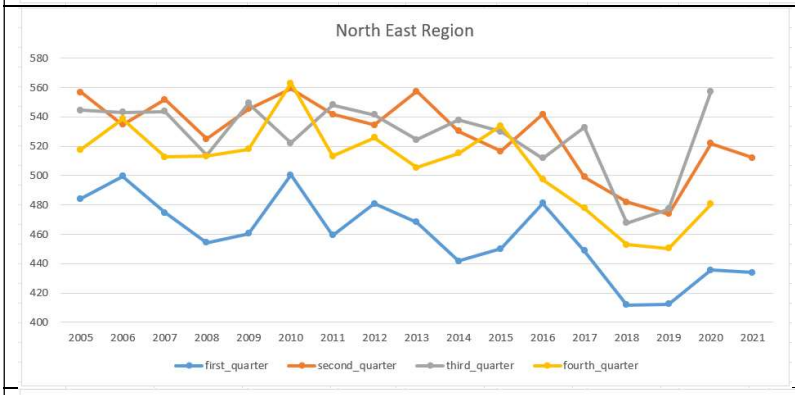
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
first_quarter
second_quarter
third_quarter
fourth_quarter


North East Region
580
560
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2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
first_quarter
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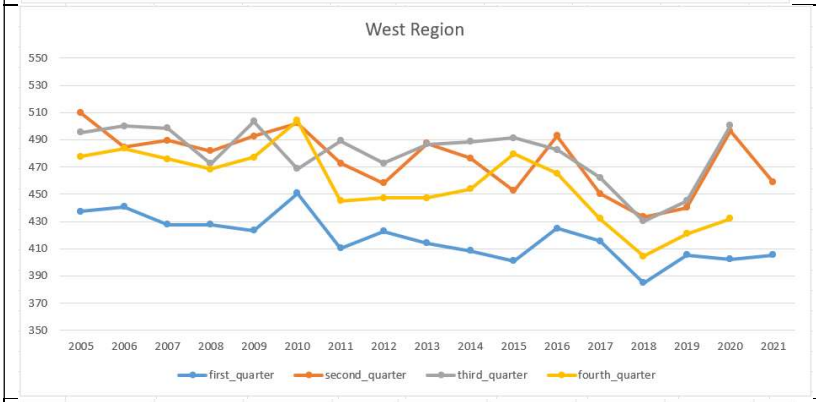
third_quarter
fourth_quarter


West Region
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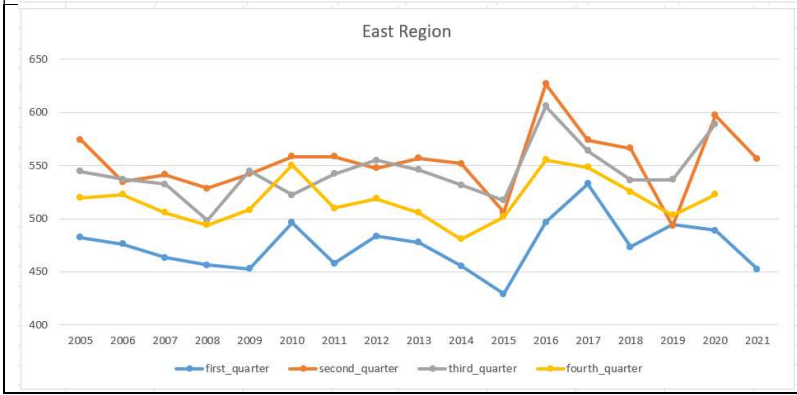
third_quarter
fourth_quarter


East Region
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2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
first_quarter
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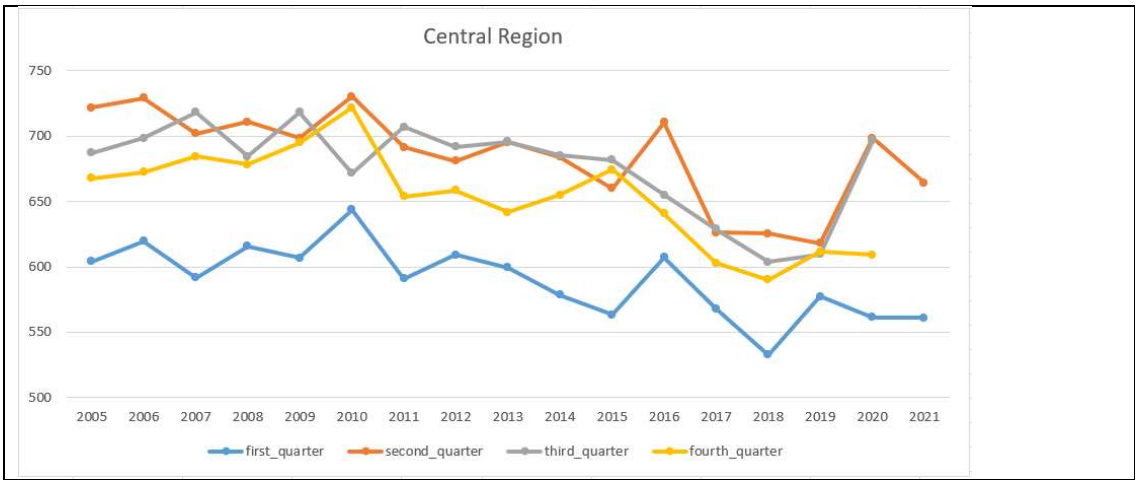
fourth_quarter



From the graphs above, we can see that the order of energy consumption from most to least would be third quarter, second_quarter, fourth_quarter and first_quarter.

11. 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>.

mySQL

sub_housing_type	year	first_quarter	second_quarter	third_quarter	fourth_quarter
1 Room and 2 Room	2005	64.56666666666666	62.833333333333336	61.366666666666674	61.333333333333336
1 Room and 2 Room	2006	61.76666666666667	59.166666666666664	59.333333333333336	61.06666666666666
1 Room and 2 Room	2007	61.06666666666666	59.800000000000004	58.70000000000001	59.86666666666667
1 Room and 2 Room	2008	60.6	61.300000000000004	60.63333333333333	60.633333333333326
1 Room and 2 Room	2009	60.93333333333334	59.29999999999999	59.43333333333334	60.63333333333333
1 Room and 2 Room	2010	59.199999999999996	57.53333333333333	58.1	59.06666666666666
1 Room and 2 Room	2011	58.86666666666667	57.56666666666666	57.86666666666667	57.96666666666667
1 Room and 2 Room	2012	58.1	57	56.833333333333336	56.46666666666667
1 Room and 2 Room	2013	56.199999999999996	55.23333333333333	56.76666666666667	55.63333333333333
1 Room and 2 Room	2014	56.53333333333333	53.53333333333333	54.56666666666666	53.26666666666667
1 Room and 2 Room	2015	55.13333333333333	53.333333333333336	54.73333333333333	54.166666666666664

[136 rows returned]

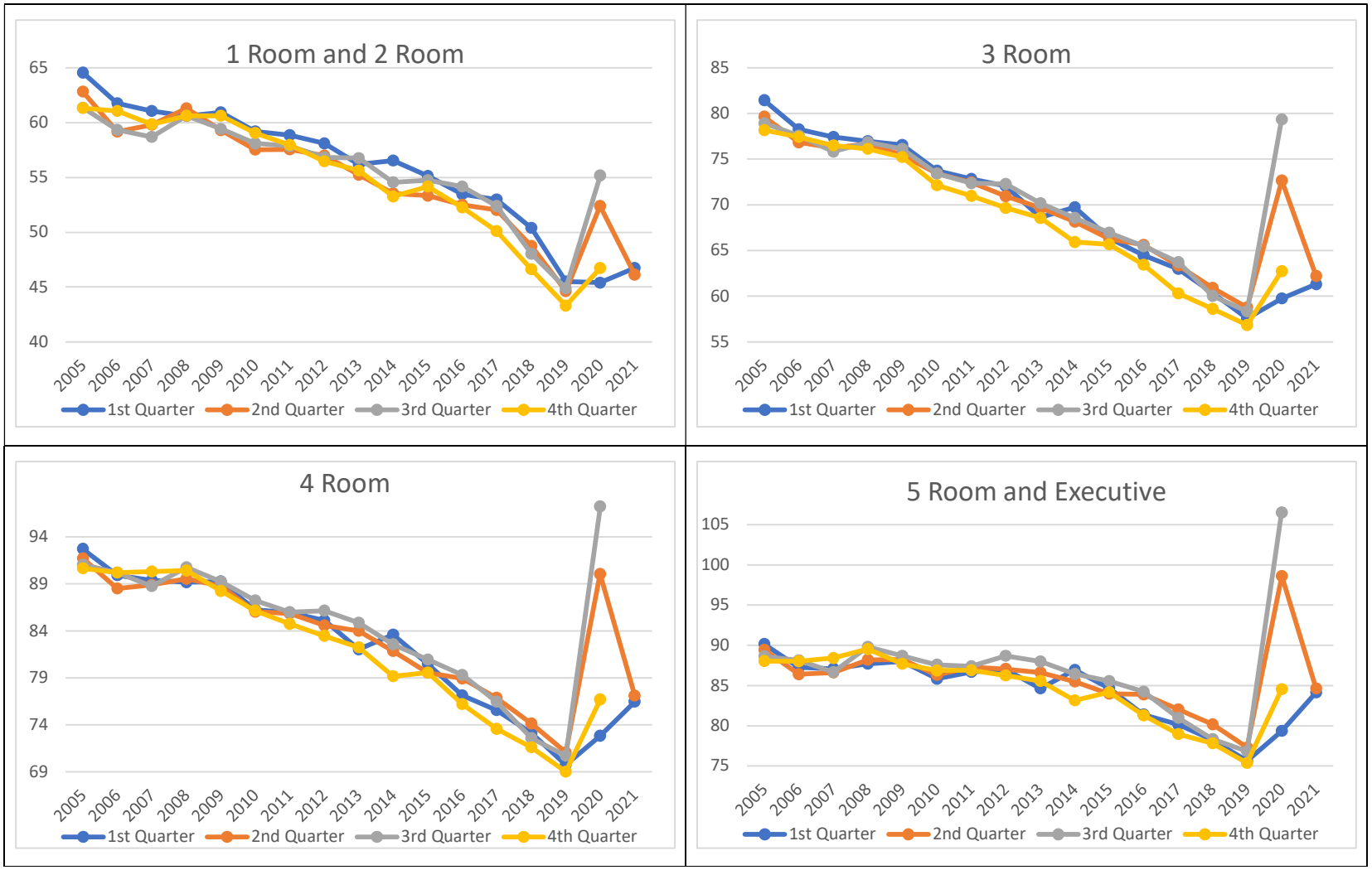
mongoDB

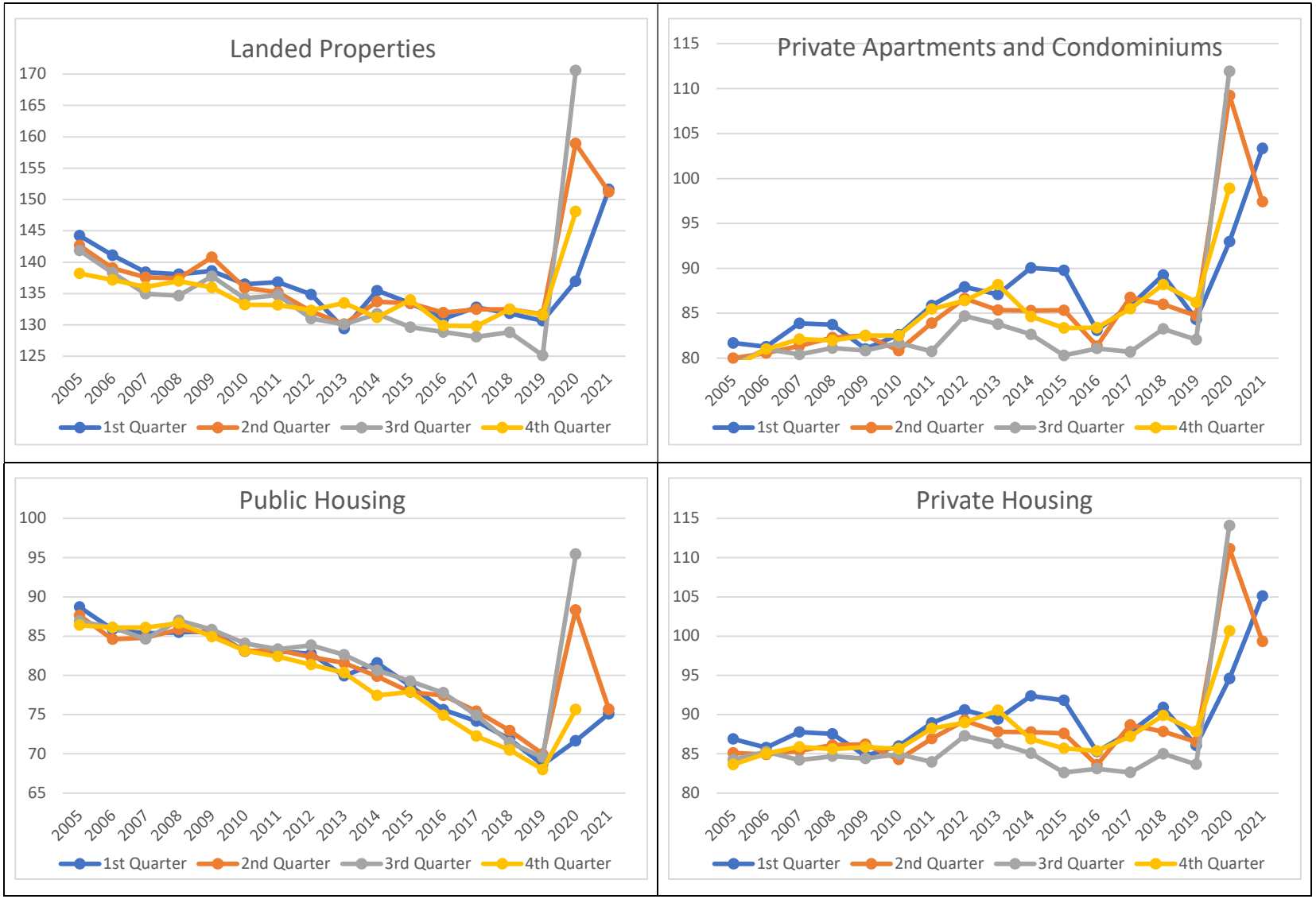
hgc 0.027 s 528 Docs

	Sub_Housing_Type	Year	Quarter	Quarterly_Ave
1	1 Room and 2 Room	2005	1	64.5667
2	1 Room and 2 Room	2005	2	62.8333
3	1 Room and 2 Room	2005	3	61.3667
4	1 Room and 2 Room	2005	4	61.3333
5	1 Room and 2 Room	2006	1	61.7667
6	1 Room and 2 Room	2006	2	59.1667
7	1 Room and 2 Room	2006	3	59.3333
8	1 Room and 2 Room	2006	4	61.0667
9	1 Room and 2 Room	2007	1	61.0667
10	1 Room and 2 Room	2007	2	59.8
11	1 Room and 2 Room	2007	3	58.7
12	1 Room and 2 Room	2007	4	59.8667
13	1 Room and 2 Room	2008	1	60.6
14	1 Room and 2 Room	2008	2	61.3
15	1 Room and 2 Room	2008	3	60.6333
16	1 Room and 2 Room	2008	4	60.6333
17	1 Room and 2 Room	2009	1	60.9333

[528 docs returned]

*Note: We have 4 quarters each year except for 2021 (2 quarters). There are 8 sub housing types. So we expect a total of 136*4 – 2*8 = 528 docs.


1 Room and 2 Room
65
60
55
50
45
40
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
3 Room
85
80
75
70
65
60
55
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
4 Room
94
89
84
79
74
69
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
5 Room and Executive
105
100
95
90
85
80
75
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter


Landed Properties
170
165
160
155
150
145
140
135
130
125
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
Private Apartments and Condominiums
115
110
105
100
95
90
85
80
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
Public Housing
100
95
90
85
80
75
70
65
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter
Private Housing
115
110
105
100
95
90
85
80
2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
1st Quarter
2nd Quarter
3rd Quarter
4th Quarter

From the above visualisations, we can see the following seasonal effects on town gas consumption:

1. For public housing (overall public housing and various individual public housing types) and landed properties, from 2005 to 2019, town gas consumption is generally highest in 1st quarter and lowest in 4th quarter. In part, this could be because gas consumption is steadily decreasing from 2005 to 2019 for these property types. Thus, the 1st quarter of any year tends to be the highest and similarly, the 4th quarter tends to be the lowest.
2. For private housing and private apartments and condominiums, gas consumption tends to be highest in 1st quarter and lowest in 3rd quarter.
3. For 2020, across all housing types, there was a sudden and significant rise in consumption compared to 2019. Also, the 3rd quarter had highest gas consumption followed by 2nd quarter, 4th quarter and 1st quarter. This is likely because of the covid pandemic, which increased the number of hours individuals spent at home, leading to higher gas consumption levels. For instance, the circuit breaker came into effect between April and June 2020 (2nd quarter). This could explain the extremely large rise in gas consumption between 1st and second quarter. After the circuit breaker, working from home was retained as a default and this was the first quarter that most individuals spent entirely at home. This could explain the continued increase in gas consumption from 2nd quarter to 3rd quarter.
4. Subsequently, for 2020 4th quarter, 2021 1st and 2nd quarter, gas consumption remained roughly the same (though lower than in previous quarters). Again, this could be due to the stabilising covid situation where government covid policies loosened up and stayed mostly unchanged during this period

Appendix B – Additional Visualisations for Q12-15

12.

Time Period	Population	GDP	GDP per capita
1965-1974	country, avg_population, avg_gdp Ireland, 2920473.4, 28657401830 New Zealand, 2815807.1, 51931951355 Israel, 2809473.3, 37156112548.4 Albania, 2126379, 6752570247.3 Libya, 2107539.9, 11596506058.7 Singapore, 2053694.4, 13510621475 Congo, 1314498, 3102731974.1 Mongolia, 1265784.6, 1494185100 Trinidad and Tobago, 947190, 12327663394 Oman, 720557.9, 3664983899.8 Kuwait, 715666.1, 29149048902.9	country, avg_population, avg_gdp Tunisia, 5019980.7, 15471341212.8 Cote d'Ivoire, 5073497.7, 15302490138.4 Angola, 6034143.8, 15152002165.8 Bolivia, 4448319.3, 14690707887.9 Afghanistan, 11102417.9, 14662519100 Singapore, 2053694.4, 13510621475 Madagascar, 6516690.8, 12453046261.3 Trinidad and Tobago, 947190, 12327663394 Tanzania, 13404130.2, 12295004191.3 Nepal, 11993220.4, 12266294800 Libya, 2107539.9, 11596506058.7	country, avg_gdp, avg_population, avg_gdp_per_capi... Chile, 74850816700.4, 9707285.6, 7699.628511495224 Bulgaria, 62990193441.4, 8473524.4, 7419.859087322526 Poland, 235926526332.4, 32522040.8, 7234.533230811799 Mexico, 353099638969.9, 50852806.8, 6885.722129544505 Iran, 192416787586.9, 28225747.4, 6688.56807377103 Singapore, 13510621475, 2053694.4, 6481.653797521627 South Africa, 142031564709.9, 21860038, 6468.889397639053 Cyprus, 3953159740, 610210.9, 6451.215464531539 Syria, 41397403152, 6588213.714285715, 6238.081828407675 Bahrain, 1327978637.8, 213547, 6157.739006923704 Peru, 80151015950, 13312340.5, 6003.48951242379...
1975-1984	country, avg_population, avg_gdp Togo, 2923317, 3800695800 Albania, 2655476.5, 9883155403 Lebanon, 2609900.6, 12484068574 Jordan, 2572452.4, 17189378651.8 Costa Rica, 2525231.8, 17382214098.6 Singapore, 2419315, 32367002924.2 Central African Republic, 2337168.6, 2931277200 Jamaica, 2234384.8, 11502325585.2 Panama, 2074079, 14690233800 Liberia, 1986039.6, 7414810000 Congo, 1758331, 5679685793.6	country, avg_population, avg_gdp Cuba, 9786327.9, 41123967600 Ethiopia, 37127702.4, 39710658911.6 Guatemala, 7213362.1, 39076447200 United Arab Emirates, 949217, 34933004946.8 Yemen, 7881303.5, 32438748781.6 Singapore, 2419315, 32367002924.2 Kenya, 17759112.2, 29043717594.4 Tunisia, 6337265.5, 28784274494.4 Uruguay, 2953832.6, 28575107600 Democratic Republic of Congo, 25997321.2, 28484488093.7 Kuwait, 1332607.9, 27752848668	country, avg_gdp, avg_population, avg_gdp_per_capita Venezuela, 233346040228.2, 14997999.1, 15637.01463608017 Greece, 131480706023.3, 9522147.8, 13789.382300926463 Spain, 508981437695.1, 37412980, 13592.421872941957 Ireland, 44659743050, 3344455.3, 13321.06354026477 Puerto Rico, 42124229200, 3165114.4, 13309.943674919235 Singapore, 32367002924.2, 2419315, 13250.290788040245 Argentina, 350719970715, 27735268.4, 12664.150851670169 Portugal, 118623417630.8, 9638582.2, 12285.900343946372 Czechia, 122531714655.3, 10275668.9, 11920.03302718286 Barbados, 2992053000, 254009.2, 11780.317944048746 Malta, 3377117956.2, 337130.6, 10016.470320946888
1985-1994	country, avg_population, avg_gdp Puerto Rico, 3394047.2, 58716304419.2 Armenia, 3363198.3333333..., 14124180306.666666 Albania, 3175171.7, 11123180522 Uruguay, 3102366.5, 32692243459.2 Costa Rica, 3087093.8, 22833603667.3 Singapore, 3013076.5, 68020924282.8 Lebanon, 2884229.5, 15507449024.9 Central African Republic, 2805212.8, 3169235450.7 Latvia, 2618375.1, 34163786032.9 Panama, 2447765, 18095849032.8 Jamaica, 2417585.6, 13651401989.7	country, avg_population, avg_gdp Hungary, 10421175.9, 106650676747.7 Morocco, 24570487, 99916019840.7 Israel, 4470356.2, 93069615585.9 Bulgaria, 8807836.4, 81141970477.1 New Zealand, 3409831.7, 75060442671.9 Singapore, 3013076.5, 68020924282.8 Sri Lanka, 17183166.4, 67048100469.9 Iraq, 17353565.1, 67031942737.8 Ecuador, 10121738.6, 65141283150.3 Ireland, 3523819.4, 63574010744.9 Slovakia, 5272871.6, 60848185886.1	country, avg_gdp, avg_population, avg_gdp_per_capita Germany, 2068447833526.5, 79025076, 26157.43600254578 United Kingdom, 1457588902265.5, 57061823.2, 25534.75441280534 Italy, 1440417543326.8, 57066816.4, 25238.549898443995 Finland, 124131798508, 4995529.9, 24846.892421177934 United Arab Emirates, 41885571615.25, 1749346.25, 23768.170161033297 Singapore, 68020924282.8, 3013076.5, 22258.352896605407 New Zealand, 75060442671.9, 3409831.7, 22016.660550189183 Israel, 93069615585.9, 4470356.2, 20739.82769977925 Spain, 715936628562.1, 39180750, 18257.608194295553 Ireland, 63574010744.9, 3523819.4, 18031.32245405515 Puerto Rico, 58716304419.2, 3394047.2, 17245.507584694675

1995-2004	country, avg_population, avg_gdp Georgia, 4494700.2, 23830768783.2 Norway, 4483880.9, 235455527148.9 Turkmenistan, 4477929.4, 20116581448.6 Croatia, 4467714.4, 55234365734 Moldova, 4233319.6, 13935511786.8 Singapore, 3924859.2, 146083981286.5 Lebanon, 3921247.6, 33436805543.7 Costa Rica, 3907273.2, 35399407745.1 New Zealand, 3857938.1, 101246338548.2 Ireland, 3785375.3, 138537418621.5 Bosnia and…, 3759968.1, 24826119873.7	country, avg_population, avg_gdp Finland, 5181897, 161414033358.4 Peru, 26135695.4, 156110147186.2 Kazakhstan, 15224720.5, 152951539525.8 United Arab Emirates, 3110089, 149619688902.3 Israel, 5863720.7, 148827763275.9 Singapore, 3924859.2, 146083981286.5 Morocco, 28597109.2, 138924509753.3 Ireland, 3785375.3, 138537418621.5 Hungary, 10235632.3, 132919115233.9 Syria, 16139359.8, 130633545734.7 Uzbekistan, 24524124, 116220262705	country, avg_gdp, avg_population, avg_gdp_per_capita United States, 12453353085575.2, 279470432, 44472.442747436246 Switzerland, 305687254063.2, 7144426.2, 42734.67526034415 Qatar, 25766441603.3, 597682.5, 41251.34772553273 Kuwait, 75437692736.2, 1937329.6, 38140.388755890934 Denmark, 200659064373, 5324920.1, 37657.51034064063 Singapore, 146083981286.5, 3924859.2, 37026.8404950799 Ireland, 138537418621.5, 3785375.3, 36309.64435369389 Netherlands, 573062369189.8, 15881054.7, 36035.06493004723 Canada, 1094126799695.9, 30463918.6, 35837.86889616014 Australia, 675834153454.1, 18903607, 35649.88845311875 Austria, 271547742943.2, 8082710.6, 33576.85087405473
2005-2014	country, avg_population, avg_gdp Kyrgyzstan, 5411142.1, 21330479372.9 Slovakia, 5407547.8, 115206082233 Finland, 5356686.5, 203129073348.6 Lebanon, 5167040.7, 78809255644.3 Turkmenistan, 5074051.9, 72085535651.1 Singapore, 4973270.9, 287770332108.7 Norway, 4869226.7, 376532141696.1 Costa Rica, 4545537.4, 53875872414 Ireland, 4460285, 222696898445.2 New Zealand, 4349901.1, 135836999793.4 Croatia, 4327441.6, 78461835765.8	country, avg_population, avg_gdp Kazakhstan, 16238452.3, 330418997044.2 Chile, 16968881.7, 325614047726.4 Romania, 20635806.4, 317630379037.4 Iraq, 29956684.2, 315666174299 Hong Kong, 6946139.9, 297704139609.2 Singapore, 4973270.9, 287770332108.7 Greece, 10946977.6, 282331668446.5 Peru, 28931936.8, 268683125674.9 Czechia, 10468969.2, 265149446881.2 Portugal, 10540685.9, 259823287497.1 Denmark, 5541112.3, 240634260383.1	country, avg_gdp, avg_population, avg_gdp_per_capita Qatar, 212583279759.1, 1708221.9, 116246.10089773608 Norway, 376532141696.1, 4869226.7, 77183.4668187056 Kuwait, 218070204503.5, 2935104.5, 73845.85485142432 United Arab Emirates, 501908798486.1, 7611455.8, 65784.57050118547 Singapore, 287770332108.7, 4973270.9, 57391.206316975135 Switzerland, 444703934926.9, 7775704, 57093.40680918911 Luxembourg, 27636493619.7, 503543.8, 54934.04569655204 United States, 15459875503697.8, 307286787.2, 50305.53517465786 Ireland, 222696898445.2, 4460285, 49950.91779821779 Australia, 981916391726.8, 21915230.6, 44716.39161027871
2015-2021	country, avg_population, avg_gdp Libya, 6636417.166666667, 48516304696.666664 Nicaragua, 6424601, 20067993877.333332 El Salvador, 6421196.142857143, 29991935987 Kyrgyzstan, 6244541.166666667, 18642521500.666668 Turkmenistan, 5801584, 86853712085.16667 Singapore, 5751811.857142857, 222751479248.14285 Denmark, 5751690.142857143, 148696221166.2857 Finland, 5519148.142857143, 118907220691 Slovakia, 5450845.142857143, 79522292625.42857 Norway, 5335827.285714285, 250817490008.7143 Congo, 5181791.5, 19761559632.333332	country, avg_population, avg_gdp Kazakhstan, 17950638, 440101906972 Norway, 5271265.25, 438930607515.25 Venezuela, 29555668, 427439241087.25 Ukraine, 44592302, 413608723536.5 Chile, 18344507.5, 397257575831 Singapore, 5677828.25, 389815088684.25 Qatar, 2681624, 389751604066.75 Austria, 8784314.5, 369678453409.75 Romania, 19720384.5, 369658370335.5 Peru, 31207584.5, 367371907362.5 Hong Kong, 7276894, 357500549181.5	country, avg_gdp, avg_population, avg_gdp_per_capita Qatar, 389751604066.75, 2681624, 145367.18135791057 Norway, 438930607515.25, 5271265.25, 83261.95882470947 United Arab Emirates, 715533862410.75, 9435510.75, 75825.23154285326 Kuwait, 279459920759, 3996466.5, 69998.80160105784 Singapore, 389815088684.25, 5677828.25, 68636.35324875645 Switzerland, 514585886824.75, 8414525.25, 61146.72117088864 Ireland, 282098047193, 4730046.25, 59587.194581978474 Luxembourg, 33576636696.5, 585541.25, 57331.2304742139 United States, 17450516266175.5, 324018824, 53849.03808651431 Saudi Arabia, 1646568458006.75, 32741265, 50304.23515898298

Population (35 rows)

country	COUNT(*)
Singapore	6
Lebanon	4
Costa Rica	4
Norway	3
Albania	3
Turkmenistan	3
New Zealand	3
Ireland	3
Congo	3
Panama	2
Central Afric…	2
Jamaica	2
Croatia	2
Libya	2
Finland	2
Slovakia	2
Kyrgyzstan	2

GDP (47 rows)

country	COUNT(*)
Singapore	6
Peru	3
Kazakhstan	3
Morocco	2
Chile	2
Romania	2
Hong Kong	2
Tunisia	2
Ireland	2
Iraq	2
Hungary	2
Israel	2
United Ara…	2

GDP per capita (40 rows)

country	COUNT(*)
Singapore	6
Ireland	5
United States	3
Switzerland	3
Qatar	3
Kuwait	3
United Arab Emirates	3
Luxembourg	2
Norway	2
Australia	2
Spain	2
Puerto Rico	2

13.

Countries with the highest maximum renewables_share_energy from 2000 [217 rows/docs returned]

owidcountries 0.269 s 217 Docs

	_id	renewables_share_energy
1	Iceland	82.835
2	Norway	71.128
3	Sweden	48.346
4	Brazil	46.054
5	New Zealand	38.04
6	Austria	36.392
7	Peru	35.138
8	Ecuador	35.111
9	Switzerland	34.959
10	Denmark	34.343
11	Colombia	33.758
12	Portugal	30.199
13	Finland	30.127
14	Canada	28.999
15	Latvia	28.7

owidcountries 0.182 s 217 Docs

	_id	renewables_share_energy
16	Croatia	26.817
17	Sri Lanka	26.122
18	Chile	24.452
19	Vietnam	24.254
20	Venezuela	23.613
21	Slovenia	20.669
22	Spain	20.311
23	Germany	19.575
24	Ireland	19.411
25	North Macedonia	18.931
26	Italy	18.539
27	United Kingdom	18.255
28	Turkey	18.105
29	Philippines	18.061
30	Romania	17.975

owidcountries 0.182 s 217 Docs

	_id	renewables_share_energy
31	Argentina	17.506
32	Greece	15.973
33	France	14.086
34	China	13.429
35	Pakistan	12.893

country	maximum_renewables_share_ene...
Iceland	82.835
Norway	71.128
Sweden	48.346
Brazil	46.054
New Zealand	38.04
Austria	36.392
Peru	35.138
Ecuador	35.111
Switzerland	34.959
Denmark	34.343
Colombia	33.758
Portugal	30.199
Finland	30.127
Canada	28.999
Latvia	28.7

Croatia	26.817
Sri Lanka	26.122
Chile	24.452
Vietnam	24.254
Venezuela	23.613
Slovenia	20.669
Spain	20.311
Germany	19.575
Ireland	19.411
North Macedonia	18.931
Italy	18.539
United Kingdom	18.255
Turkey	18.105
Philippines	18.061
Romania	17.975

Argentina	17.506
Greece	15.973
France	14.086
China	13.429
Pakistan	12.893

For Perspective 1:
Annual GDP and renewables_share_energy for the 12 countries (Iceland, Norway, Sweden, New Zealand, Brazil, Peru, Ecuador, Colombia, Sri Lanka, Vietnam, Philippines, Pakistan) from 2000 onwards

owidcountries 0.038 s 252 Docs

	country	year	gdp	renewables_share_energy
1	Brazil	2000	1,734,491,269,177 (1.7T)	41.859
2	Brazil	2001	1,780,379,352,398 (1.8T)	37.723
3	Brazil	2002	1,857,599,313,953 (1.9T)	39.376
4	Brazil	2003	1,902,060,940,834 (1.9T)	40.844
5	Brazil	2004	2,036,566,862,830 (2.0T)	40.814
6	Brazil	2005	2,127,880,873,244 (2.1T)	41.656
7	Brazil	2006	2,239,747,965,006 (2.2T)	41.541
8	Brazil	2007	2,405,103,626,412 (2.4T)	42.872
9	Brazil	2008	2,559,007,092,658 (2.6T)	41.869
10	Brazil	2009	2,587,477,649,695 (2.6T)	44.795
11	Brazil	2010	2,816,706,146,073 (2.8T)	42.723
12	Brazil	2011	2,965,069,861,485 (3.0T)	42.327
13	Brazil	2012	3,022,025,708,241 (3.0T)	40.513
14	Brazil	2013	3,112,905,996,042 (3.1T)	38.212
15	Brazil	2014	3,128,572,443,040 (3.1T)	37.224
16	Brazil	2015	3,270,706,238,309 (3.3T)	38.448
17	Brazil	2016	2,889,037,264,385 (2.9T)	41.315
18	Brazil	2017	2,926,999,211,353 (2.9T)	40.973
19	Brazil	2018	2,965,401,452,084 (3.0T)	43.544
20	Brazil	2019	null	44.543
21	Brazil	2020	null	46.054
22	Colombia	2000	330,667,819,568 (0.33T)	28.246

[252 docs returned]

For Perspective 2:
Annual renewables_electricity for the 12 countries (Iceland, Norway, Sweden, New Zealand, Brazil, Peru, Ecuador, Colombia, Sri Lanka, Vietnam, Philippines, Pakistan) from 2000 onwards

owidcountries 0.024 s 260 Docs

	country	year	renewables_electricity
1	Brazil	2000	308.77
2	Brazil	2001	273.71
3	Brazil	2002	292.95
4	Brazil	2003	313.88
5	Brazil	2004	329.43
6	Brazil	2005	346.96
7	Brazil	2006	359.55
8	Brazil	2007	387.88
9	Brazil	2008	385.61
10	Brazil	2009	410.13
11	Brazil	2010	431.96
12	Brazil	2011	458.04
13	Brazil	2012	450.6
14	Brazil	2013	432.88
15	Brazil	2014	426.98
16	Brazil	2015	425.54
17	Brazil	2016	459.86
18	Brazil	2017	460.91
19	Brazil	2018	488.98

[260 docs returned]

country	year	gdp	renewables_share_ener...
Brazil	2000	1734491269177.0	41.859
Brazil	2001	1780379352398.0	37.723
Brazil	2002	1857599313953.0	39.376
Brazil	2003	1902060940834.0	40.844
Brazil	2004	2036566862830.0	40.814
Brazil	2005	2127880873244.0	41.656
Brazil	2006	2239747965006.0	41.541
Brazil	2007	2405103626412.0	42.872
Brazil	2008	2559007092658.0	41.869
Brazil	2009	2587477649695.0	44.795
Brazil	2010	2816706146073.0	42.723
Brazil	2011	2965069861485.0	42.327
Brazil	2012	3022025708241.0	40.513
Brazil	2013	3112905996042.0	38.212
Brazil	2014	3128572443040.0	37.224
Brazil	2015	3270706238309.0	38.448
Brazil	2016	2889037264385.0	41.315
Brazil	2017	2926999211353.0	40.973
Brazil	2018	2965401452084.0	43.544
Brazil	2019		44.543
Brazil	2020		46.054
Colo...	2000	330667819568.0	28.246

[252 docs returned]

country	year	renewables_electric...
Brazil	2000	308.77
Brazil	2001	273.71
Brazil	2002	292.95
Brazil	2003	313.88
Brazil	2004	329.43
Brazil	2005	346.96
Brazil	2006	359.55
Brazil	2007	387.88
Brazil	2008	385.61
Brazil	2009	410.13
Brazil	2010	431.96
Brazil	2011	458.04
Brazil	2012	450.6
Brazil	2013	432.88
Brazil	2014	426.98
Brazil	2015	425.54
Brazil	2016	459.86
Brazil	2017	460.91
Brazil	2018	488.98

[260 docs returned]

14.

Percentage change in solar energy consumption each year in Singapore

solar_cons_change_pct	solar_share_energy	year
435.461	0.001	2009
92.053	0.001	2010
57.586	0.002	2011
66.302	0.003	2012
52.272	0.004	2013
114.802	0.008	2014
78.538	0.013	2015
80.505	0.023	2016
37.942	0.031	2017
9.436	0.034	2018
43.458	0.049	2019
51.077	0.077	2020
		2021

Average percentage change in solar energy consumption in Singapore across the years

avg(solar_cons_change_pct)
86.11015384615386

Natural gas imports to Singapore yearly from 2008

gas_share_elec	year
69.3	2008
70.176	2009
70.382	2010
70.805	2011
75.09	2012
88.845	2013
94.969	2014
95.157	2015
96.015	2016
95.339	2017
95.665	2018
95.381	2019
94.97	2020
94.888	2021

Finding countries and their carbon intensity elec across the years where fossil fuel share and nuclear energy share is greater than 95%

country	year	carbon_intensity_elec	nuclear_share_energy	fossil_share_energy
Belgium	2000	270.806	18.073	81.535
Belgium	2001	259.824	17.432	82.164
Belgium	2002	258.34	17.782	81.791
Belgium	2003	261.936	17.018	82.553
Belgium	2004	260.251	16.823	82.644
Belgium	2005	255.529	17.014	82.233
Belgium	2006	249.308	16.53	82.424
Belgium	2007	244.801	16.874	81.906
Belgium	2008	240.43	15.599	82.889
Belgium	2009	244.117	17.199	80.609
Belgium	2010	242.705	16.284	80.971
Belgium	2011	219.652	17.445	78.954
Belgium	2012	229.947	15.118	80.37
Belgium	2013	208.027	15.482	79.714
Belgium	2014	215.957	13.088	81.414
Belgium	2015	245.596	9.936	84.088

[199 rows returned]

Number of micro nuclear reactors needed to power 10% of Singapore primary energy consumption

country	year	carbon_intensity_elec	nuclear_share_energy	fossil_share_energy
Belgium	2000	270.806	18.073	81.535
Belgium	2001	259.824	17.432	82.164
Belgium	2002	258.34	17.782	81.791
Belgium	2003	261.936	17.018	82.553
Belgium	2004	260.251	16.823	82.644
Belgium	2005	255.529	17.014	82.233
Belgium	2006	249.308	16.53	82.424
Belgium	2007	244.801	16.874	81.906
Belgium	2008	240.43	15.599	82.889
Belgium	2009	244.117	17.199	80.609
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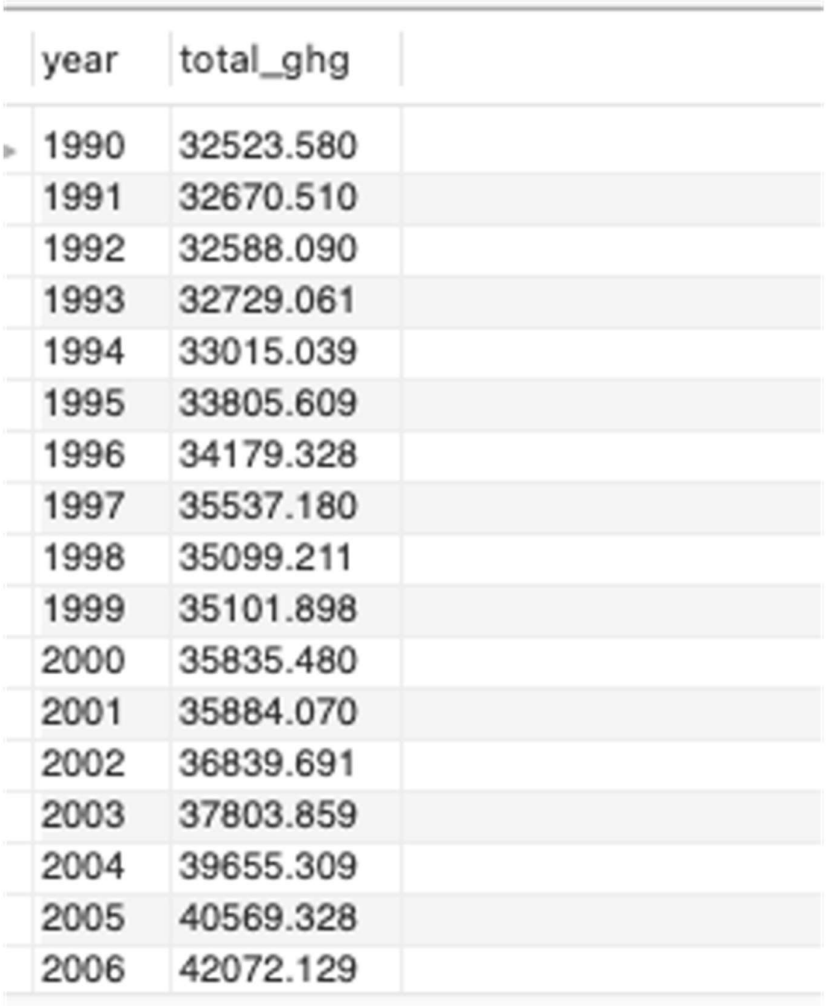
Belgium	2011	219.652	17.445	78.954
Belgium	2012	229.947	15.118	80.37
Belgium	2013	208.027	15.482	79.714
Belgium	2014	215.957	13.088	81.414
Belgium	2015	245.596	9.936	84.088

15.

Total greenhouse gas emissions each year


year	total_ghg
1990	32523.580
1991	32670.510
1992	32588.090
1993	32729.061
1994	33015.039
1995	33805.609
1996	34179.328
1997	35537.180
1998	35099.211
1999	35101.898
2000	35835.480
2001	35884.070
2002	36839.691
2003	37803.859
2004	39655.309
2005	40569.328
2006	42072.129

[30 rows returned]

Rise in land temperature

year	avg_extent	max_extent	min_extent	hemisphere
1978	12.487	14.585	10.231	north
1979	12.3195604…	16.635	6.895	north
1980	12.3341475…	16.302	7.533	north
1981	12.1354863…	15.801	6.902	north
1982	12.4394450…	16.325	7.16	north
1983	12.3358961…	16.412	7.204	north
1984	11.9126010…	15.809	6.396	north
1985	11.9865989…	16.163	6.486	north
1986	12.2082240…	16.158	7.122	north
1987	11.3972272…	16.293	6.89	north
1988	12.0931694…	16.309	7.048	north
1989	11.9668547…	15.766	6.888	north
1990	11.6938410…	16.249	6.011	north
1991	11.7492575…	15.647	6.259	north
1992	12.1104808…	15.576	7.159	north
1993	11.9230520…	16.048	6.161	north
1994	12.0113178…	15.77	6.934	north

[26 rows returned]

Fall in average sea extent (respective hemisphere)

year	avg_extent	max_extent	min_extent	hemisphere
1978	12.487	14.585	10.231	north
1979	12.3195604…	16.635	6.895	north
1980	12.3341475…	16.302	7.533	north
1981	12.1354863…	15.801	6.902	north
1982	12.4394450…	16.325	7.16	north
1983	12.3358961…	16.412	7.204	north
1984	11.9126010…	15.809	6.396	north
1985	11.9865989…	16.163	6.486	north
1986	12.2082240…	16.158	7.122	north
1987	11.3972272…	16.293	6.89	north
1988	12.0931694…	16.309	7.048	north
1989	11.9668547…	15.766	6.888	north
1990	11.6938410…	16.249	6.011	north
1991	11.7492575…	15.647	6.259	north
1992	12.1104808…	15.576	7.159	north
1993	11.9230520…	16.048	6.161	north
1994	12.0113178…	15.77	6.934	north

[84 rows returned]

Fall in average sea extent (both hemisphere)

Year	avg_extent	max_extent	min_extent	total_ghg
1990	11.5517178…	18.379	2.784	32523.580
1991	11.6470657…	18.671	2.554	32670.510
1992	11.7545491…	18.467	2.492	32588.090
1993	11.6714958…	18.71	2.281	32729.061
1994	11.8926438…	18.827	3.083	33015.039
1995	11.6049328…	18.762	3.33	33805.609
1996	11.8049576…	18.831	2.597	34179.328
1997	11.5288328…	18.792	2.264	35537.180
1998	11.7478767…	19.244	2.772	35099.211
1999	11.7260739…	18.981	2.707	35101.898
2000	11.6277008…	19.159	2.582	35835.480
2001	11.6363205…	18.494	3.441	35884.070
2002	11.2922369…	18.116	2.697	36839.691
2003	11.6832547…	18.68	3.626	37803.859
2004	11.6009658…	19.124	3.259	39655.309
2005	11.3009273…	19.295	2.804	40569.328

[30 rows returned]

Fall in annual mass balance

Year	avg_annual_balance	total_ghg
1990	-417.36842105263156	32523.580
1991	-411.4736842105263	32670.510
1992	-583.9736842105264	32588.090
1993	-234.92105263157896	32729.061
1994	-577.078947368421	33015.039
1995	-176.3421052631579	33805.609
1996	-323.39473684210526	34179.328
1997	-450.89473684210526	35537.180
1998	-914.1315789473684	35099.211
1999	-74.65789473684211	35101.898
2000	-162.6315789473684	35835.480
2001	-600.8157894736842	35884.070
2002	-481.6842105263158	36839.691
2003	-1265.5526315789473	37803.859
2004	-978.2631578947369	39655.309
2005	-1147.2368421052631	40569.328

[30 rows returned]

Increasing occurrence of natural disasters

year	newtotal
1900	5
1901	2
1902	9
1903	8
1904	2
1905	4
1906	17
1907	5
1908	4
1909	11
1910	15
1911	5
1912	7
1913	5
1914	6
1915	7
1916	2

[120 rows returned]

Increasing economic damages

year	total_damage
1942	56000000
1943	2000000000
1944	200000000
1945	960000000
1946	51000000
1947	260000000
1948	2086000000
1949	318400000
1950	402000000
1951	3056500000
1952	305800000
1953	1968620000
1954	1774000000
1955	1754000000
1956	50000000
1957	350000000
1958	1060200000

[77 rows returned]

Rise of neglected tropical diseases and malaria

year	newtotal
1900	5
1901	2
1902	9
1903	8
1904	2
1905	4
1906	17
1907	5
1908	4
1909	11
1910	15
1911	5
1912	7
1913	5
1914	6
1915	7
1916	2

[30 rows returned]