BC2402 Designing and Developing Databases

Semester 1, AY 2022/2023

Project Report

Seminar Group: 02

Project Team: 07

Prepared By:

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Question 12

To evaluate the performance of Singapore, the data relating to Singapore is compared to the data from countries such as Luxembourg and Ireland. The rationale for choosing these 2 countries is that Luxembourg and Ireland have similar-sized economies in terms of their GDP per capita (Worldometer, n.d.). Moreover, these are also first-world countries which make them suitable for comparison with Singapore.

12.1 Energy per GDP

Instead of being a component that contributes to the GDP, our team believes that energy consumption is a scaled version of the GDP. Energy is necessary for all sectors to produce goods and services and thus, the amount of energy consumed in a country sets an upper bound on the possible GDP that can be produced. To show this relationship between GDP and energy consumption, we calculated the correlation between the *change in GDP per capita* and *change in primary energy consumption* for all records. The correlation matrix came out to be 0.65 which illustrates a moderately strong positive correlation between these two factors. Therefore, energy consumption of a country drives GDP.

Energy per GDP portrays the energy intensity of a country and it can be interpreted as the energy consumed for earning every dollar. As per our initial view of energy consumption being a scaled factor of GDP, we expected this to be a constant horizontal line. However, with reference to Figure 12.1, we saw decreasing trends in the energy per GDP across all 3 countries. According to research, the possible rationale for the observed trends are as follows (Mckinsey & Company, 2019):

1. The countries are transitioning from manufacturing-based economies to highly specialized service-based economies. This signifies that the amount of GDP produced from activities consuming the same amount of energy is likely to increase.
2. Technological advancements make processes more efficient. With more efficient processes, less energy is required to carry out the same amount of work and this ultimately results in a slower rise in the energy demand.

Therefore, with a steep increasing trend in GDP and a gentler increase in energy demand, the energy per GDP will decrease as shown in Figure 12.1.

12.2 Energy Per Capita

The energy per capita can be defined as the energy consumed by every person and this value illustrates the changes in energy consumption due to factors aside from an increase in population. With reference to Figure 12.2, different trends are observed for all 3 countries. An increasing trend is observed for Singapore, a decreasing trend is observed for Luxembourg and lastly, the energy per capita of Ireland remained relatively constant over the years. This signifies that Singapore may be more invested in high energy demanding work and this might be the result of the petrochemical and oil industries that have opened in Singapore.

12.3 Coal Consumption Per Capita

In comparison with the other countries, the coal consumption per capita for Singapore is very low (Figure 12.3). One possible rationale for this may be that Singapore does not have natural resources of its own and relies on imports of energy products to generate energy. Therefore, there is a scarcity of coal in Singapore and Singapore relies on other energy products as well. Another possible reason is due to Singapore's stance in phasing out coal usage by 2050 which prevented Singapore from boosting its coal usage (National Climate Change Secretariat, 2021). As for the other countries, a steep decreasing trend is observed for Luxembourg while a gentler decrease is observed for Ireland (Figure 12.3). This decrease is due to investment in renewable sources and increase in the awareness of sustainability.

12.4 Oil Consumption Per Capita

As illustrated in Figure 12.4, Singapore has the highest oil consumption per capita amongst the 3 countries and it has been experiencing an increasing trend over the years. This may be because Singapore is home to companies with major refining and petrochemical operations. Despite the increasing trend, Singapore's oil consumption per capita dipped in recent years. This dip may be attributed to the shift to renewable energy sources as well as the movement to use low-carbon alternatives.

12.5 Gas Consumption Per Capita

For all 3 countries, there is an increasing trend in gas consumption per capita over the years (Figure 12.5). To explain this trend, the increasing gas consumption could be attributed to the low carbon emission and simplicity in production. However, as observed in Figure 12.5, gas consumption per capita in recent years has been increasing at a decreasing rate. This may be due to the increasing interest in adopting renewables as an energy source.

Question 13

Economic growth refers to an increase in the quantity and quality of goods and services of a country observed over a period of time. To evaluate sustained economic growth, good indicators are the increase in GDP per capita observed over a period of time and employment rate. Therefore, these metrics will be used in the evaluation of the ability of renewable energy to sustain economic growth.

13.1 Analysis of GDP per capita

To begin our analysis, our team classified countries into 2 groups, namely "Highly renewable countries" and "Non-Renewable countries". The definitions of these countries are as follows:

- Renewable Countries: These are the top 5 countries with the highest renewable share energy. These countries are Iceland, Norway, Brazil, Sweden, and New Zealand
- Non-Renewable Countries: These are the top 5 countries with the lowest renewable share energy and a high carbon intensity electricity production. These countries are Botswana, Mongolia, Poland, South Africa, and Hong Kong.

Subsequently, we analysed the average economic growth rate in terms of GDP per capita for the countries in each category. As illustrated in Figure 13.1, the average growth rate for non-renewable countries is higher as compared to the average growth rate for renewable countries. Moreover, further calculations show that the average growth rate for renewable countries amounts to 1.86% while average growth rate for non-renewable countries has more than double growth rate at 4.03%. Therefore, this indicates that renewable energies may be sufficient in sustaining economic growth albeit having lower growth rates than non-renewable energy.

13.2 Analysis of Employment

To assess if renewable energy can adequately sustain economic growth, another metric that could be used is the number of jobs created. With higher employment rates, the disposable income of individuals rises and this can result in higher GDP per capita (Skills Training Group, n.d.). From our analysis, renewable energies such as hydropower, solar power and wind power result in significant levels of job creation. In China, hydropower, solar power and wind energy generated more than 2 million jobs for the population and this can result in significant increases in employment rate and subsequently the result in economic growth (Figure 13.2-13.4).

Question 14

With the increasing demand for energy and the shift to using cleaner fuels to generate energy, it is crucial to consider alternative fuel options. Advancements in technology have resulted in the development of micro-nuclear reactors which could be a possible energy source for Singapore. Thus, to determine if it should be adopted by Singapore, our report evaluates the cleanliness of the fuel, energy generation capacity, impact on the number of imported energy products and size of the reactors in Singapore's context. As evidenced in Fig 14.1, Singapore's primary energy consumption is rising consistently from 2000 to 2020 with its peak at 948.879 TWh in 2020. Currently, Singapore is heavily reliant on fossil fuels to meet its energy demand as illustrated in Fig 14.3 where the share of energy produced by fossil fuels remains above 99.7% from 1965 to 2020. Considering the lower power generating capacity of each micro-nuclear reactor currently, it is unlikely that it would be able to replace fossil fuel as the main energy source of Singapore. However, it is a possible contender as an additional source of energy to diversify Singapore's energy mix.

14.1 Analysis of cleanliness of fuel

Nuclear power is the world's second-largest source of low-carbon electricity after hydropower and one of the cleanest sources of energy after wind and solar (Igini, 2022). Therefore, nuclear energy is an efficient source of energy that has a lesser impact on the environment than other sources of energy (Goncalves, 2019). Additionally, it is proven that over the past 50 years, carbon dioxide emissions have decreased by 60 gigatonnes due to the use of nuclear power (Iea,

2019) . Thus, the adoption of this source of energy is in congruence with Singapore's goal of becoming net zero by 2050 and it should be adopted to diversify Singapore's energy mix.

14.2 Analysis of energy generation capacity

To evaluate nuclear's energy generation capacity, it is compared to other sources of energy. In recent years, Singapore has adopted solar energy as a source of energy, generating up to 0.077% of Singapore's energy demand in 2020 as shown in Fig 14.2. Therefore, for nuclear to be adopted as an energy source, it should be able to generate a comparable amount of energy as compared to solar energy. Optimistically, each micro-nuclear reactor has an energy generation capacity of 20MW and thus 100 reactors are required to generate the same amount of energy as solar energy in 2020 (Fig 14.4). According to the Energy Market Authority, 4,447 solar PV systems were implemented in Singapore in 2020. Thus, the number of micro-nuclear reactors is significantly lower than solar panels and thus signaling their efficiency in energy generation. Moreover, in comparison with renewable energy, nuclear power has higher energy generation capacity as it is not limited by climatic factors and is instead able to operate for longer periods of time (Rhodes, 2018).

14.3 Analysis of impact on the amount of imported energy products

Additionally, the impact of adopting nuclear energy on Singapore's imports of energy products is evaluated. Considering Singapore's goal of achieving net zero by 2050 and the movement to phase out the usage of coal, our evaluation focuses on the change in the amount of coal imported by Singapore whilst attempting to sustain its current energy demand using nuclear energy instead. With reference to Fig 14.5, the amount of coal imported by Singapore in the past few years is relatively consistent around 400ktoe, with the exception of 2017. Noting that 6 grams of nuclear fuel can generate the same amount of energy as a ton of coal, the change in the amount of imported energy products in 2020 can be calculated (Sen, 2019). As shown in Fig 14.6, the complete replacement of coal with nuclear fuel can reduce the total amount of imports by 433ktoe. Therefore, our team believes that incorporating nuclear energy into Singapore's energy mix will be beneficial in reducing Singapore's reliance on other countries for energy in terms of quantity imported as well as achieving greater efficiency in energy generation.

14.4 Analysis of the size of energy source

Next, Singapore is a small country with limited land which means that size of the energy source is also a crucial evaluation criterion to decide if nuclear should be adopted. According to the article, the micro-nuclear reactor is of similar size to a standard 40-foot shipping container (Nunez, 2021). In comparison, Singapore's most land efficient energy plant occupies 4.8 hectares of land while generating 120MW of power every day (National Environment Agency, 2022). As shown in the calculation in Fig 14.7, only 0.01784616 hectares of land is required to generate the same amount of energy as the aforementioned power plant. Therefore, micro-nuclear reactors are significantly more land efficient than the current energy plants. Thus, incorporating nuclear in place of other power plants may be a land efficient solution for Singapore.

14.5 Conclusion

Despite the numerous benefits of nuclear energy, it is important to remember that nuclear energy generates energy from the finite resource of uranium fuel. As with all finite resources, excessive usage will eventually cause supply to decline before it can be replenished. Therefore, nuclear power is not a sustainable energy source for Singapore in the long term and should not be considered a replacement for fossil fuels as Singapore's main energy source. Instead, it can be utilised to diversify Singapore's energy mix and reduce emission levels whilst awaiting future breakthroughs in renewable energy that could replace fossil fuels in a sustainable manner.

Question 15

15.1 Analysis on the trend of emissions, greenhouse effect and changes in temperatures

Amongst the climate change controversies, our team seeks to illustrate the climate change problems associated with greenhouse gas emissions. According to the United States Environmental Protection Agency (EPA), the net global greenhouse gas emissions increased by 43% from 1990 to 2015 (United States Environmental Protection Agency, 2022). In recent years, there have been increasing efforts to reduce greenhouse gas emitted from human activities as evidenced in Figure 15.1. However, EPA has found that greenhouse gases can remain in the atmosphere for up to thousands of years and thus our evaluation will focus on the effects of the cumulative greenhouse gases in the atmosphere (United States Environmental Protection

Agency, 2022). Thus, with limited actions taken to remove these gases from the atmosphere, they will accumulate in vast amounts as illustrated in Figure 15.2. The accumulation of greenhouse gases will eventually increase temperatures due to the "greenhouse effect" (NASA, 2022). This trend aligns with insights from Figure 15.3 where the increase in cumulative emissions is coupled with the increase in average land temperatures from 1900 to 2014. To supplement our findings, research has also proven that the rapid warming rate of 0.14°C per decade is the outcome of the high emission rates (Lindsey, 2022). Therefore, to exemplify the devastating climate-related consequences resulting from greenhouse gas emissions and greenhouse effect, its impact on sea ice extent, glacier mass and natural disasters is analysed.

15.2 Analysis of changes to sea ice extent with rising emission levels

Firstly, the relationship between rising emission levels and sea ice extent is analysed. The worsening greenhouse effect indicates rising temperatures which expedites melting of sea ice. With reference to Figure 15.4, the cumulative emission levels rose while the average yearly sea ice extent decreased, dipping to its lowest of 10.9 million square kilometers in 2011. Moreover, within the decade 2009 to 2019, the average sea ice extent decreased by 19.55% (Figure 15.5). To illustrate the severity of this issue, the continuation of this trend may cause the Arctic to become ice-free in summer within the 21st century (Wunderling, Willeit, Donges, & Winkelmann, 2020). Thus, this has a significant impact on the wildlife living in those areas where the lower sea ice extent indicates the loss of habitat. Additionally, the coastal communities are at higher risk of flooding due to the heightened sea levels resulting from melting of sea ice (Hancock, n.d.). Essentially, the rising emission can cause many devastating downstream consequences on the climate and individuals worldwide.

15.3 Analysis of changes to glacier area with rising emission levels

On a similar note, the effect of rising emission levels on glacier area is also evaluated. In our evaluation, glaciers with annual records from 2005 to 2014 in relation to its area is assessed to prevent any variations due to missing values. As such, the change in area of 54 glaciers over the decade is observed. Our findings have indicated a declining trend in the glacier area along with the rising cumulative emissions over the decade from 2005 to 2014 (Figure 15.6). Moreover, the glacier area has decreased by 1.49% over the span of the decade (Figure 15.6). The melting of glaciers will cause sea levels to rise and result in similar consequences as the melting of sea ice such as flooding and loss of biodiversity (Hancock, n.d.). However, research has also identified another devastating consequence where the melting of glaciers will reduce carbon cycling rates of rivers and ultimately increase the levels of carbon dioxide emissions (Climate Adaptation Science Centers, 2021). Therefore, this creates a perpetual cycle where the rising emission levels cause glacier loss and glacier loss in turn increases emission levels. Ultimately, the impact of rising emissions is devastating and the existence of climate change should be noted by all in order to take action to prevent the severity of the impact in the near future.

15.4 Analysis of changes to frequency of natural disasters with rising emission levels

Next, the rising greenhouse gas emissions impact the climate and increases probability of climate-related natural disasters. With reference to the United States Geological Survey (USGS), the rising temperatures and intense heat can worsen storms, droughts and floods (USGS, n.d.). Therefore, our evaluation strives to determine if the rising emission levels have increased the likelihood of the aforementioned natural disasters. According to our findings in Figures 15.6 and 15.7, it is observed that there has been an increasing number of natural disasters such as droughts, extreme temperatures, floods and storms along with the rising cumulative emissions. Moreover, the increase in frequency of natural disasters has also led to an increasing trend in the number of affected individuals and higher death counts. Research conducted corresponds with our findings where climate change increases likelihood and severity of natural disasters where 1.2 billion people are predicted to be displaced by 2050 due to climate-related natural disasters (Zurich, 2022). Hence, the impact of rising emissions is more significant than the mere rise in temperatures and instead can devastate the lives of individuals worldwide.

15.5 Conclusion

Additionally, it is crucial to note the delay in consequences resulting from the rising greenhouse gas emissions. Even with increasing efforts to reduce emission levels in recent years, the consequences of the high emission levels in the past are starting to materialise and cause devastating outcomes worldwide. This is evidenced by research which asserts that the effects of today’s emissions will materialise in 10 to 20 years (Mulhern, 2020). Thus, even if the current consequences seem insignificant, we are to bear in mind that we have yet to bear the brunt of the storm.

<u>Appendix</u>

Appendix 12

Figure 12.1

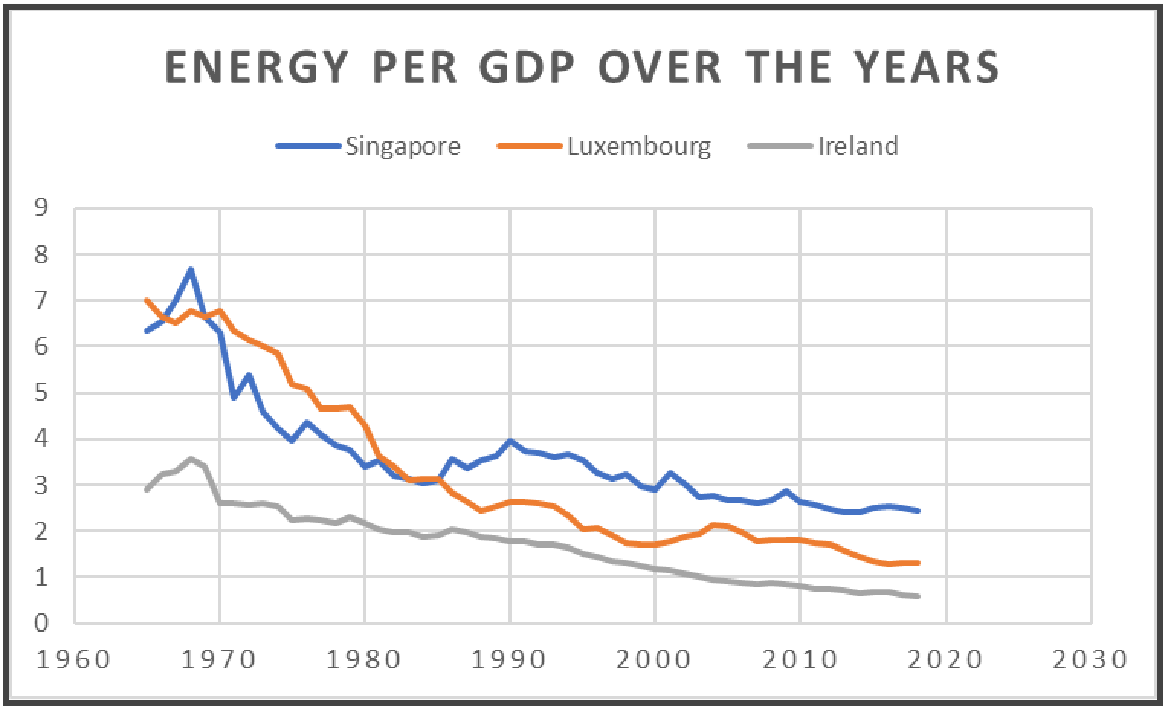


Figure 12.2

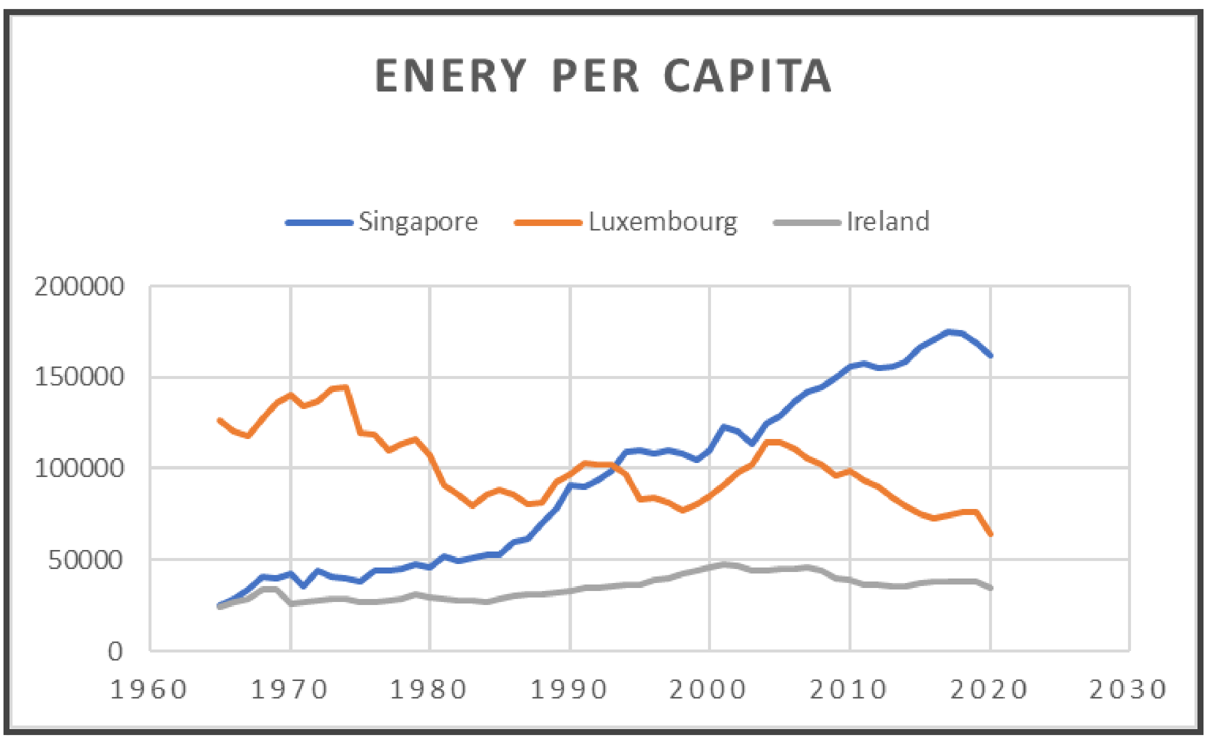


Figure 12.3

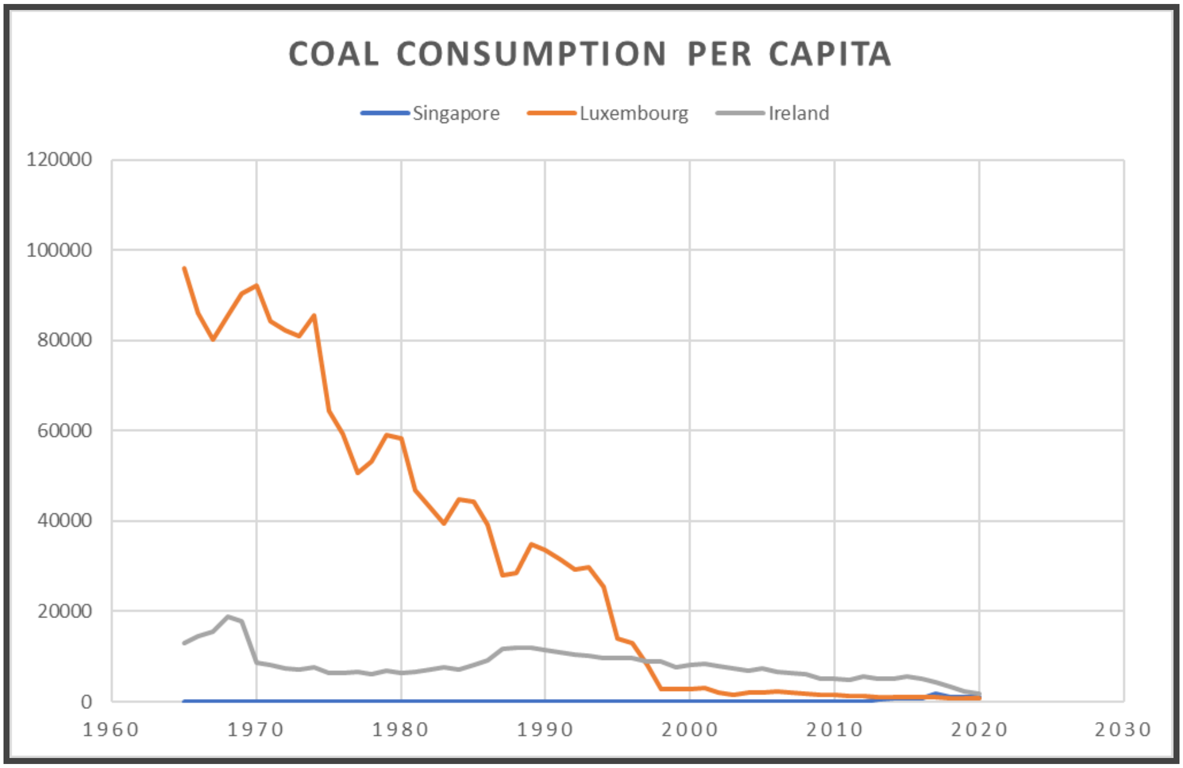


Figure 12.4

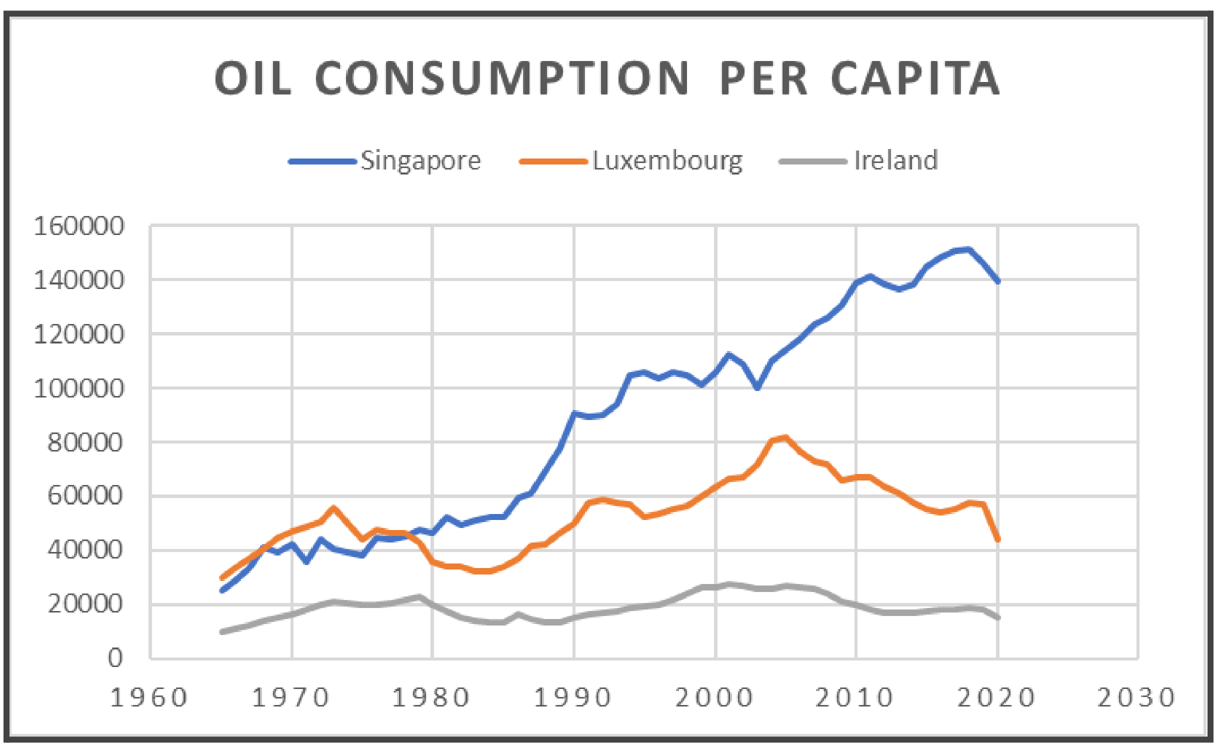
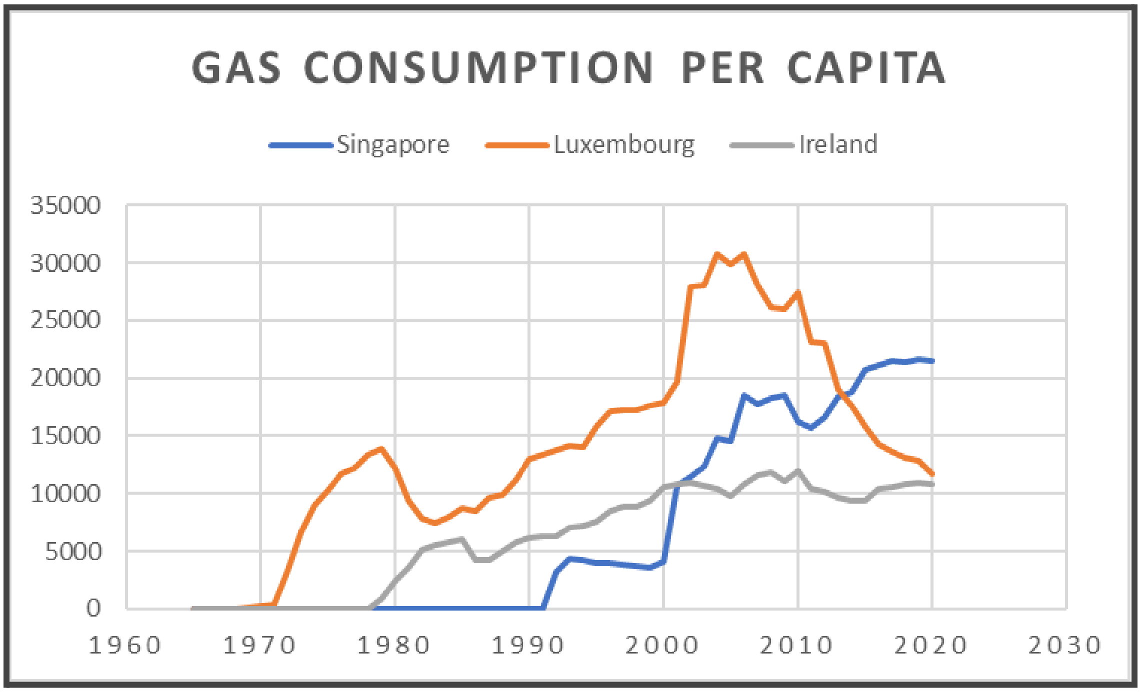


Figure 12.5



Appendix 13

Figure 13.1

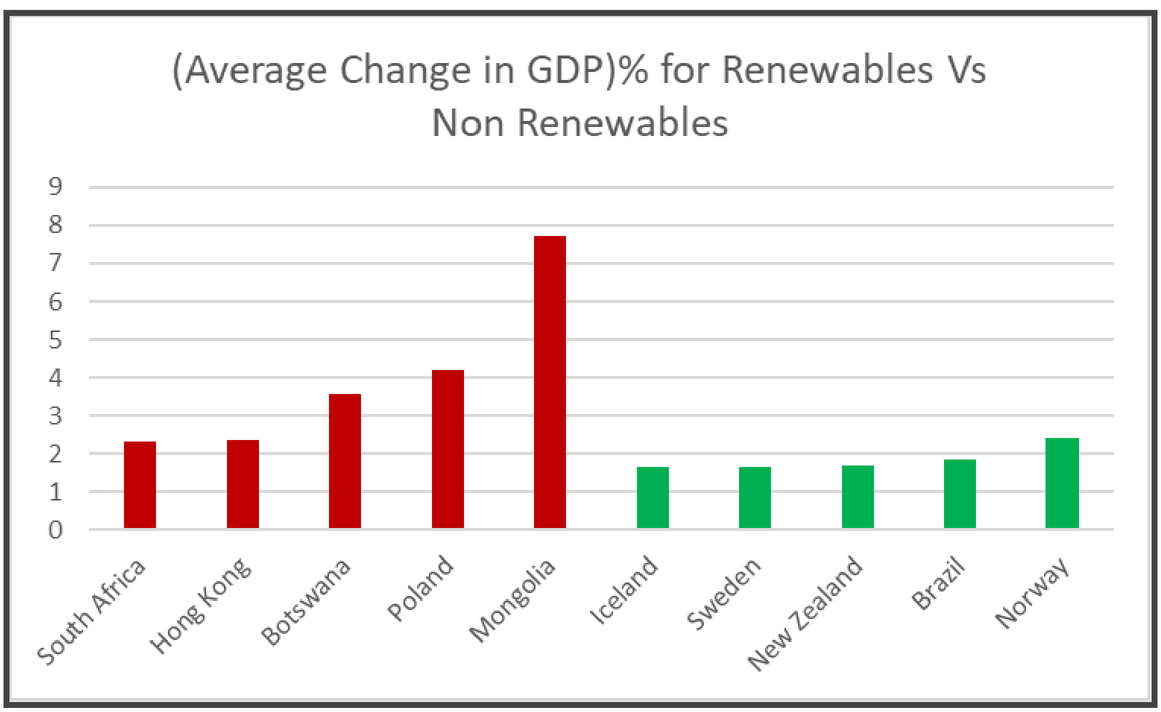


Figure 13.2

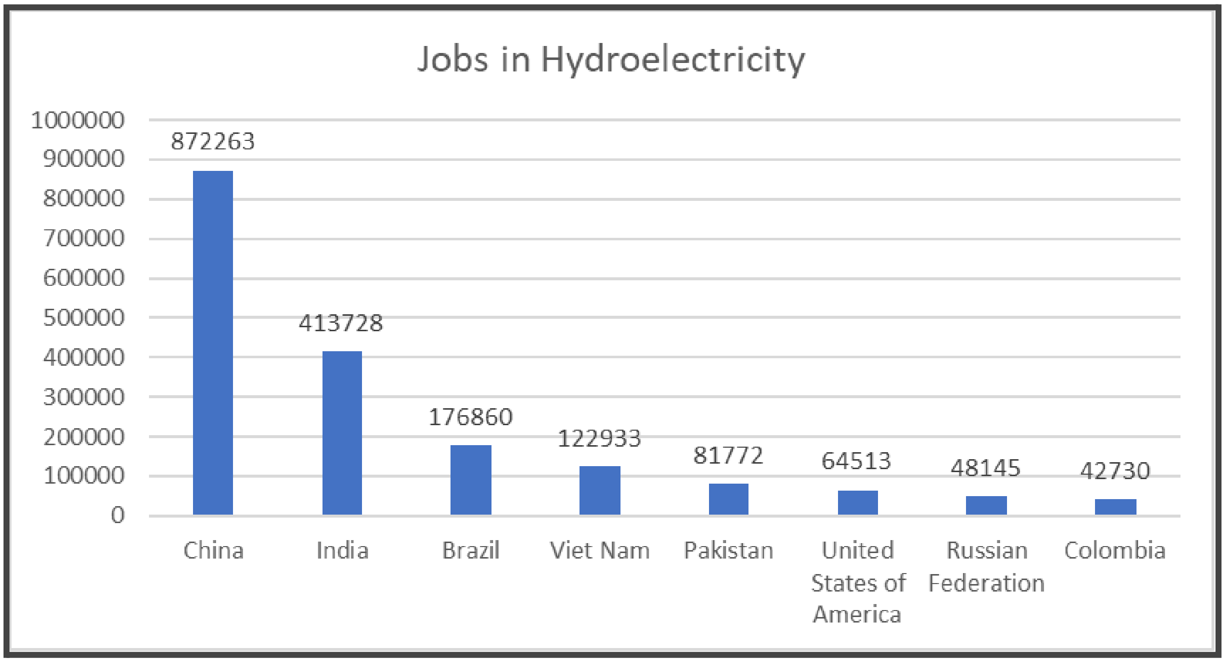


Figure 13.3

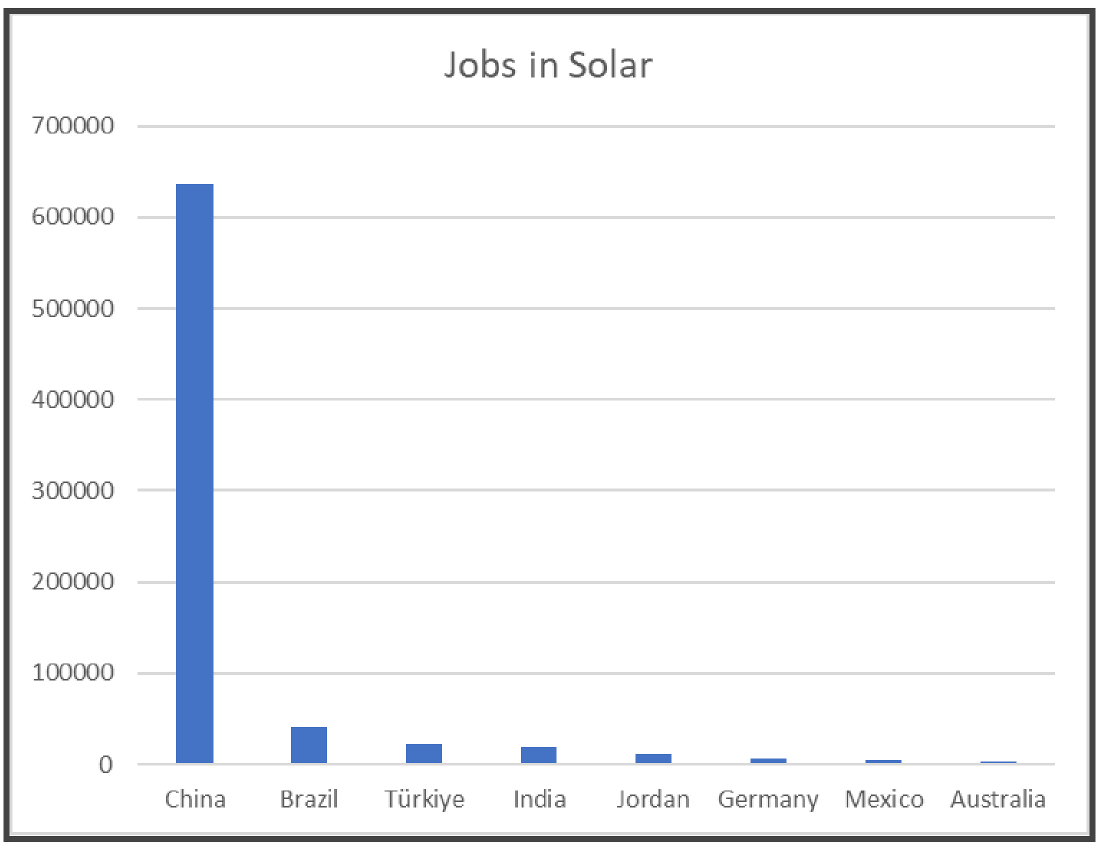
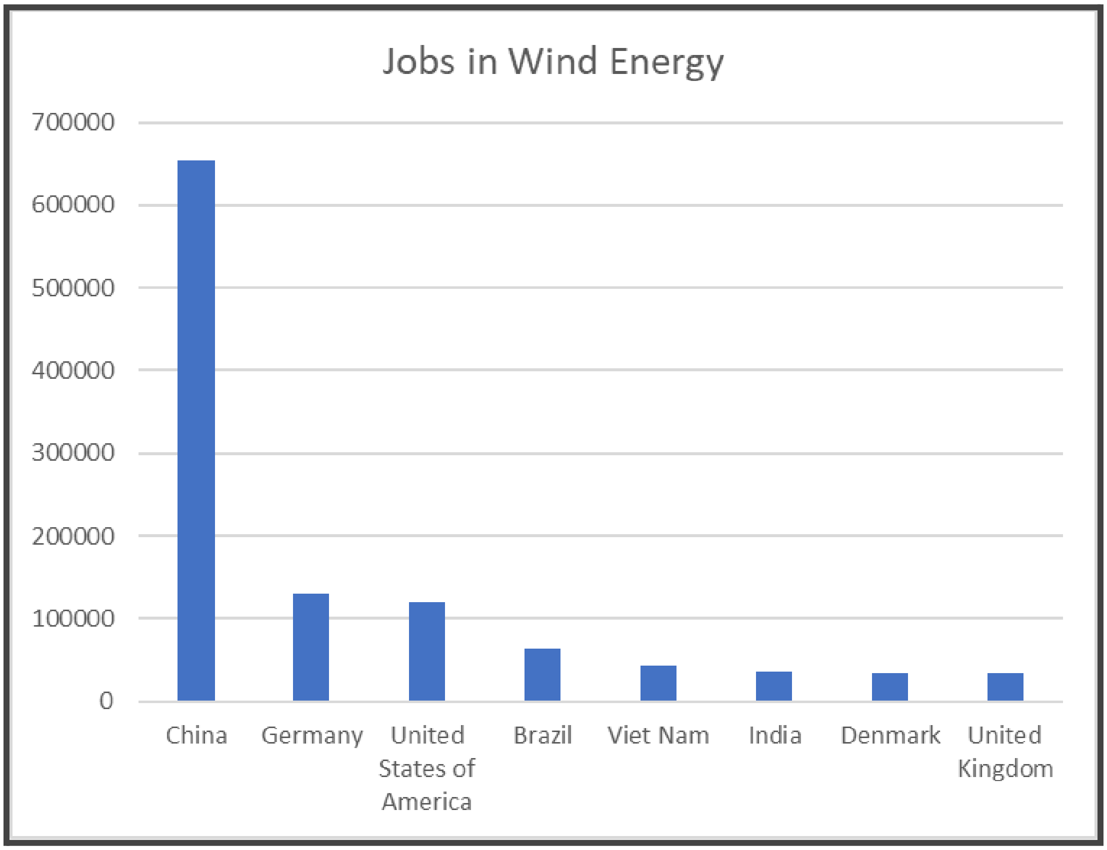


Figure 13.4


Jobs in Wind Energy
700000
600000
500000
400000
300000
200000
100000
0
China
Germany
United States of America
Brazil
Viet Nam
India
Denmark
United Kingdom

Appendix 14

Figure 14.1

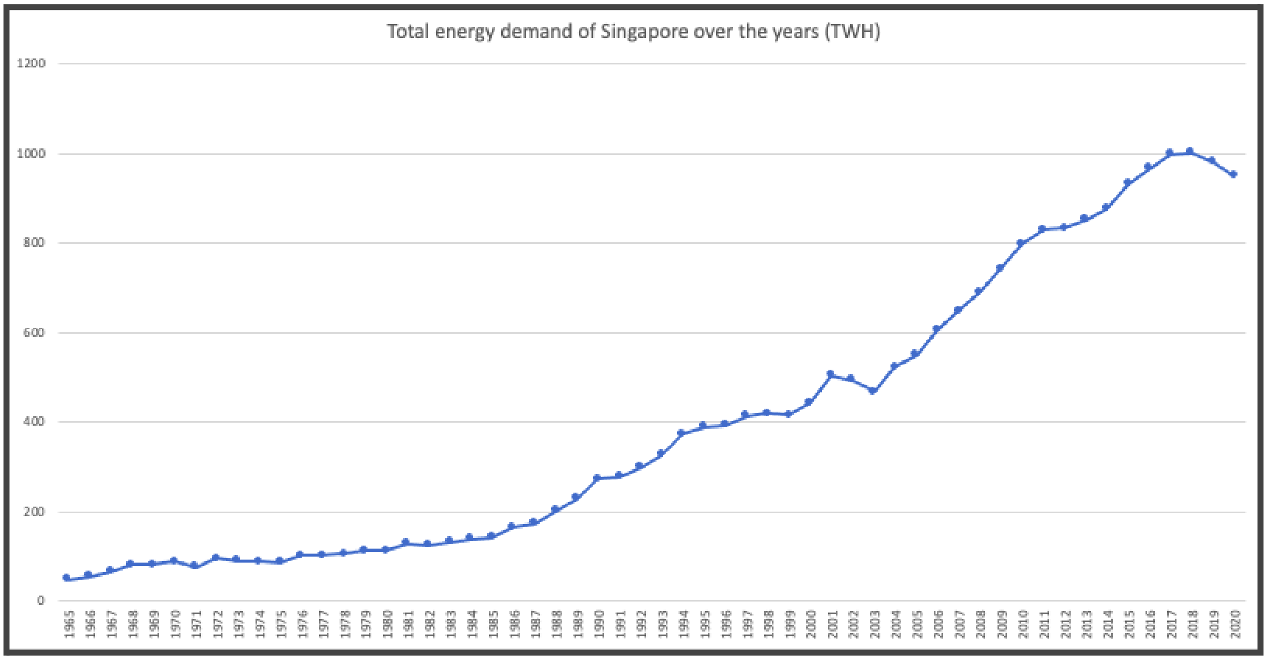


Figure 14.2

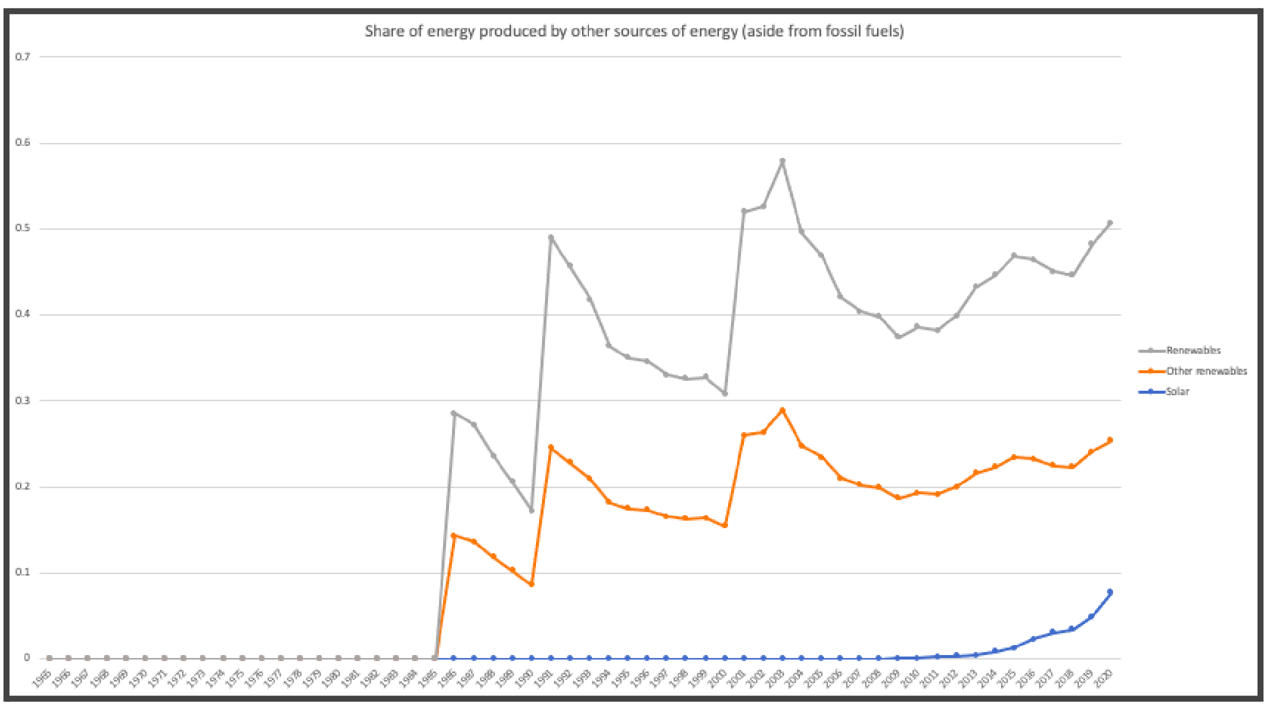


Figure 14.3

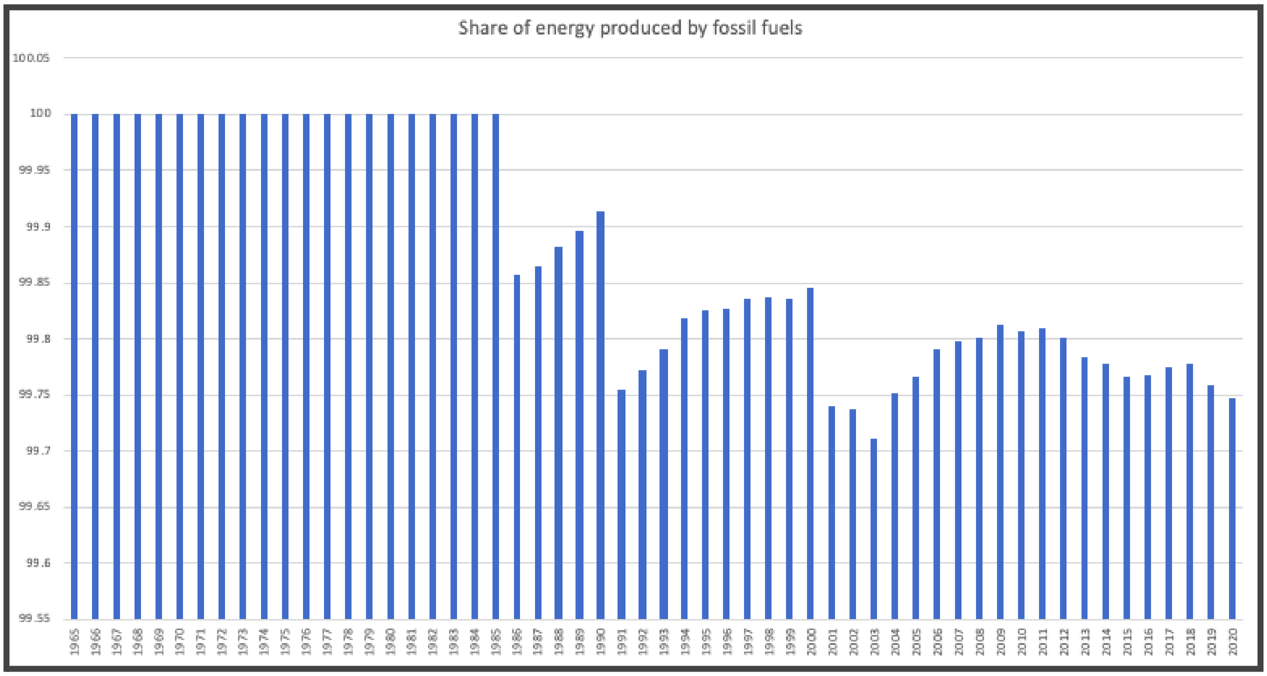


Figure 14.4

Calculation of number of micronuclear reactors needed to produce the same amount of energy as solar power in 2020

Energy produced by solar energy in 2020	948.879TWH * 0.077% = 0.730636TWH = 730,637MWH
Daily energy produced by solar energy in 2020	730,637MWH / 365 = 2002MWH
Daily energy generation capacity of each micronuclear reactors	20MWH
Number of micronuclear reactors needed to generate same amount of energy	2002 / 20 = 100 reactors

Figure 14.5

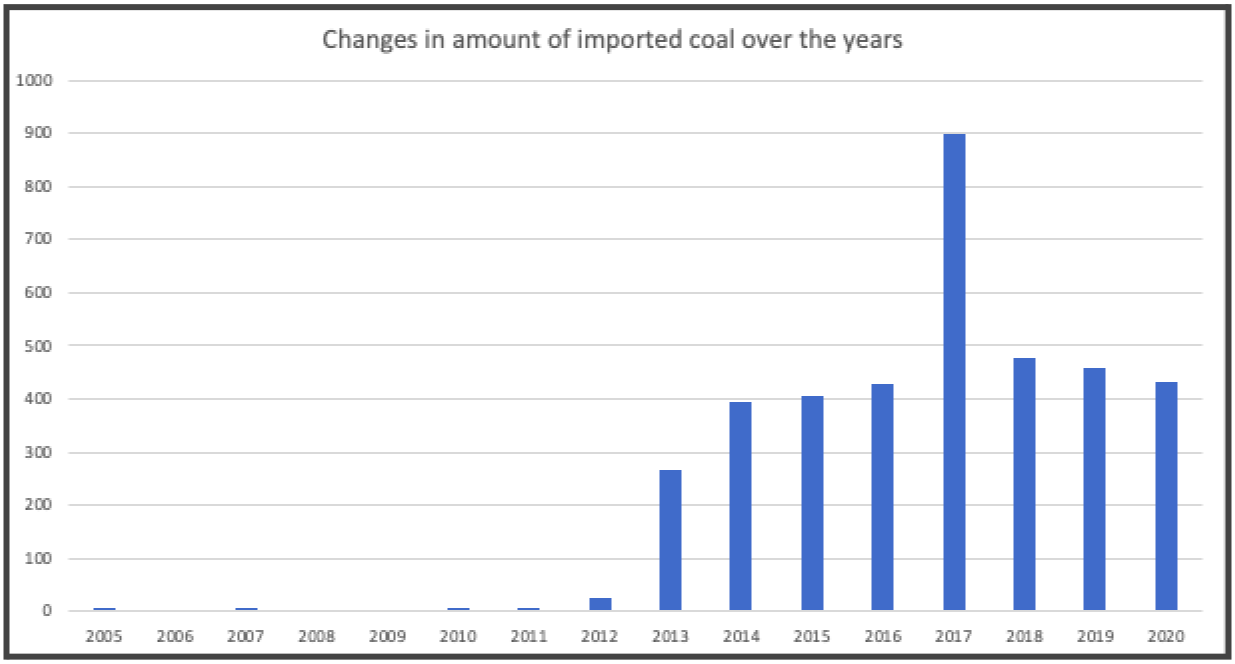


Figure 14.6

Calculation of change in imported products in 2020

Amount of coal imported in 2020	433.2 ktoe = 433,200 tonnes = 433,200,000kg
Amount of nuclear fuel that needs to be imported to generate same amount of energy	6grams of nuclear fuel = 1 US ton of coal 1 US tone = 907.185kg 6 grams of nuclear fuel = 907.185kg of coal 1 gram of nuclear fuel = 151.1975kg of coal 433,200,000/151.1975 = 2,865,126.738g = 2,865.1267kg = 2.851 tonnes = 0.002865ktoe
Total amount of imported energy products in 2020 (with no change in fuel)	151,230.90 ktoe
Total amount of imported energy products in 2020 (if all coal is replaced with nuclear)	151,230.90 - 433.2 + 0.002865 = 150,797.7029
Difference in amount of energy products imported in 2020	151,230.90 - 150,797.7029 = 433.1971 ktoe

Figure 14.7

Calculation of land occupied by micronuclear reactors

Number of micronuclear reactors needed to generate same amount of energy daily	120MW/ 20MW = 6
Land occupied by the micronuclear reactors	Land area occupied by each micronuclear reactor = 12.19 x 2.44 = 29.7436 m^2 Total land occupied = 29.7436 x 6 = 178.4616m^2 = 0.01784616 hectares

Appendix 15

Figure 15.1

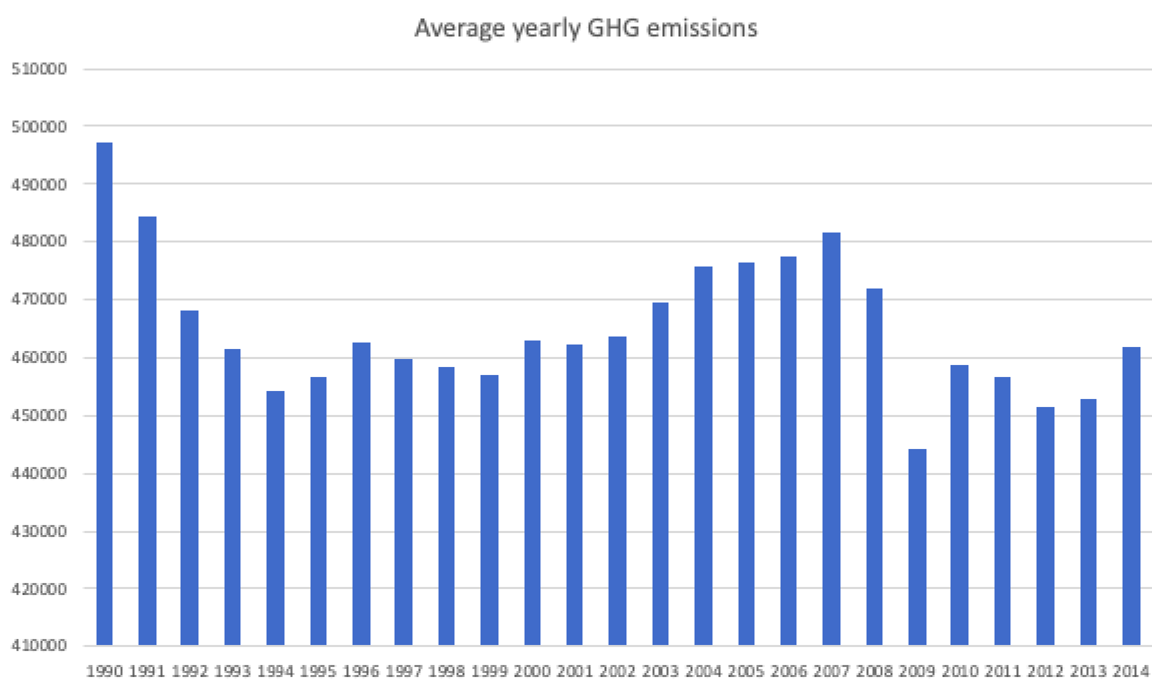
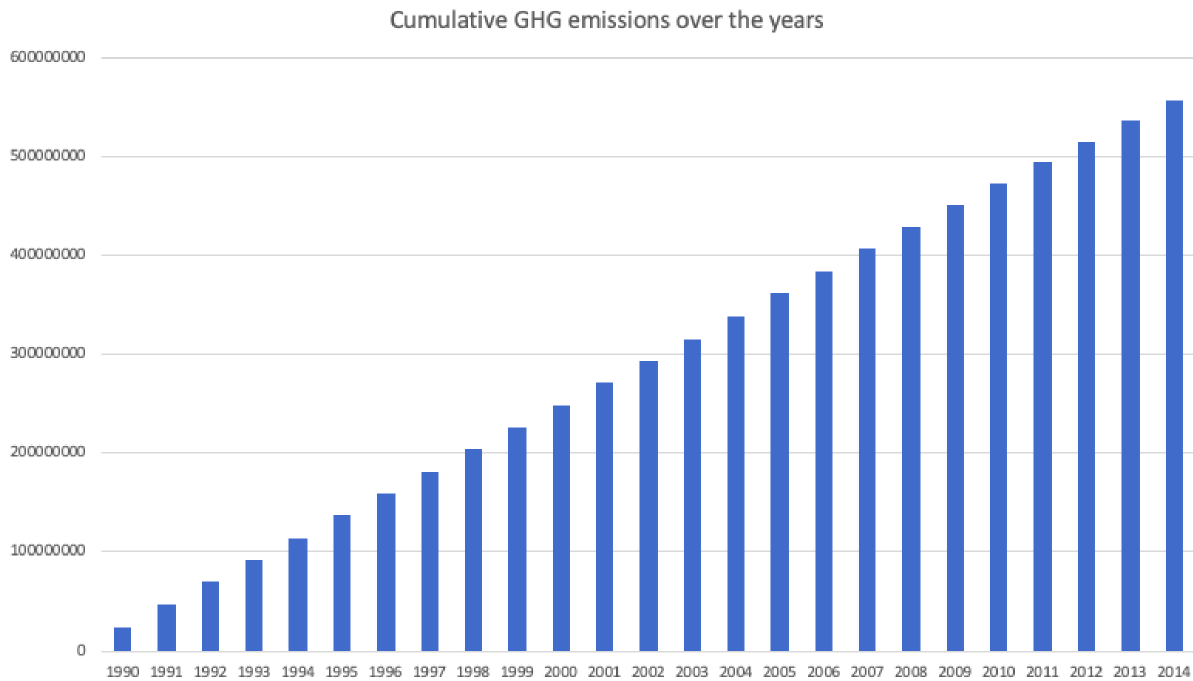


Figure 15.2



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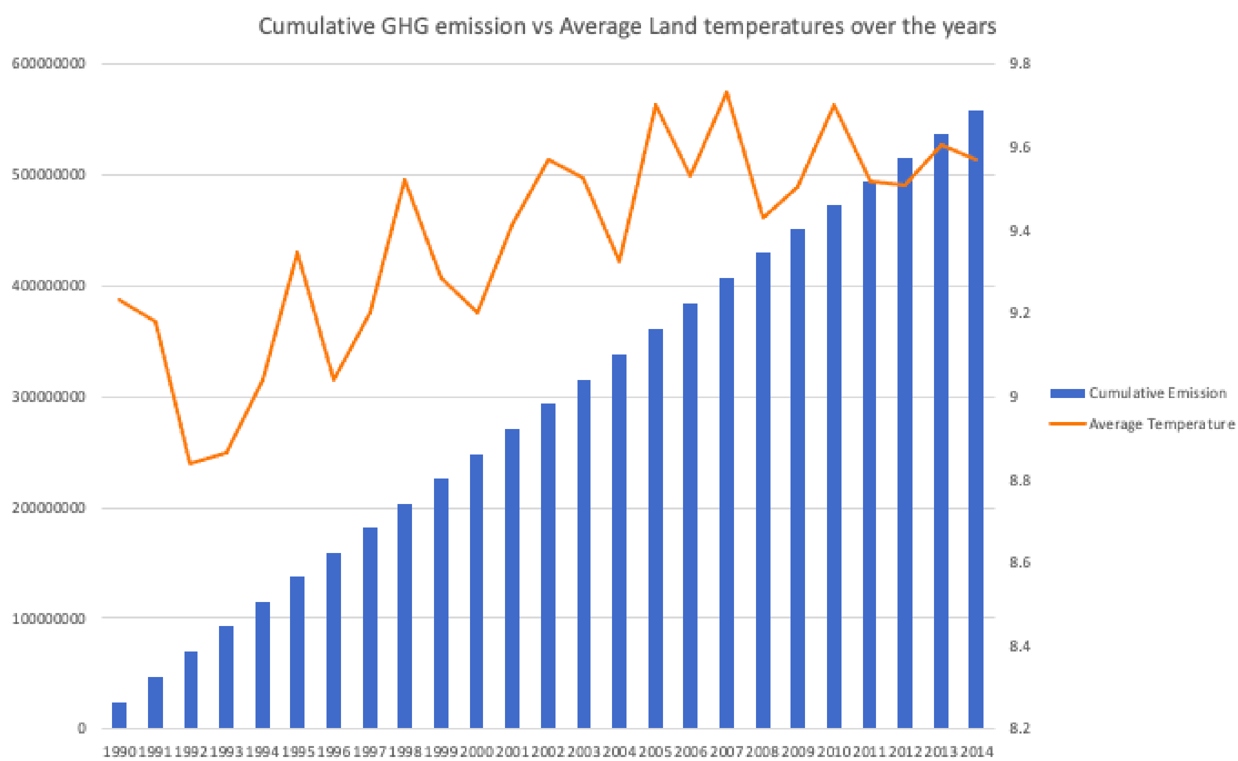


Figure 15.4

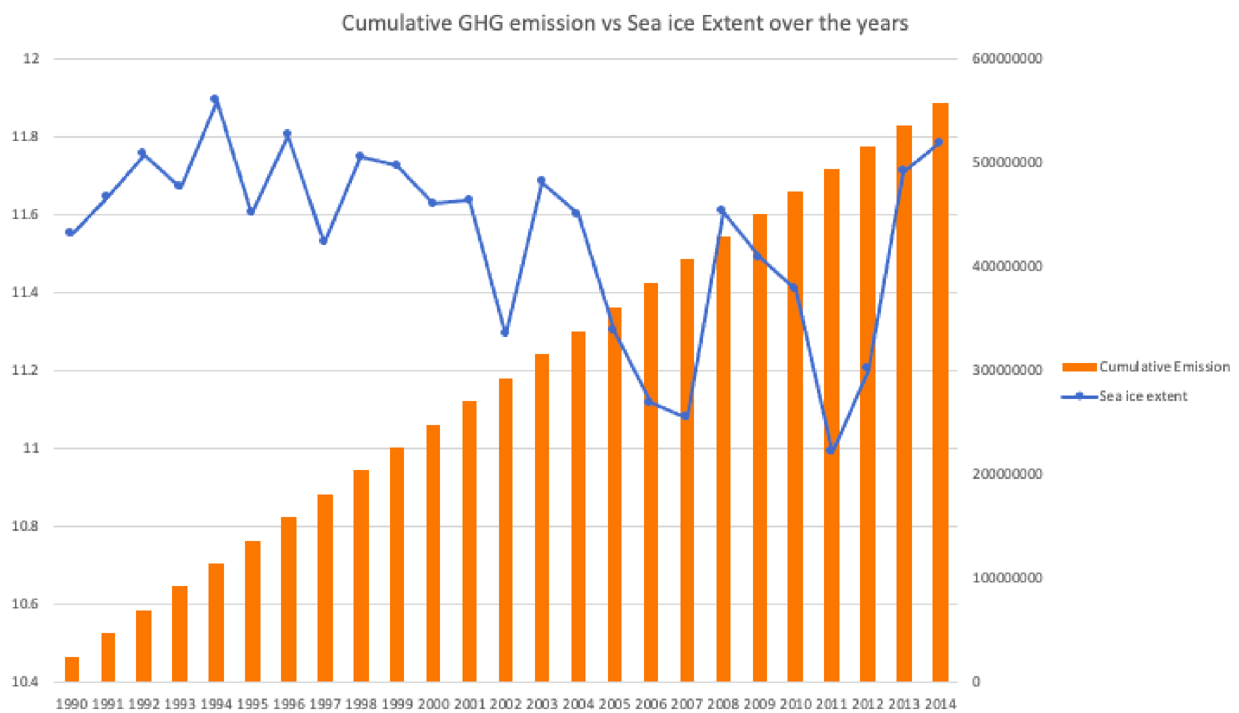
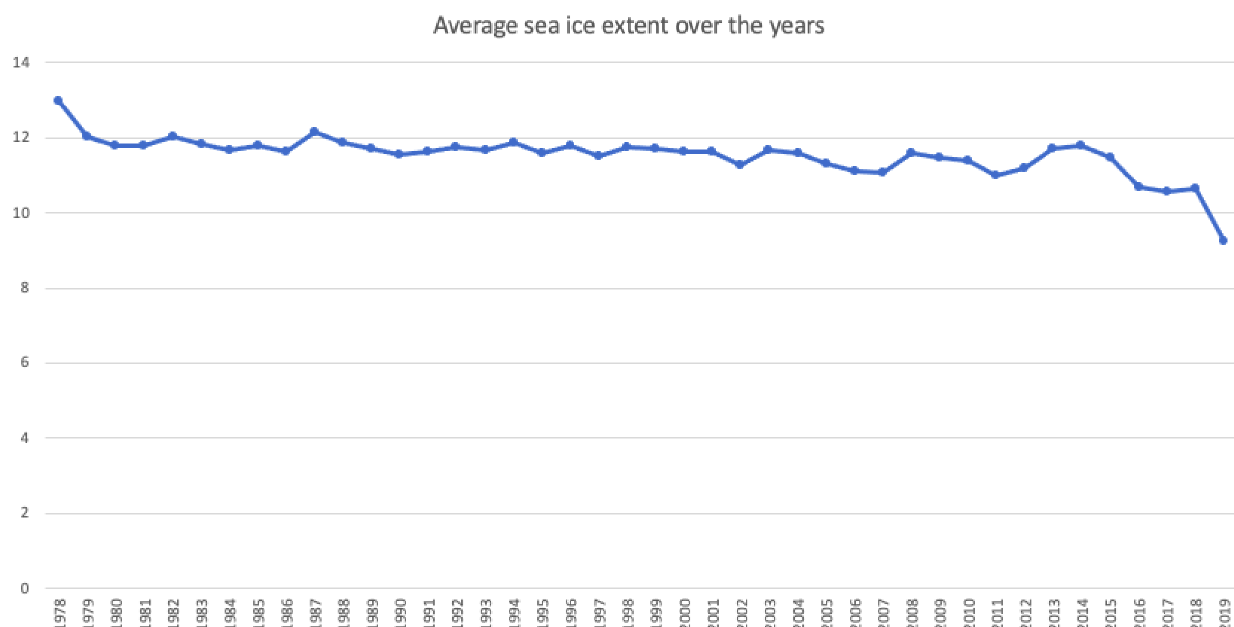


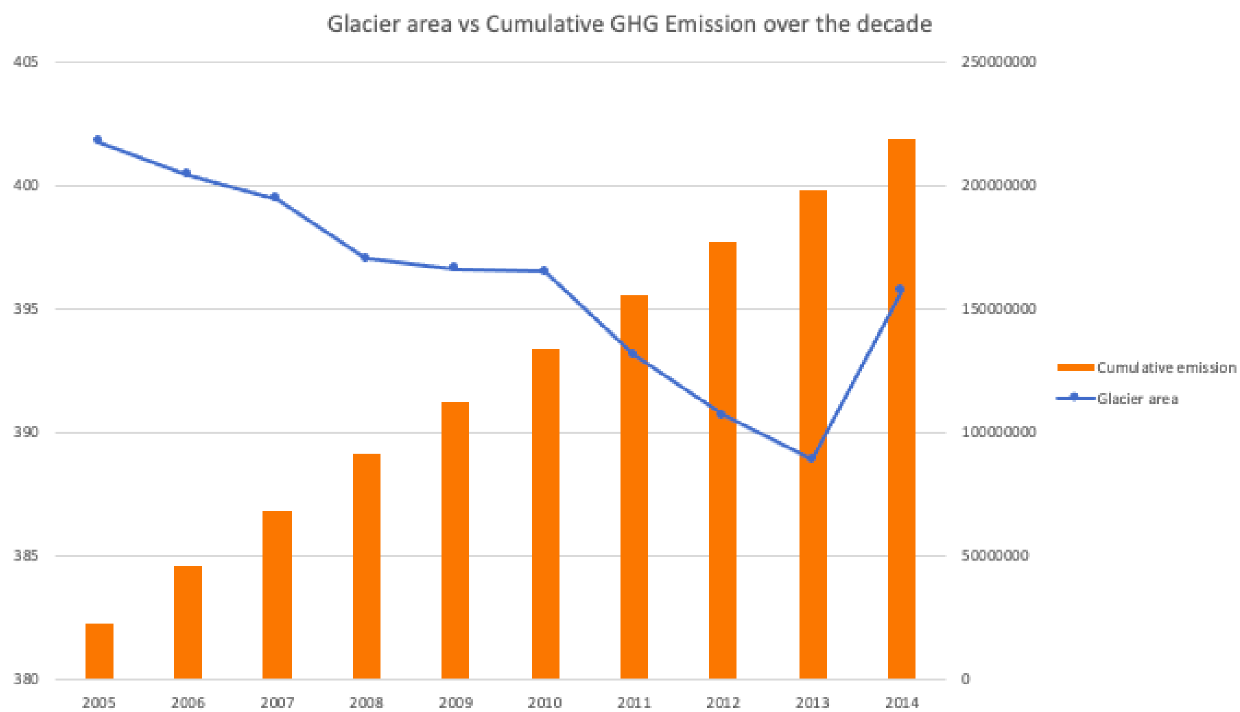
Figure 15.5



Average sea ice extent in 2009	11.4902

Average sea ice extent in 2019	9.2436
% change in average sea ice extent	((9.2436-11.4902)/11.4902)*100 = -19.55%

Figure 15.6



Sum of glacier area in 2005	401.7488
Sum of glacier area in 2014	395.7451
% change in average glacier area	-1.494%

Figure 15.7

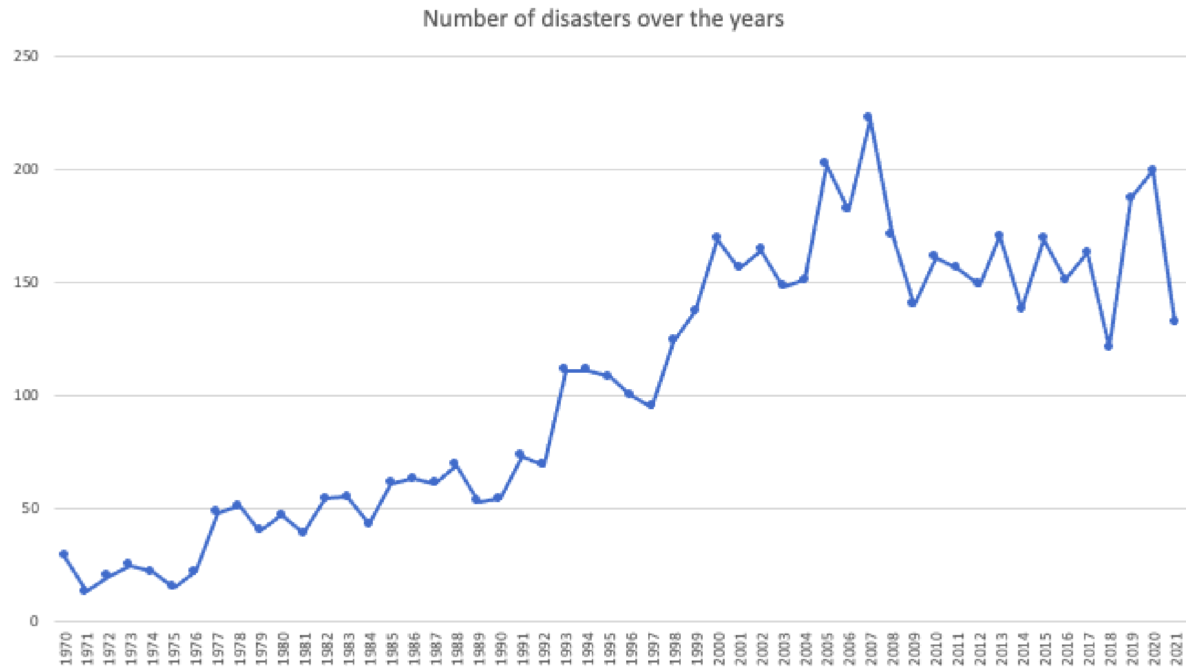
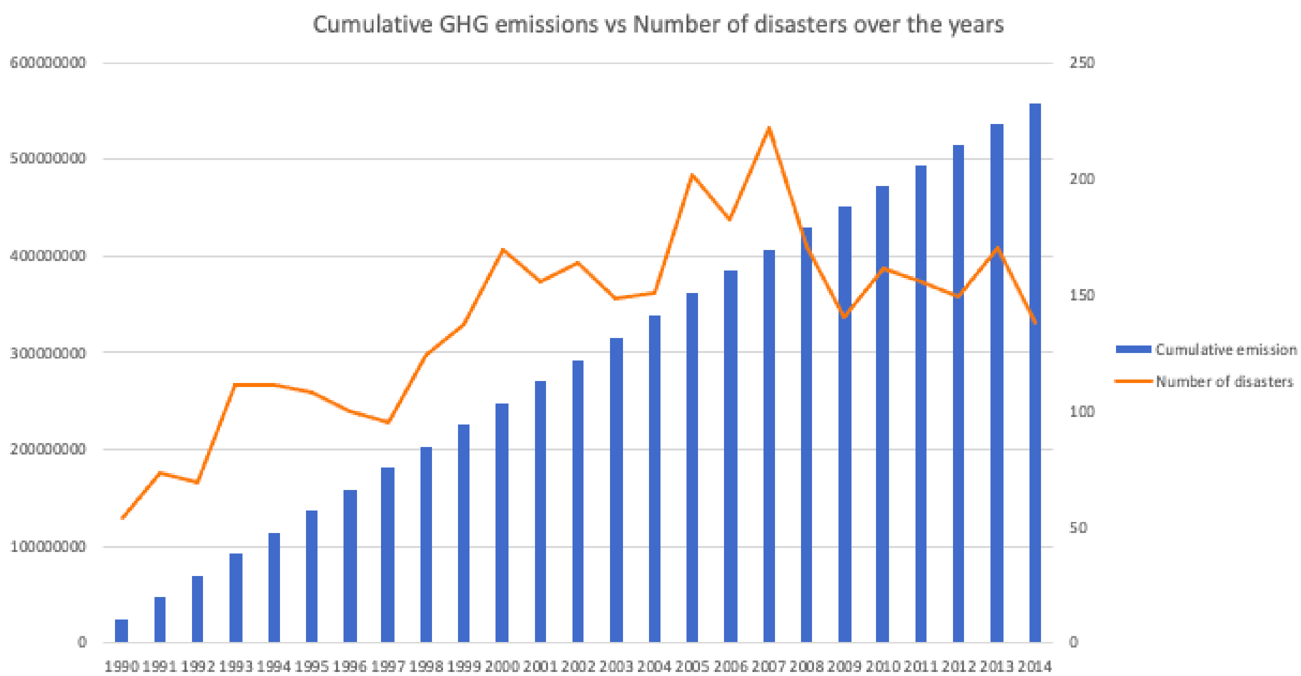

Number of disasters over the years
250
200
150
100
50
0
1970 1971 1972 1973 1974 1975 1976 1977 1978 1979 1980 1981 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021

Figure 15.8


Cumulative GHG emissions vs Number of disasters over the years
600000000
500000000
400000000
300000000
200000000
100000000
0
250
200
150
100
50
0
Cumulative emission
Number of disasters
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014

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1. External data set on natural disasters: **https://www.kaggle.com/datasets/brsdincer/all-natural-disasters-19002021-eosdis?resource=download**
2.
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