Answers to data response and decision making exercises

1. The graph below shows the data extracted from ice cores in Antarctica. Here, deep ice contains ancient air bubbles that in turn contain isotopes of oxygen and CO_2, allowing us to measure temperature and CO_2 levels in the atmosphere over time.

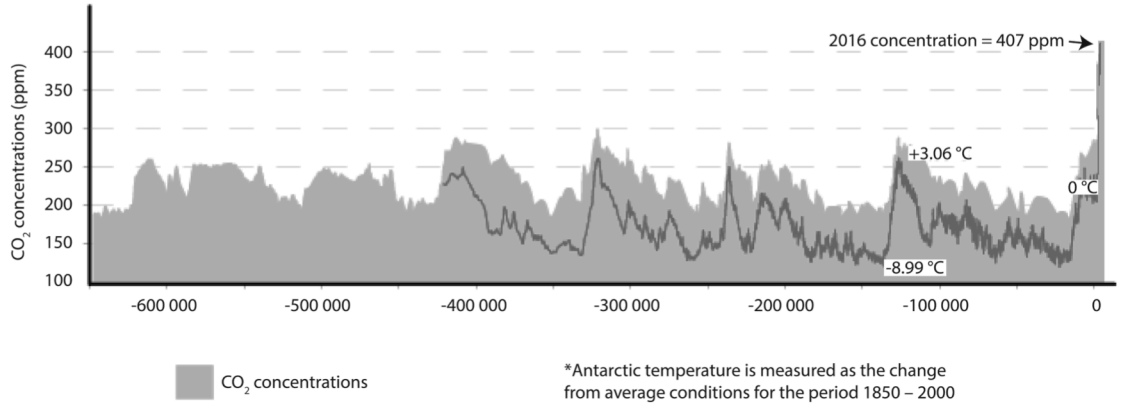

Fig. 7.10 Changes in temperature and CO_2 levels from Antarctic ice cores.

a) Describe the trend in CO_2 concentrations in Antarctica over time.
CO_2 concentrations in Antarctica have fluctuated over the past 600 000 years. Until recently, the amount of CO_2 in the atmosphere has varied between 180 and 260 parts per million. However, by 2016 it had risen sharply to 407 ppm.

b) Suggest reasons for the variations in the level of CO_2 in the atmosphere before there was significant human population expansion and industrialisation.
There is natural variation in the amount of CO_2 in the atmosphere due to volcanic activity, fluctuations in solar output and variations in the orbit of the Earth.

c) Describe the observed relationship between CO_2 concentrations and temperature in Antarctica over time.
There is a clear relationship between CO_2 levels and the temperature in Antarctica. When CO_2 levels are higher, there is an increase in temperature.

d) Name two greenhouse gases other than carbon dioxide.
Both methane and ozone are greenhouse gases.

e) Outline the importance of greenhouse gases to life on Earth.
Greenhouse gases trap heat and warm the planet. They make life on Earth possible by keeping the temperatures above a level that ensures the planet is habitable.

2. CO_2 concentrations have been recorded in the centre of the Pacific Ocean for many years and these have been compared to global temperatures.

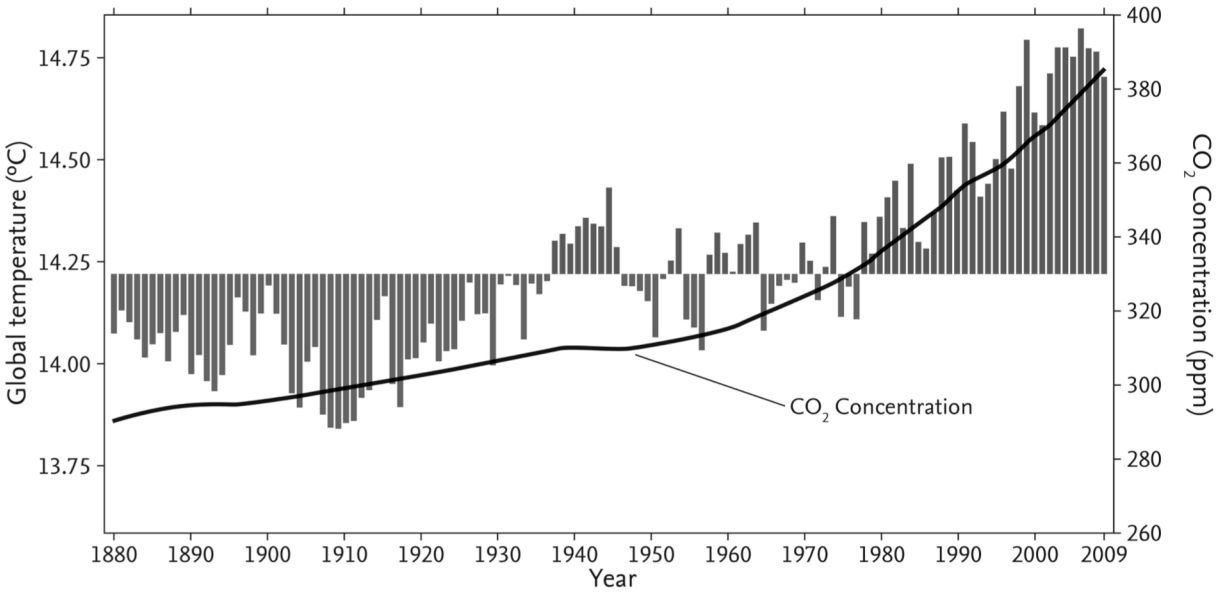

Fig. 7.11 The increase in atmospheric carbon dioxide levels and temperatures from 1880 to the present.

a) Describe the trend in atmospheric CO_2 concentrations and global temperatures since 1880.
Since 1880, there has been a significant rise in CO_2 concentrations observed in the Pacific Ocean. At just under 300 ppm in 1880, there was a steady rise to 330 ppm by 1980. However, since then the rate of increase has accelerated to 385 ppm in 2009. From 1880 to 1940, temperatures fluctuated between 14 and 14.25 °C. Since 1940, temperatures have been seen to increase, with the greatest increases seen since 1980. There has been nearly a 1 °C rise in global temperatures since 1880.

b) Using both graphs in Figures 7.10 and 7.11, explain why there was significant global concern about the CO_2 concentration figures – 404 ppm in July 2016.
Given the observed relationship between temperatures and CO_2 concentrations in Antarctica over the past 600 000 years, a rise to 404 ppm has caused significant concern. Global temperatures are linked to CO_2 concentrations, so this rise will lead to a further increase of global temperatures. There is concern about the wide ranging impacts of global climate change fuelled by manmade greenhouse gases.

c) Describe and explain the enhanced greenhouse effect.
The enhanced greenhouse effect is caused by the burning of fossil fuels, intensive agriculture and vehicle emissions. These activities have led to a significant increase in levels of greenhouse gases in the atmosphere. These in turn absorb more of the outgoing solar radiation and lead to a warming of the atmosphere. Human activity is enhancing the natural greenhouse effect and making it more effective at trapping heat.

d) Climate change has always and will always occur on planet Earth. Humans are accelerating the rate of change. Outline the human and natural causes of climatic variation.

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Natural causes of climate change	Human causes of climate change
Volcanic activity Variations in solar output Variation in the orbit of the Earth. Changes in the tilt of the Earth's axis	Agriculture Transportation Energy generation Vehicle emissions Manufacturing industries

3. In 2016, July was the tenth month in a row to break a monthly temperature record and, at this point, it was officially the hottest month since records began in 1880, with the average combined global surface temperature of the planet 1.2 °C higher than the 20th century average. 2015 was the warmest year since records began, beating 2014 and 2013. Temperatures had been pushed higher in part by El Niño, although this had dissipated by July. In Siberia, melting permafrost released anthrax from a deer carcass that had been preserved for years, causing an outbreak of the disease. In Baghdad, the government had to shut down due to extreme temperatures, whilst in Kuwait the temperature reached 54 °C. Temperatures like this are likely to cause significant disruption to human activity in the future. Meanwhile, wildfires in California and floods in Louisiana again added to the weather extremes being experienced. Whilst individual areas of extreme weather cannot be directly linked to climate change they give an indication of the challenges to come in a hotter world.

   The graph below shows predictions for global surface warming up to the year 2100.

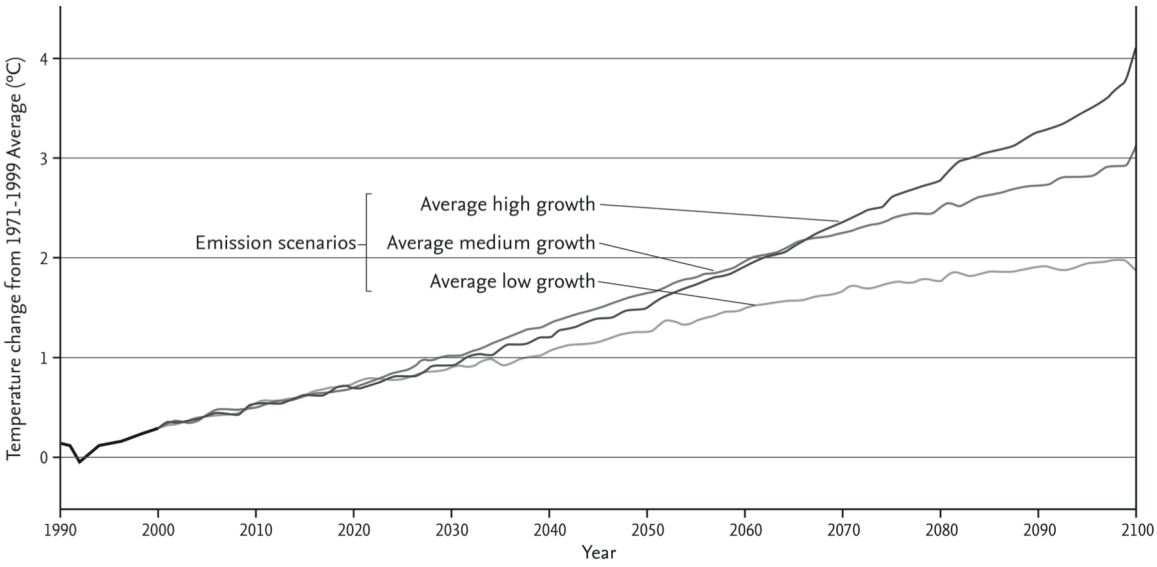

Fig. 7.12 Predictions for global surface warming.

a) Describe the predicted temperature rise by 2100 if carbon emissions continue to grow at the current rate.

   If emissions of greenhouse gases continue to grow at the current rate, there will be a predicted rise in global temperatures of up to 4 °C.

b) Suggest reasons why we can't accurately predict the level of surface warming by 2100.
It is a challenge to accurately predict surface warming as we don't know exactly what will happen to greenhouse gas emissions. There may also be some technological fixes that lower emissions in the next 30 years which might in turn reduce temperature rises.

c) Outline the possible effects of a 4 °C increase in global surface temperatures by 2100.
A 4 °C increase in global surface temperatures by 2100 would cause major extinctions around the globe. Billions of people would be living in water stress areas, with major crop producing areas seeing decreases in productivity. Millions of people would be at risk of coastal flooding caused by rising sea levels of over 2 metres. People would be much more vulnerable to floods, cyclones, heat waves and droughts with associated increased deaths from these. Ice sheets would be in significant decline.

The world map below shows the predicted average mean temperature change (°C) by the year 2080.

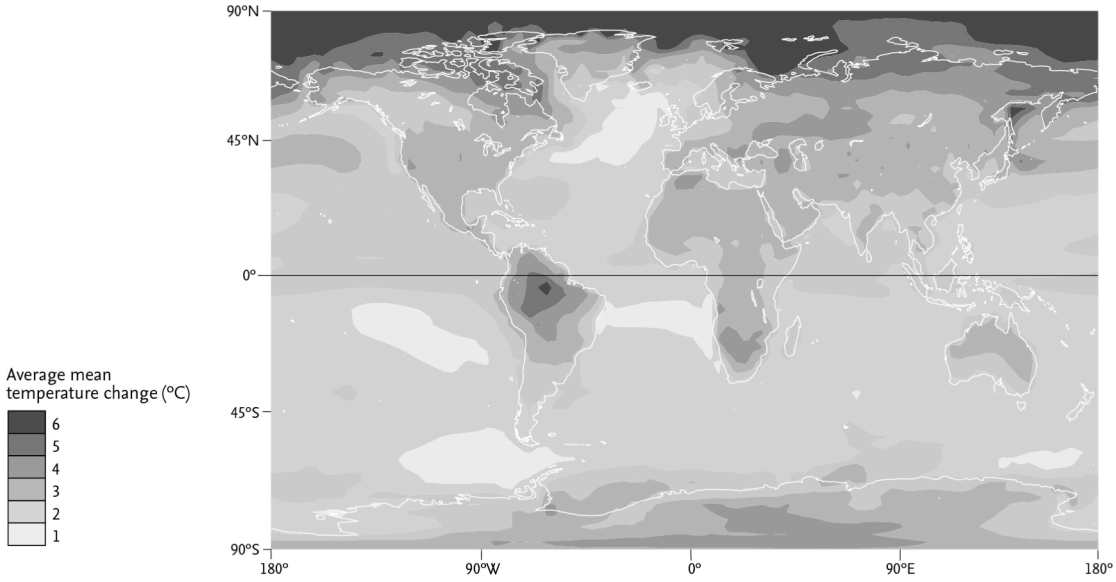

Fig. 7.13 Surface warming is predicted to be unevenly distributed.

d) Describe the pattern of predicted surface warming by 2080. Ensure you use statistics and places/regions to describe the pattern.
Average temperature changes are unevenly distributed. Temperatures are predicted to rise faster in polar regions with rises of over 6 °C. Inland areas will see greater rises than coastal areas. The Amazon Basin is predicted to experience a 5 to 6 °C increase in temperatures.

e) Temperatures are rising faster at the north and south poles than in other places on Earth. The images below show the reduction in sea ice for the same period between 1984 and 2012. Use these images and the WWF website to identify how climate change is impacting the Arctic Ocean.
http://wwf.panda.org/what_we_do/where_we_work/arctic/what_we_do/climate/

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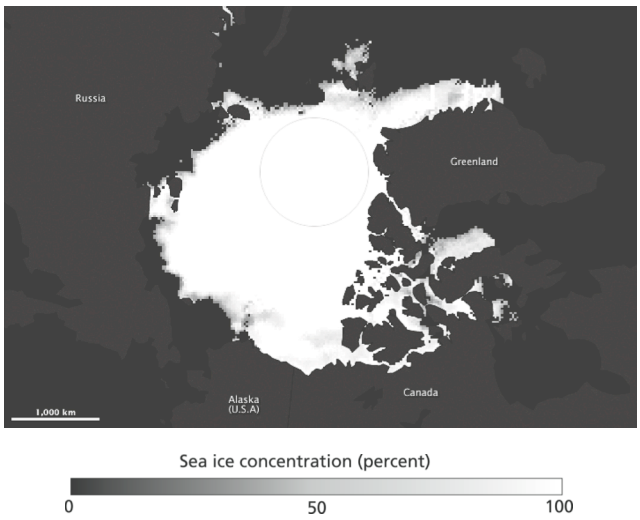


Fig. 7.14 Arctic Ocean ice coverage in September 1984.

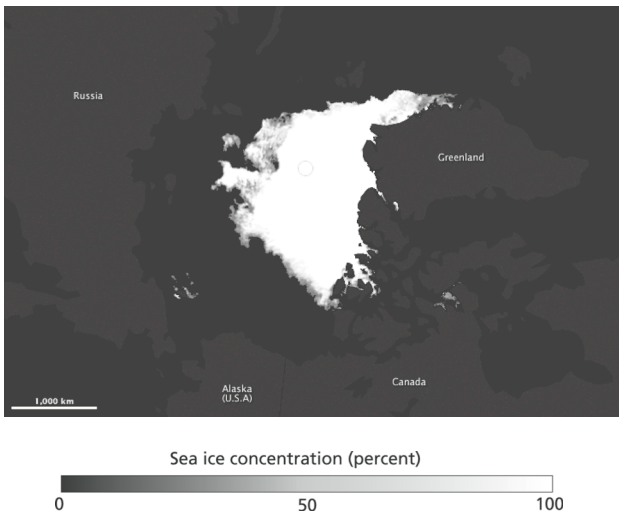


Fig. 7.15 Arctic Ocean ice coverage in September 2012.

There has been a significant decrease in the coverage of sea ice in the Arctic region since 1984. It has experienced an increase of 5 °C in the past 100 years. The melting ice is replaced with dark ocean and bare rock which absorb radiation rather than reflect it – increasing temperatures faster. The increased levels of CO_2 are causing ocean acidification at a faster rate in the Arctic region than elsewhere. As snow and ice melt, the ability to reflect heat back to space is reduced, accelerating the overall rate of global warming. These changes will cause the disappearance of some Arctic fisheries as well as the continued melting of glaciers and the ice caps. A warmer Arctic region could disrupt the Gulf Stream, which brings warmer water and weather to northwestern Europe.

4. The image below shows Male, the capital city of the Maldives in the Indian Ocean. The Maldives is a chain of 1200 low-lying coral islands. Male is densely populated and has lost much of its coral reef. A 90 cm rise in sea level will cause 85 per cent of Male to be inundated by water. A metre rise in sea level could see the Maldives – a tourist hotspot, home to a population of 340 000 – disappear completely by 2080.

Fig. 7.16 Location of the Maldives.

Fig. 7.17 Aerial view of Male, the capital of the Maldives.

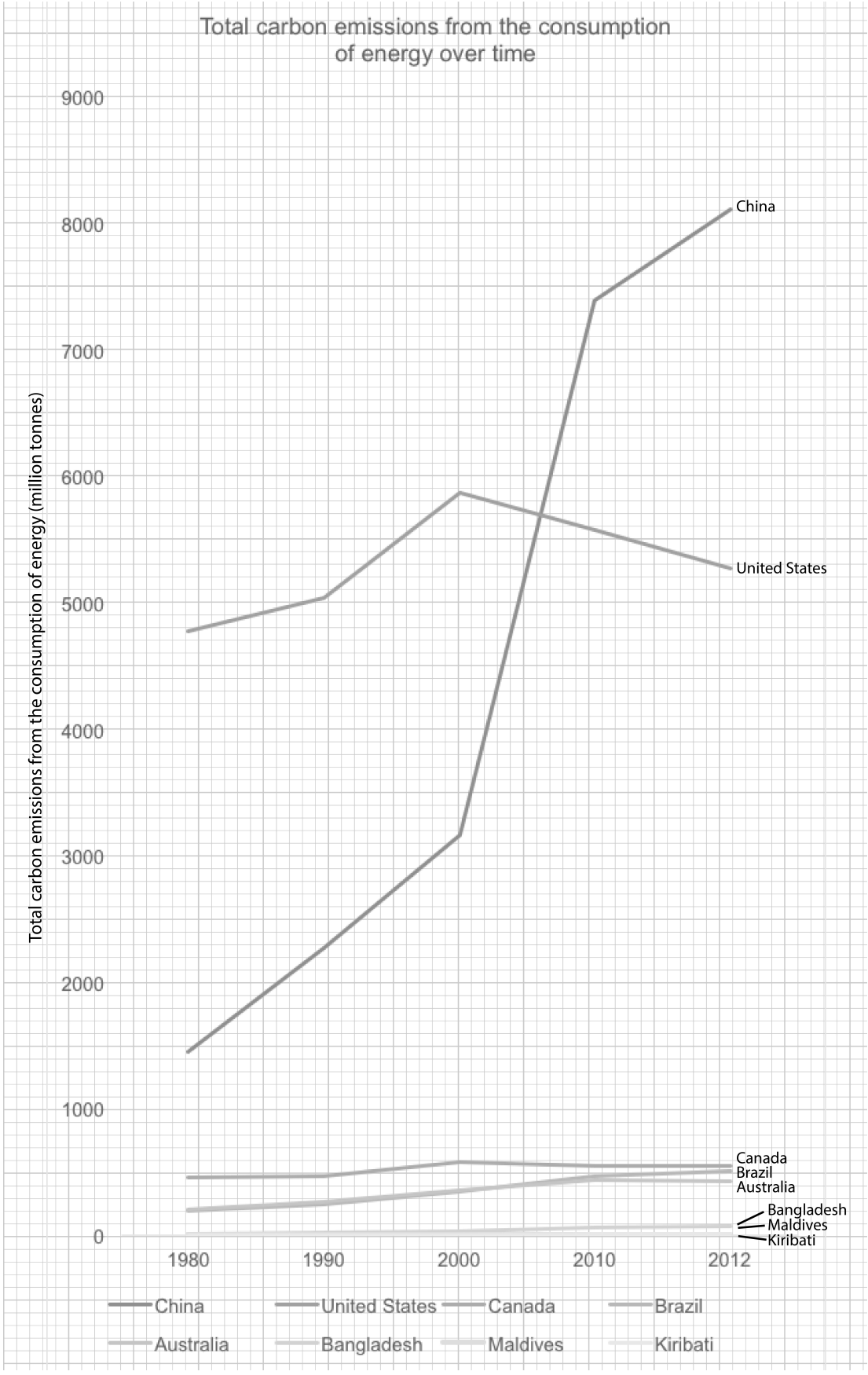
The Maldives is just one of many small island states that faces a significant risk from rising sea levels. Places like the Kiribati in the Pacific Ocean are also threatened by the highest tides each year. Furthermore, low-lying highly-populated Bangladesh could see 15 million people displaced by rising seas and an increase in storm surges from tropical cyclones.

Examine the data table below.

	1980	**1990**	**2000**	**2010**	**2012**
China	1448	2269	3165	7389	8106
United States	4776	5041	5864	5580	5270
Canada	457	471	573	548	551
Brazil	186	237	344	461	500
Australia	199	268	356	431	421
Bangladesh	8	15	29	54	63
Maldives	0.01	0.1	0.5	1.1	1.1
Kiribati	0.02	0.02	0.03	0.1	0.1

Table 7.1 Total carbon emissions from the consumption of energy over time (million tonnes).

a) Plot a line graph on the grid on the next page that shows the total carbon emissions over time of Kiribati, Maldives, Bangladesh and three other nations.



b) Compare and contrast the carbon emissions of the selected countries.

Kiribati, Maldives and Bangladesh have all seen increases in carbon emissions since 1980. Bangladesh has seen the greatest growth out of these 3 nations with emissions growing

from 8 to 63 million tonnes. Both Kiribati and the Maldives have very small emissions with 0.1 and 1.1 million tonnes respectively. In contrast, China has seen an exponential increase in its carbon emissions from 1448 to 8106 million tonnes. In the same period, emissions from the USA grew from 4776 to 5864 million tonnes in the year 2000 before declining to 5270 in 2012 – a much lower rate of growth compared to China. This was a similar pattern to that found in Canada, although with lower overall emissions.

c) It is possible for countries to take steps to reduce the impact of climate change through adaptation, which involves efforts to limit vulnerability to climate change impacts whilst not dealing with the cause. They can also attempt to mitigate the worst effects by reducing their carbon footprint and shifting to more renewable forms of energy. Using research and your own ideas, complete the table on the next page.

Possible steps to adapt to rising sea levels and climate change in low income countries like Bangladesh and the Maldives.	**Possible mitigation steps to reduce the magnitude of sea level rise and climate change.**
Build hard engineering structures such as sea walls and flood defences. Use soft engineering strategies at the coast like beach replenishment, and coastal wetland or mangrove protection or planting. Build houses on stilts so that flooding has a lower impact. Develop floating gardens so that floods do not devastate food supplies. Install storm surge warning systems and shelters. Develop evacuation plans for low-lying areas	Ideas relate to reducing carbon emissions to try and restrict temperature change and reduce the amount of sea level rise. Possible strategies include: • shifting to renewable energy sources • increasing energy efficiency • carbon capture and storage • afforestation • transport policies Reducing individual carbon footprints by: • using public transport • flying less • eating more locally produced food • driving less, walking more • repairing not replacing, reducing waste, reusing materials, recycling more

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d) Countries such as the Maldives and Bangladesh are not responsible for rising sea levels so should not be liable for the cost of taking measures to adapt to rising seas or for reducing their own carbon emissions. To what extent do you agree with this statement?

N.B. The answer below has been authored to reflect only one person's opinion. Students should be encouraged to express their own views and ideas on this topic.

Both the Maldives and Bangladesh are highly vulnerable to changing temperature and sea level rise. Bangladesh does emit much more carbon dioxide than the Maldives, but it does have a much higher population. The Maldives is responsible for only 1.1 million tonnes of CO_2 per year. If both countries were to continue at this rate, it would make little difference to global temperature rises. However, both countries have signed up for climate change international agreements that attempt to limit the rate of emissions growth. Meeting these targets will have economic costs. At the same time, both countries are amongst the most likely to be adversely affected by climate change in the next 20-30 years. Predictions estimate that even with low emissions growth then reduction, we are still likely to see a rise in sea level of between 0.75 and 1.0 m. A rise like this will flood large areas of coastal Bangladesh and would make islands in the Maldives uninhabitable. Tropical cyclone activity will increase, further increasing the risk of storm surges in both nations. In order to adapt to these scenarios, both countries will require significant investment from the government. Both of the countries are low-income countries that will struggle to reduce carbon emissions. Neither country is responsible for the warming that has happened and will continue to happen in the next 30 years. It could be argued that the world's leading emitters of carbon dioxide over time are directly responsible for the warming that is happening now and the associated sea level rise that threatens these low lying nations. It is clear that they themselves are not the cause of the current level of global carbon emissions. Given that the countries will need to adapt to rising sea levels, it would be ethical for higher income, industrialised nations to support both the Maldives and Bangladesh in adapting to sea level change and reducing their own emissions. This support could come in the form of aid or technological support and could be organised through the United Nations. The distribution of the aid would be complex, but the level of vulnerability of people in these poorer nations has been increased by human activity in other parts of the world, so it is unethical to leave them to face the consequences alone.