CLEAN ENERGY GENERATION, INTEGRATION AND STORAGE (EEE-801)

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Introduction: Energy and Civilization

- Energy technology plays a central role in societal economic and social development.
- Fossil fuel - based technologies have advanced our quality of life, but at the same time, these advancements have come at a very high price.
- Fossil fuel sources of energy are the primary cause of environmental pollution and degradation; they have irreversibly destroyed aspects of our environment.
- Global warming is a result of our fossil fuel consumption.

Introduction: Energy and Civilization

- For example, the fish in our lakes and rivers are contaminated with mercury, a byproduct of rapid industrialization.
- The processing and use of fossil fuels has escalated public health costs: Our health care dollars have been and are being spent to treat environmental pollution - related health problems, such as black lung disease in coal miners.
- Our relentless search for and need to control these valuable resources have promoted political strife. We are now dependent on an energy source that is unsustainable as our energy needs grow and we deplete our limited resources.

Introduction: Energy and Civilization

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- As petroleum supplies dwindle, it will become increasingly urgent to find energy alternatives that are sustainable as well as safe for the environment and humanity.

Introduction: Fossil Fuel

- It is estimated that fossil fuels — oil, natural gas, and coal — were produced 300 to 370 million years ago.
- Over millions of years, the decomposition of the flora and fauna remains that lived in the world's oceans produced the first oil.
- As the oceans receded, these remains were covered by layers of sand and earth, and were subjected to severe climate changes: the Ice Age, volcanic eruption, and drought burying them even deeper in the earth's crust and closer to the earth's core.

Introduction: Fossil Fuel

- From such intense heat and pressure, the remains essentially were boiled into oil. If you check the word, “ petroleum ” in a dictionary, you will find it means “ rock oil ” or “ oil from the earth. ”
- The ancient Sumerians, Assyrians, Persians, and Babylonians found oil on the banks of the Karun and Euphrates Rivers as it seeped above ground.
- Historically, humans have used oil for many purposes. The ancient Persians and Egyptians used liquid oil as a medicine for wounds.
- The Zoroastrians of Iran made their fire temples on top of percolating oil from the ground. Native Americans used oil to seal their canoes.

A canoe is a lightweight narrow water vessel, typically pointed at both ends and open on top, propelled by one or more seated or kneeling paddlers facing

Introduction: Fossil Fuel

- In fact, although our formally recorded history of humanity ’s energy use is limited, we can project the impact of energy on early civilizations from artifacts and monuments.
- The legacy of our oldest societies and their use of wood, wood charcoal, wind, and water power can be seen in the pyramids of Egypt, the Parthenon in Greece, the Persepolis in Iran, the Great Wall of China, and the Taj Mahal in India.

Introduction: Depletion of Energy Sources

- Figure 1.1 depicts the time needed to develop various energy sources. Coal, oil, and natural gas take millions of years to form.
- The oil that was made more than a million years ago is being used today.
- As we look at our energy use over the ages, it becomes clear that our new energy resources are substituting for old resources.
- Our first energy source was wood. Then coal replaced wood, and oil began to replace some of our coal usage to the point that oil now supplies most of our energy needs.

Introduction: Depletion of Energy Sources

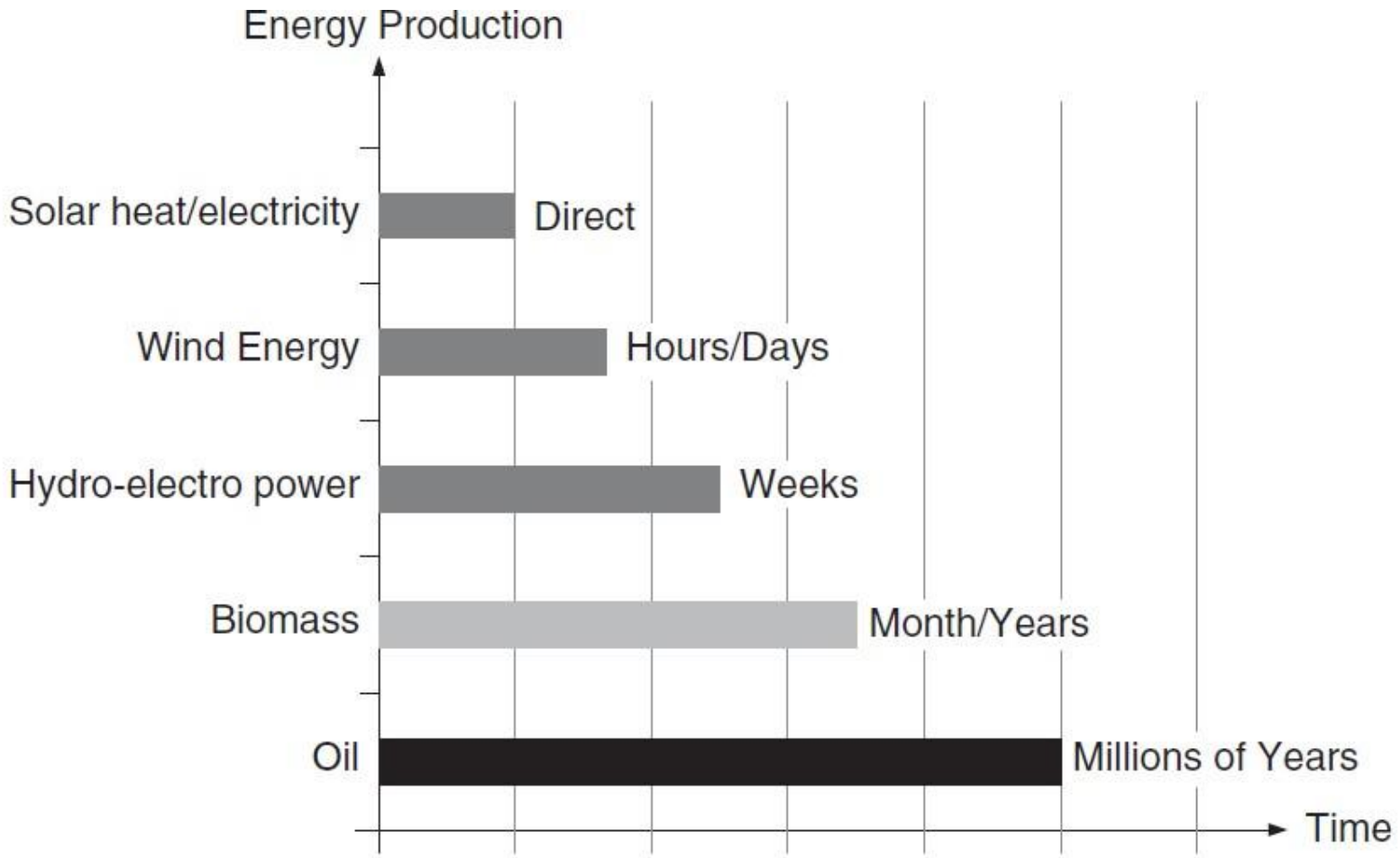

Figure 1.1 The Approximate Time Required for the Production of Various Energy Sources.

Introduction: Depletion of Energy Sources

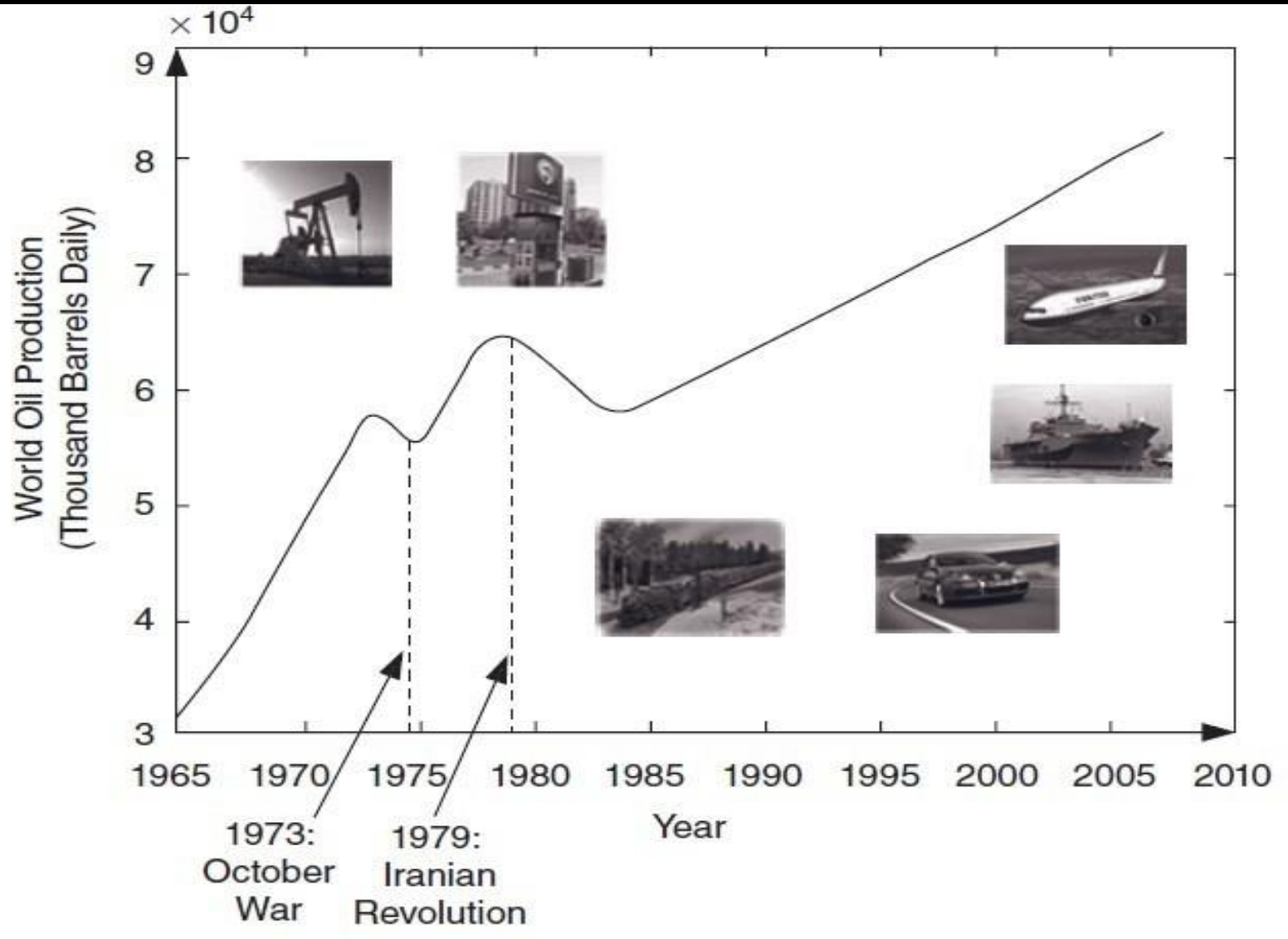

Figure 1.2 The World's Oil Production (Consumption) from 1965–2000 and Estimated

Introduction: Depletion of Energy Sources

- Since the Industrial Revolution, we have used coal. Since 1800, for approximately 200 years, we have used oil.
- However, our first energy source was wood and wood charcoal, which we used to cook food. Recorded history shows that humanity has been using wood energy for 5000 of the 100,000 years living on earth.
- Similarly, we have been using oil for 200 years of the 5000 years of recorded history. In the near future, we will exhaust our oil reserves. Oil is not renewable: we must conserve energy and save our oil — and gas as well.

Introduction: Depletion of Energy Sources

- The Middle East provides more than 50% of the oil imported to the United States. The United States' own oil production peaked around 1970.
- Europe's oil production is limited except for the North Sea oil reserve; it depends entirely on oil production from other parts of world.
- In Asia, China, India, Japan, and Korea depend on imported oil. The rapid economic expansion of China, India, and Brazil are also rapidly depleting the world oil reserves.

Introduction: Depletion of Energy Sources

- A closer look at Table 1.1 reveals that if the world reserves are used at the same rate as we do today, oil will run out in 40 years, our natural gas reserves will be depleted in less than 60 years, and our coal reserves will be exhausted in 200 years.
- No one can predict the future. However, we can empower every energy user in a new energy economy based on renewable sources to become an energy producer by conserving energy, reducing carbon footprints, and installing distributed renewable energy sources.

Introduction: Depletion of Energy Sources

TABLE 1.1 Proven Energy Resources around the World.[3,4]

Region	Petroleum		Natural Gas		Coal	
	2002 Preserved Resources (10^9 bbls)	R/P (Years)	2002 Proved Reserves (10^{12} SCF)	R/P (years)	2002 Preserved Reserves (10^9 tons)	R/P (years)
North America	49.9	10.3	52.4	9.4	257.8	240
South & Central America	98.6	42	250.2	68.8	21.8	404
Europe & Eurasia	97.5	17	2155.8	58.9	355.4	306
Middle East	685.6	92	1979.7	>100	????	>500
Africa	77.4	27.3	418.1	88.9	55.3	247
Asia-Pacific	38.7	13.7	445.3	41.8	292.5	126
World	1047.7	40.6	5501.5	60.7	984.5	204

Introduction: AN ALTERNATIVE ENERGY SOURCE: NUCLEAR ENERGY

- In 1789, Martin Heinrich Klaproth, a German chemist, discovered uranium in the mineral pitchblende. Eugène - Melchior Péligot, a French chemist, was the first person to isolate the metal, but it was Antoine Becquerel, a French physicist, who recognized its radioactive properties almost 100 years later.
- In 1934, Enrico Fermi used the nuclear fuel to produce steam for the power industry.
- Later, he participated in building the first nuclear weapon used in World War II. The U.S. Department of Energy estimates worldwide uranium resources are generally considered to be sufficient for at least several decades.

Introduction: An Alternative Energy Source: Nuclear Energy

- The amount of energy contained in a mass of hydrocarbon fuel such as gasoline is substantially lower in much less mass of nuclear fuel.
- This higher density of nuclear fission makes it an important source of energy; however, the fusion process causes additional radioactive waste products.
- The radioactive products will remain for a long time giving rise to a nuclear waste problem.
- The counterbalance to a low carbon footprint of fission as an energy source is the concern about radioactive nuclear waste accumulation and the potential for nuclear destruction in a politically unstable world.

Introduction: Global Warming

- Figure 1.4 depicts the process of solar radiation incident energy and reflected energy from the earth's surface and the earth atmosphere.
- Greenhouse gases in the earth's atmosphere emit and absorb radiation. This radiation is within the thermal infrared range.
- Since the burning of fossil fuel and the start of the Industrial Revolution, the carbon dioxide in the atmosphere has substantially increased as shown in Figures 1.5 and 1.6.
- The greenhouse gasses are primarily water vapor, carbon dioxide, carbon monoxide, ozone, and a number of other gases. Within the atmosphere of earth, greenhouse gasses are trapped.

Introduction: Global Warming

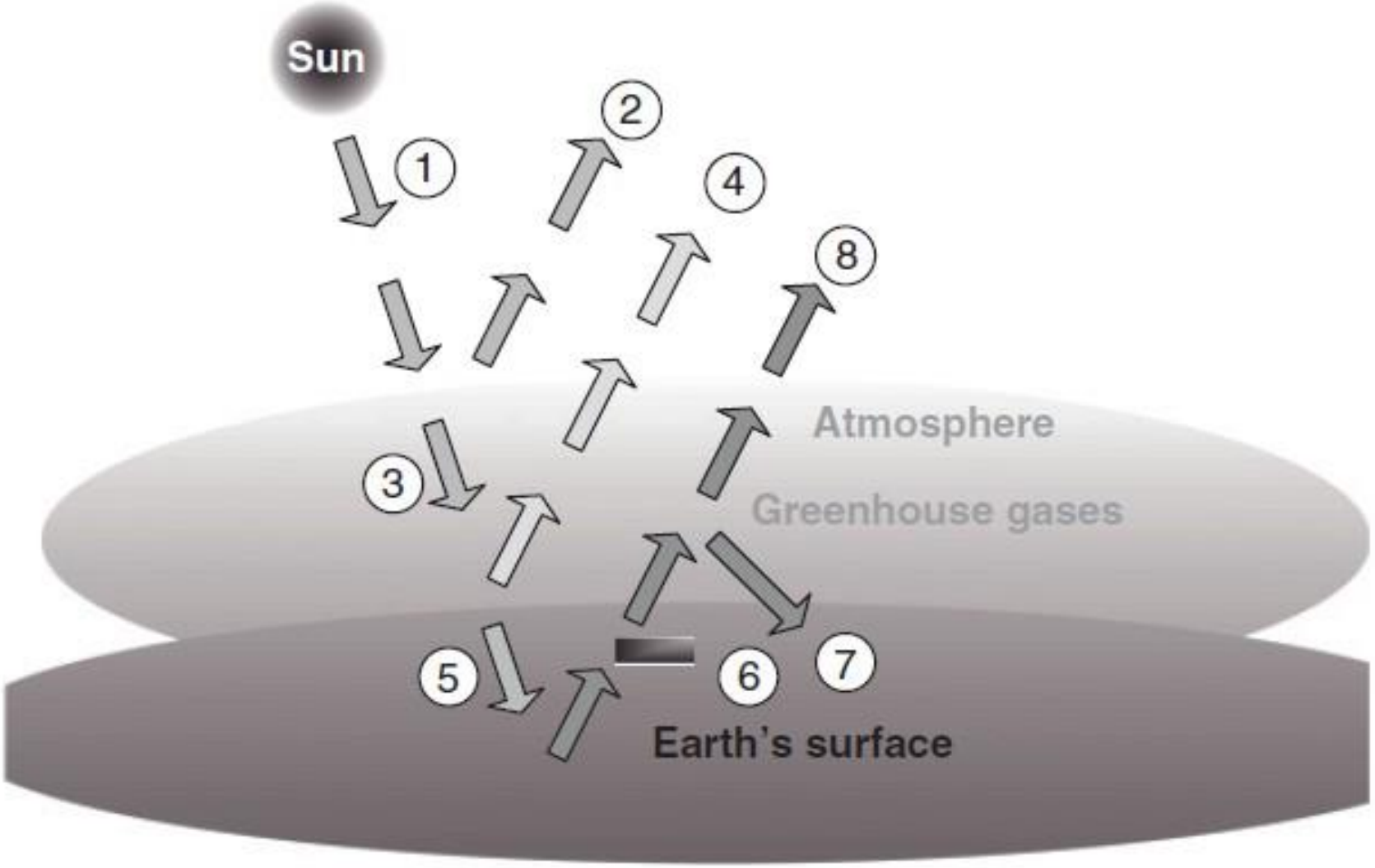

Figure 1.4 The Effects of Sun Radiation on the Surface of the Earth.

Introduction: Global Warming

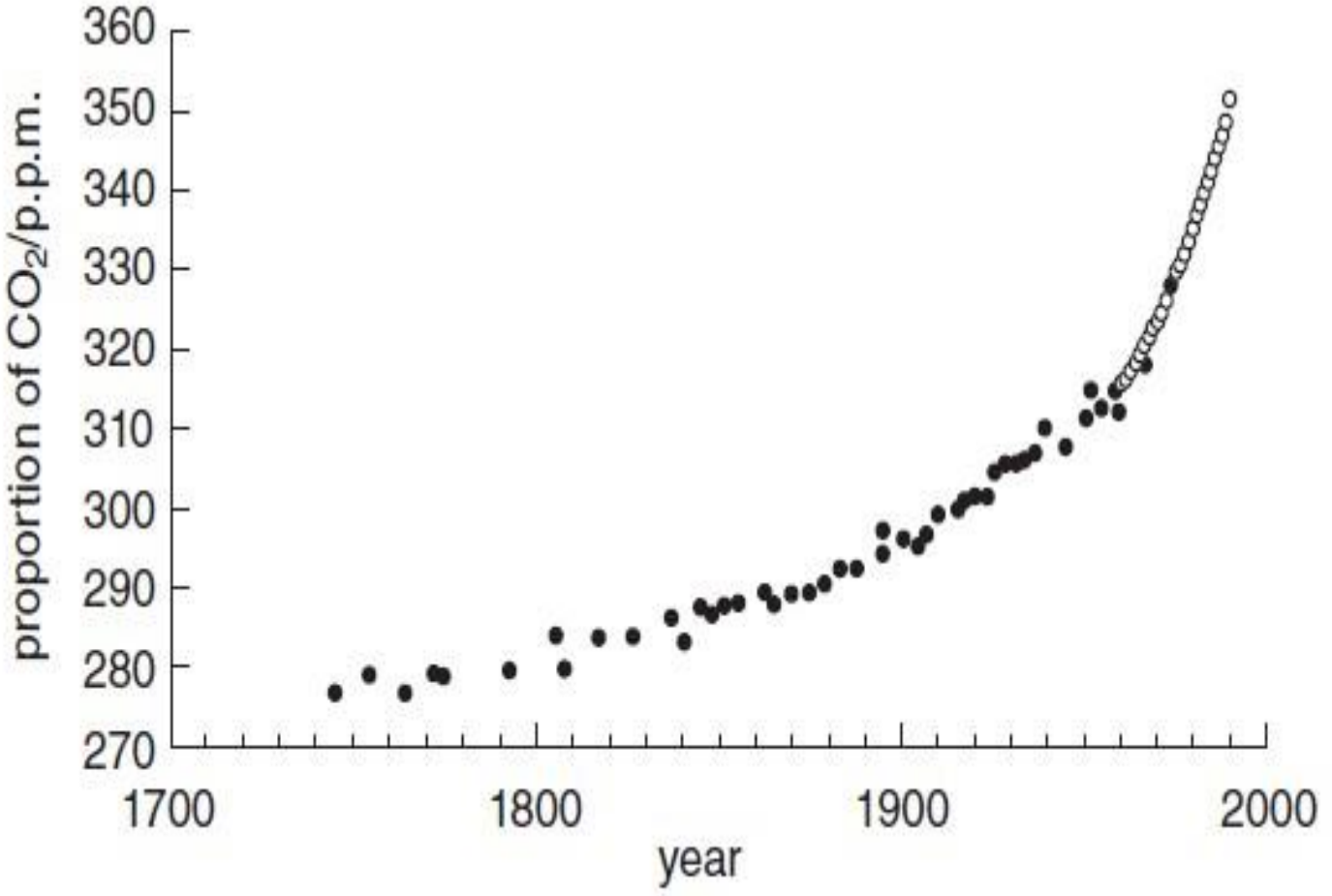

Figure 1.5 The Production of CO_2 since 1700. (Data from the Intergovernmental Panel on Climate Change, IPCC Third Annual Report.)

Introduction: Global Warming

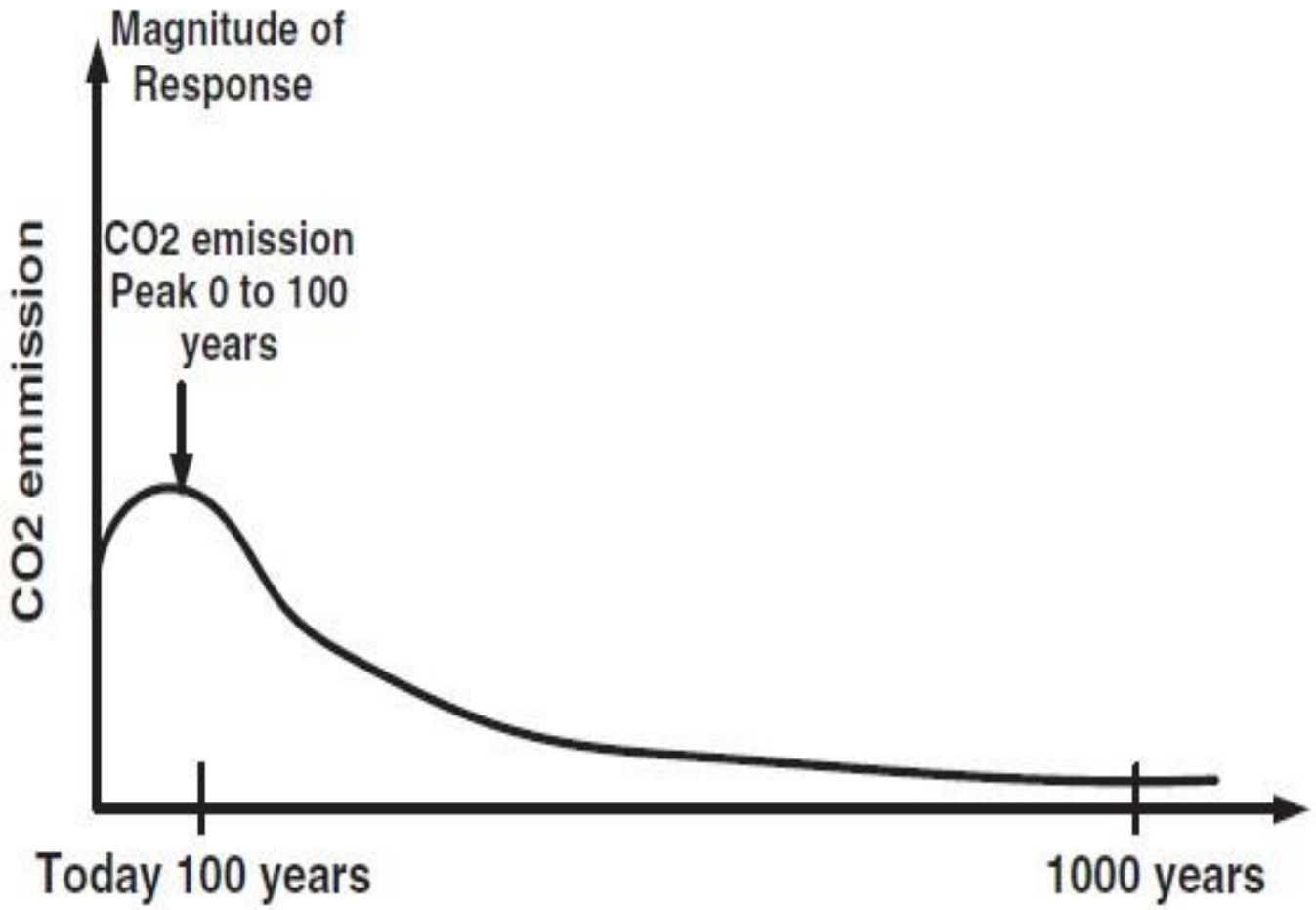

Figure 1.6 The Effect of Carbon Dioxide Concentration on Temperature and Sea Level. (Data from the Intergovernmental Panel on Climate Change, IPCC Third Annual Report.*)

Introduction: Global Warming

- The solar radiation incident energy as depicted by circle 1 emitted from the sun and its energy is approximated as 343 W/m^2 .
- Some of the solar radiation, depicted by circle 2 and circle 4, is reflected from the earth's surface and the earth's atmosphere.
- The total reflected solar radiation is approximated as 103 W per m^2.
- Approximately 240 W per m^2 of solar radiation, depicted by circle 3, penetrates through the earth's atmosphere.

Introduction: Global Warming

- About half of the solar radiation (circle 5), approximately 168 W per m^2 , is absorbed by the earth's surface.
- This radiation (circle 6) is converted into heat energy. This process generates infrared radiation in the form of the emission of a long wave back to earth.
- A portion of the infrared radiation is absorbed. Then, it is re – emitted by the greenhouse molecules trapped in the earth ' s atmosphere.
- Circle 7 represents the infrared radiation. Finally, some of the infrared radiation (circle 8), passes through the atmosphere and into space.
- As the use of fossil fuel is accelerated, the carbon dioxide in the earth ' s atmosphere is also accelerated. The growth of carbon dioxide in our atmosphere is shown in parts per million in Figure 1.5.

Introduction: Global Warming

- The World Meteorological Organization (WMO) is the international body for the monitoring of climate change.
- The WMO has clearly stated the potential environmental and socioeconomic consequences for the world economy if the current trend continues.
- In this respect, global warming is an engineering problem, not a moral crusade.
- Until we take serious steps to reduce our carbon footprints, pollution and the perilous deterioration of our environment will continue.

Introduction: Global Warming

- Figure 1.6 depicts the condition of CO2 in the upper atmosphere. The Y axis represents the magnitude of response. The X axis is plotted showing the years into future.
- The Y axis, showing response efforts, does not have units. The CO2 emission into the atmosphere has peaked during the last 100 years.
- If concentrated efforts are made to reduce the CO2 emission and it is reduced over the next few hundred years to a lower level, the earth temperature will still continue to rise, however, then stabilize.
- Figure 1.7 depicts the stabilization of CO2 over the subsequent centuries.

Introduction: Global Warming

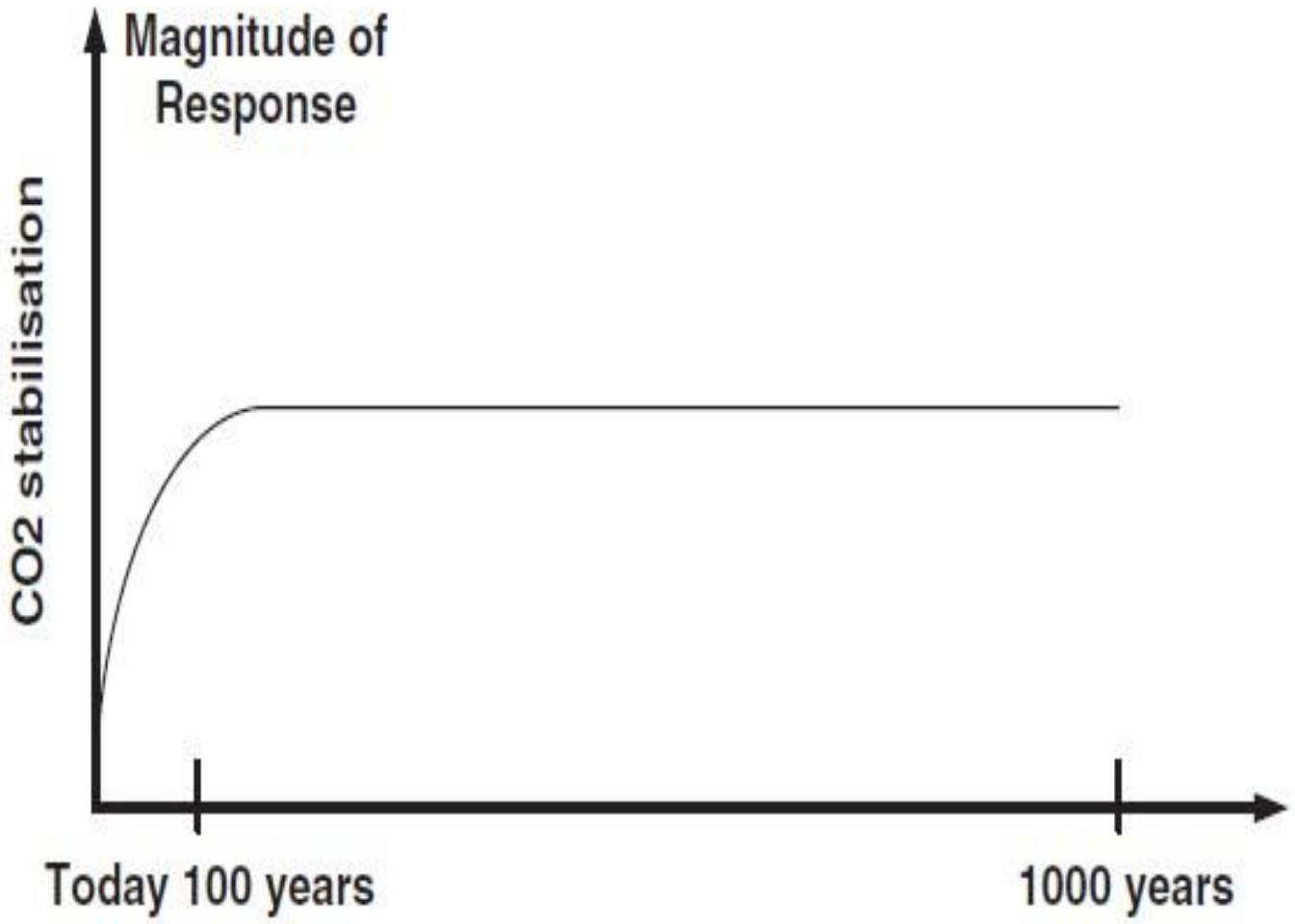

Figure 1.7 CO_2 Stabilization after CO_2 Has Been Reduced. (Data from the Intergovernmental Panel on Climate Change, IPCC Third Annual Report.[11])

Introduction: Global Warming

- The reduction of CO2 will reduce its impact on the earth atmosphere; nevertheless, the existing CO2 in the atmosphere will continue to raise the earth's temperature by a few tenths of a degree.
- The earth's surface temperature will stabilize over a few centuries as shown in Fig. 1.8.

Introduction: Global Warming

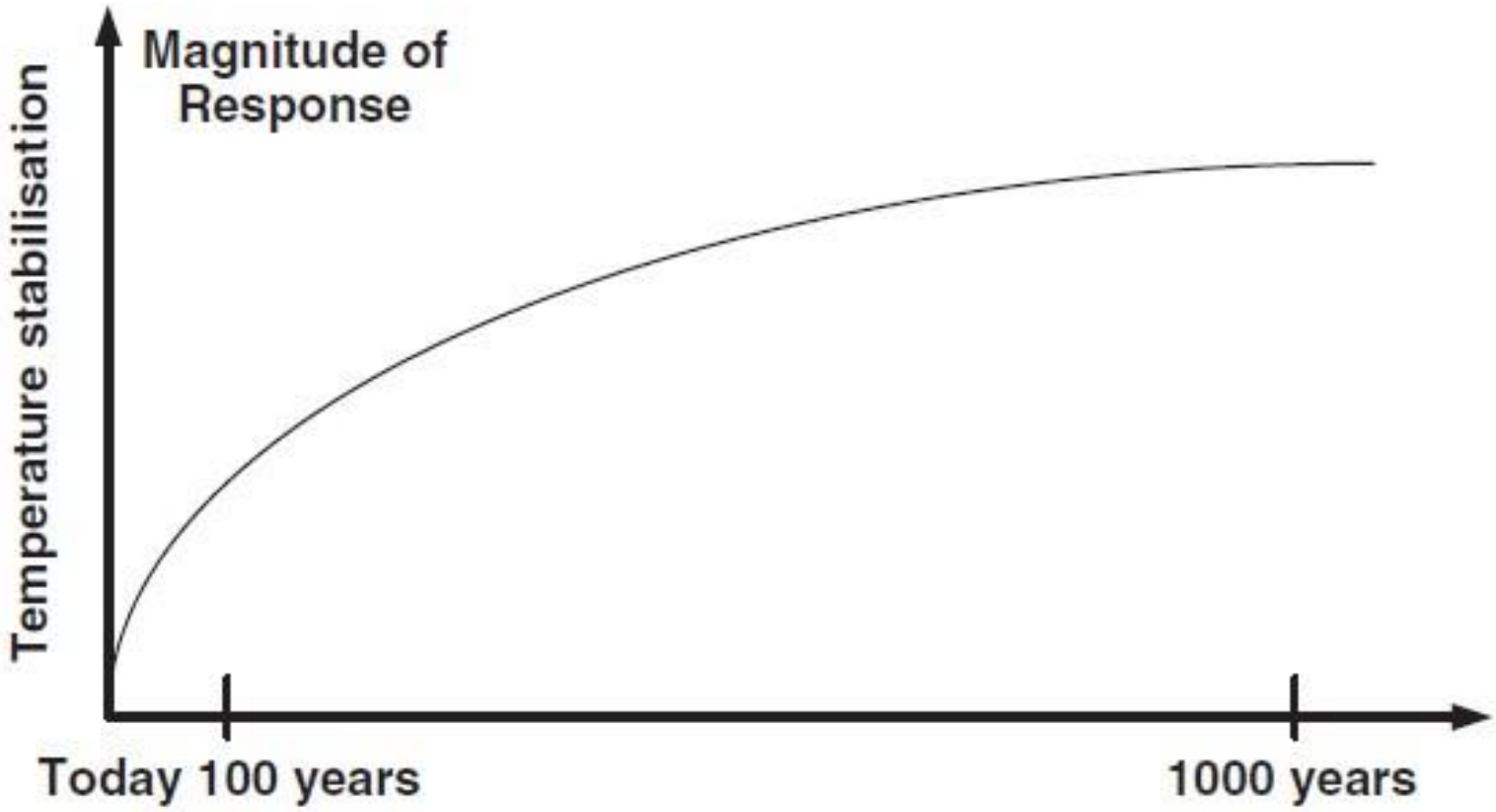

Figure 1.8 Temperature Stabilization after Reduction of CO_2 Emission.

Introduction: Global Warming

- The rise in the temperature due to trapped CO2 in the earth's atmosphere will impact the thermal expansion of oceans.
- Consequently, the sea level will rise due to melting of ice sheets as shown in Fig. 1.10.

Introduction: Global Warming

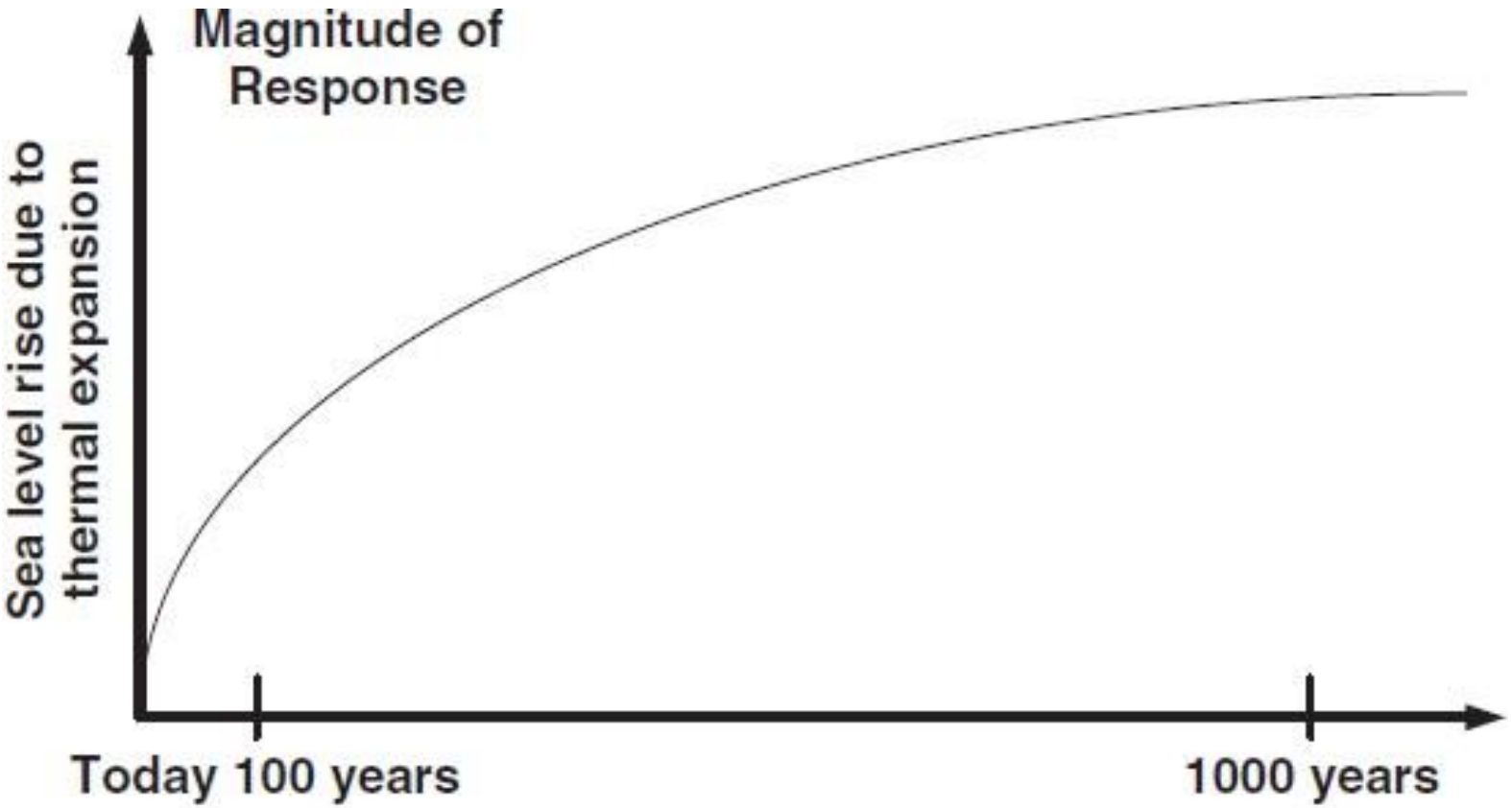

Figure 1.9 The Sea Level Rise after the Reduction of CO_2.

Introduction: Global Warming

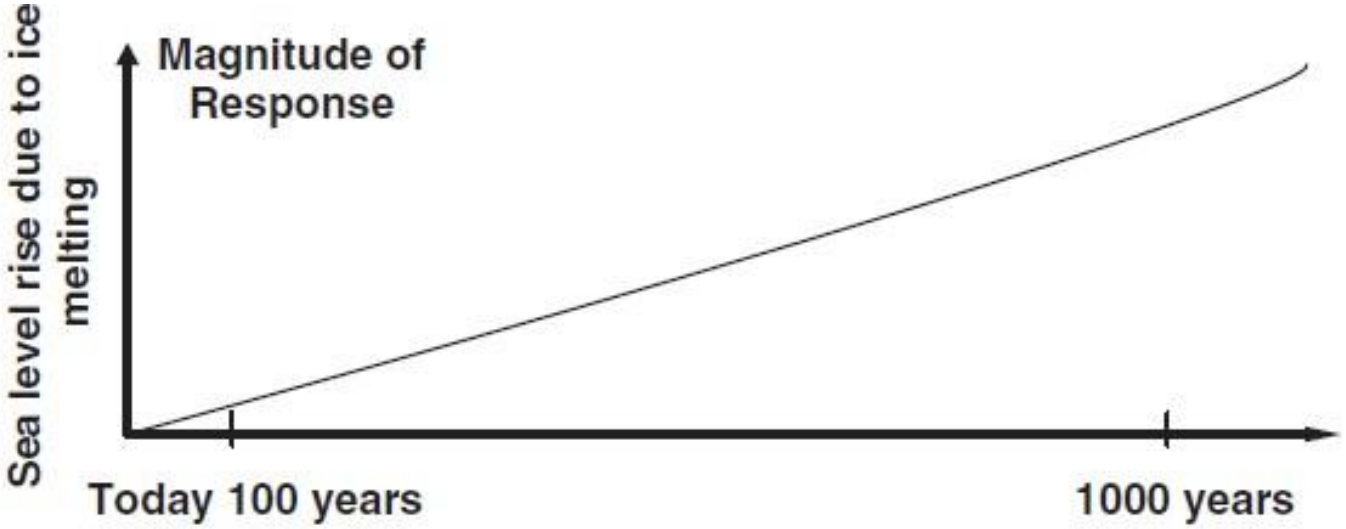

Figure 1.10 The Sea Level Rise after the Reduction of CO_2 in the Atmosphere.

Introduction: Global Warming

- As the ice sheets continue to melt due to rising temperatures over the next few centuries, the sea level will also continue to rise.
- Figures 1.6 through 1.10 depict the earth's conditions as a function of our level of response.
- As a direct consequence of trapped CO2 in the atmosphere, with its melting of the polar ice caps causing increased sea levels that bring coastal flooding, our pattern of life on earth will be changed forever.