ENERGY, ENVIRONMENT, AND CLIMATE, Third Edition

CHAPTER 1: A Changing Planet

QUESTIONS

1. Life has changed Earth's atmosphere.

2. In the first few hundred million years after the planet's formation, Earth's active geology and bombardment from solar system debris eradicated any evidence of early life.

3. Oxygen is highly reactive.

4. Fuels (such as oil or coal) store energy. Flows (such as sunlight) deliver streams of energy.

5. Volcanoes emitted CO_2 (carbon dioxide).

6. Higher standards of living and greater education, which are associated with higher energy consumption, tend to enable and encourage people to choose smaller families.

7. In 1988, more people were reproducing.

EXERCISES

1. Solar radiation intensity $S = 1{,}360\ \text{W/m}^2$ = power/area. The power is the rate at which solar energy arrives at Earth.

The effective absorbing area of Earth is that of a disk of radius $R_E = 6.37 \times 10^6$ m:

$$\text{area} = \pi R^2 = \pi\left(6.37\times10^6\,\text{m}\right)^2 = 1.27\times10^{14}\,\text{m}^2$$

Therefore, power = $S \times$ area = 1.72×10^{17} W $\approx$ <u>170 PW</u>.

2. From Figure 1.8, geothermal energy provides 0.025% of Earth's total power and solar energy provides 99.98% of Earth's total power.

$$\text{geothermal power} = 0.025\% \quad \text{total power} = 0.025\% \times \frac{\text{solar power}}{99.98\%}$$

$$\text{geothermal power} = 0.025\% \times \frac{1.74\times10^{17}\ \text{W}}{99.98\%} = 4.3\times10^{13}\ \text{W} = \underline{43\ \text{TW}}$$

Because the Sun's power provides nearly 100% of Earth's total power, we could just as well have approximated this as

$$\text{geothermal power} = 0.025\% \times 1.7 \times 10^{17}\ \text{W} = 4.3 \times 10^{13}\ \text{W}$$

3. Let P_0 = the initial population and $P(t)$ = population at a later time, t. As long as we look at population increases over short time periods (just a year), we can approximate the population growth as linear: $P(t) = P_0 + m \times t$, where the growth rate in people per year, m, is proportional to the percentage growth rate, g, and to the initial population: $m = P_0 \times g$.

The population grows each year by approximately $\Delta P = P(t) - P_0 = m \times t = g \times P_0 \times t$, where t = 1 year.

1965: P_0 = 3.4 billion people, g = 2% per year. Population grows this year by approximately $\Delta P = g \times P_0 \times t$ = 3.4 billion people × 2%/y × 1 y = <u>68 million people</u>.

1985: P_0 = 4.9 billion people, g = 1.7% per year. Population grows this year by approximately $\Delta P = g \times P_0 \times t$ = 4.9 billion people × 1.7%/y × 1 y = <u>83 million people</u>.

2000: P_0 = 6.1 billion people, g = 1.2% per year. Population grows this year by approximately $\Delta P = g \times P_0 \times t$ = 6.1 billion people × 1.2%/y × 1 y = <u>73 million people</u>.

Although there were more people in 2000, the growth rate was lower, so the population grew by a smaller number than in 1985.

4. The population growth is exponential: $P = P_0\, e^{rt}$. Here P_0 is the initial population of 7.5 billion, r is the growth rate of 1% per year or 0.01/year, and t = 2050 –2017 = 33 years. Then

$$P = (7.5\ \text{billion})(e^{(0.01/\text{year})(33\ \text{years})}) = \underline{10.4\ \text{billion people}}$$

5. Total fossil and nuclear energy flow = 0.008% or 0.00008 of the solar energy flow, which is 1.7×10^{17} W. So the total fossil and nuclear flow is $(0.00008)(1.7 \times 10^{17}\ \text{W}) = 1.4 \times 10^{13}$ W, or <u>14 TW</u>. This is consistent to this level of approximation with the human energy consumption of 18 TW (nearly all of which is from fossil and nuclear sources).

ARGUE YOUR CASE

1. The natural flows have been in equilibrium. The "human uses" flow, although small, has significantly disrupted the equilibrium of the Earth system.

2. Waterpower is fundamentally driven by solar radiation, which evaporates water and drives the hydrologic cycle.