**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 CO2 (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 W/m2 = 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 *RE* = 6.37 × 106 m:



Therefore, power = *S*  area = 1.72×1017 W  170 PW.

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.



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



3. Let *P0* = 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*) = *P0* + *m*  *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  *g.*

The population grows each year by approximately Δ*P* = *P*(*t*) − *P0*= *m*  *t* = *g*  *P0*  *t*, where *t* = 1 year.

1965: *P0* = 3.4 billion people, g = 2% per year. Population grows this year by approximately Δ*P* = *g*  *P0*  *t* = 3.4 billion people  2%/y  1 y = 68 million people.

1985: *P0* = 4.9 billion people, *g* = 1.7% per year. Population grows this year by approximately Δ*P* = *g*  *P0*  *t* = 4.9 billion people  1.7%/y  1 y = 83 million people.

2000: *P0* = 6.1 billion people, *g* = 1.2% per year. Population grows this year by approximately Δ*P* = *g*  *P0*  *t* = 6.1 billion people  1.2%/y  1 y = 73 million people.

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 *ert*. 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 billion)(*e*(0.01/year)(33 years) = 10.4 billion people

5. Total fossil and nuclear energy flow = 0.008% or 0.00008 of the solar energy flow, which is  
1.7  1017 W. So the total fossil and nuclear flow is (0.00008)(1.7  1017 W) = 1.4  1013 W, or 14 TW. 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.