

Chapter 2: Dreams of a Sustainable Future

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1.
 - a. The neighbour who uses stone pathways and drought-resistant wildflowers and shrubs has the more sustainable front yard. This is because maintaining the yard requires the same amount of water as would fall naturally as precipitation and the yard has no need for fertilizers or other chemical applications.
 - b. Cumulative effects of non-sustainable landscaping practices include water shortages and algal blooms in waterways that receive untreated runoff containing fertilizers from lawns or fields.
2. Earth is so large that, for most people, it seems inconceivable that their behaviour could impact the entire planet. What they forget is that if millions of people behave in the same way, the cumulative effects can have global implications. Global climate change is just one example. The “spaceship Earth” notion is useful because it brings the scope of the problem down to a scale most people can understand. Imagine a large storeroom on a spaceship filled with a set amount of supplies that can only be restocked through recycling. Given the harshness of space, the spaceship notion reinforces how important it would be to care for the onboard life-support systems.

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3. Answers will vary. Contact your teacher for a sample analysis of a nuclear power generation.
4. Answers will vary. The sample answers given are consistent with the sample analysis provided for question 3.
 - a. Energy production using nuclear fission is more sustainable than using coal. Unlike coal, nuclear power does not produce all the harmful emissions that are released into the environment. This results in a much higher score for ecological sustainability. Recall from the “Minimizing Exposure to Radiation” activity in Unit C that there is a greater exposure to ionizing radiation if you live close to a coal-fired power plant than if you live close to a nuclear power plant. In terms of societal sustainability, nuclear power scored better than coal due to the fact that a higher degree of education and constant training is required by the workforce. Both coal-fired power and nuclear power scored well in terms of economic sustainability.
 - b. Most students agreed that nuclear power should be ranked higher than coal. However, some students thought the process was flawed, considering the impact that any release of nuclear waste could have on the environment. There was some discussion about the need to give weightings to each of the individual criteria listed, but it was not clear as to how a consensus can be reached.

Other students really liked nuclear power as an option. These students insisted that those who were not in favour of nuclear power suddenly wanted to revamp the evaluation system. There was much debate.

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5. In addition to generating electricity, the hot water and steam associated with geothermal energy is used to heat homes and buildings.
6. The western areas of British Columbia, just north of Vancouver, are thought to have the greatest potential as a source of geothermal energy. These areas are close to the boundary between the Pacific Plate and the North American Plate, making it geologically active and the most logical place for geologic hot spots.

7. Answers will vary. Some advantages and disadvantages of geothermal energy are given.

GEOTHERMAL ENERGY

Advantages	Disadvantages
<ul style="list-style-type: none"> • Geothermal energy is a renewable source of energy. • Building the plant to harvest the energy from this source is relatively inexpensive. 	<ul style="list-style-type: none"> • Geothermal energy is a highly localized form of energy. • Emissions of H₂S(g), and its rotten-egg smell, often accompany the hot water and steam coming from deep within Earth.

8. Answers will vary. Contact your teacher for a sample analysis of geothermal power generation.

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9. The Bay of Fundy is one of the world’s most promising tidal energy sites because the tides in this region are the highest in the world. This is due to the fact that the natural motion of the water in the bay happens to be “in tune” with the natural cycle of the tide, which causes large differences between low tide and high tide.
10. Answers will vary. Contact your teacher for a sample analysis of tidal power generation.

2.1 Questions, page 535

Knowledge

1.
 - a. Sustainable development is the development of industrial and natural resources that meet the needs of the present generation without compromising the ability of future generations to meet their own needs.
 - b. Geothermal energy is the heat that originates from radioactive decay within Earth’s core.
 - c. Tidal energy is the gravitational potential energy and the kinetic energy of ocean water generated by tidal effects.

2.
 - a. Geothermal energy involves harnessing the heat that originates from intranuclear potential energy released during radioactive decay in Earth’s core. In areas where crustal plates meet—where Earth’s crust is either thin or fractured—water comes into contact with rock that has been heated by Earth’s mantle. When this water reaches the surface, it is a combination of hot water and steam that possesses both kinetic energy and potential energy. The steam then turns a turbine, showing that the kinetic energy of the steam is converted into the kinetic energy of the rotating blades and shaft. The turbine is connected to a generator that converts the kinetic energy of an armature rotating in a magnetic field into electrical energy.

 - b. Tidal energy involves the gravitational potential energy and kinetic energy of ocean water influenced by gravitational forces of the Sun and the Moon. Twice daily, as high tide develops, water is allowed to pass through the gates of a special dam—called a barrage—and enter an estuary. Once the water reaches the high-water mark, high tide is reached and the gates of the barrage are closed. At this point, the water in the estuary has a great deal of gravitational potential energy. When low tide is near, the water stored in the estuary is allowed to flow through the barrage. The gravitational potential energy of the water converts into kinetic energy, which causes the blades and shaft of a turbine to turn. The transfer of kinetic energy from the water to the turbine allows for a transfer of energy to a generator that converts the kinetic energy of an armature rotating in a magnetic field into electrical energy.

3.
 - a. Coal is a non-renewable form of energy. The current supply of coal was formed through a natural process that began millions of years ago. Coal reserves cannot be replenished naturally in a short period of time.
 - b. Nuclear power is a non-renewable form of energy. The current supply of uranium-235 was produced when Earth formed. The uranium-235 reserves cannot be replenished naturally in a short period of time.
 - c. The fission of isotopes in Earth’s core that produce geothermal energy is a renewable form of energy. This source of energy will not be depleted for millions of years, even if it’s used at higher rates of consumption.
 - d. The movement of water in ocean tides that creates tidal energy is a renewable form of energy because the source of tidal energy is the gravitational interactions of the Earth-Moon-Sun system. This source of energy is continuously available.

Applying Concepts

4. As described in the answer to question 2.a., geothermal energy involves harnessing the heat that originates from radioactive decay in Earth’s core. The hot steam from deep within Earth is used to turn the blades and shaft of a turbine that is connected to a generator. The operation of a coal-fired power plant involves extra steps: the mining, transporting, and pulverizing of coal; then the combustion of coal to heat water to produce steam. Since geothermal energy automatically produces steam, a geothermal power plant is more efficient than a coal-fired power plant because it requires fewer energy transformations. This allows for fewer opportunities for energy to be lost from the system.
5. Answers will vary depending on each student’s analyses performed earlier. A sample answer is provided.

Sustainability Categories and Weightings	Source of Energy			
	Coal	Nuclear Power	Geothermal Energy	Tidal Energy
Ecological Sustainability Weighting = 50	17.2	35.9	43.8	37.5
Societal Sustainability Weighting = 25	10.9	17.2	20.3	17.2
Economic Sustainability Weighting = 25	16.7	16.7	16.7	11.1
Overall Sustainability Weighting = 100	44.8	69.8	80.8	65.8

The sources with the highest overall scores for sustainability were nuclear fission and geothermal energy. Both of these sources scored well in terms of ecological sustainability, with geothermal energy scoring slightly higher because it is a renewable source of energy and does not require elaborate systems for storing radioactive waste. Nuclear fission scored slightly higher than geothermal energy in terms of economic sustainability because it is much more flexible in terms of where a power plant can be located. Geothermal energy can be used only in regions that are near geological “hot spots.”

Tidal energy ranked third in terms of overall sustainability. Even though tidal energy is a renewable source of energy, the fact that there could be negative effects on the ecology of the estuary lowered its score in terms of ecological sustainability. However, the main reason for the low ranking of tidal energy is the fact that its score for economic sustainability was so low. Tidal energy is highly localized. These power plants can be located only in marine locations that have large differences between high and low tide. In addition, tidal energy is cyclic in nature, producing bursts of energy that peak every 12 hours 25 minutes. This makes it difficult for an industry to maintain a steady production of electricity.

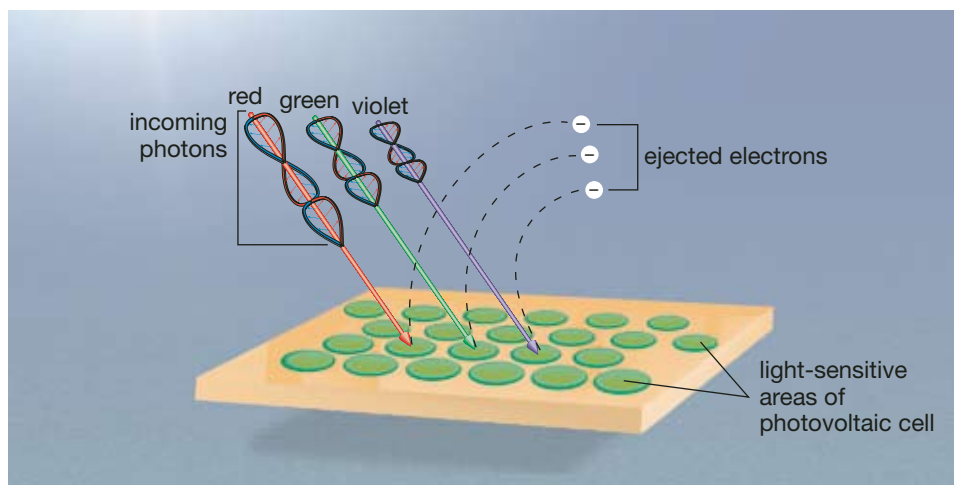
The source of energy with the lowest ranking is coal. This is due primarily to its very low score in the ecological sustainability category. The combustion of coal uses a great deal of land—disrupting ecosystems—and produces numerous emissions that are harmful to the environment. Despite the fact that coal scored favourably in the economic sustainability category—mostly because it is a relatively inexpensive fuel—the fact that I chose to weight the ecological category considerably higher than the societal and economic categories resulted in ranking coal last as an energy source in terms of overall sustainability.

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11. Solar energy used for passive heating is an inexhaustible energy source. Although the Sun's energy will eventually run out due to the depletion of hydrogen, this will not occur within a human time scale. The Sun is predicted to keep burning for billions of years.
12. Earth energy systems utilize the heat stored in the ground—a form of stored solar energy. Since this energy can be replenished naturally in a short period of time, earth energy systems are a form of renewable energy.
13. Two factors responsible for fluctuation in natural gas prices are changes to supply and demand. A decrease in supply or an increase in demand by users influences the price.
14. An earth energy system should not be subject to the same price instability because it is based on a sustainable energy source. The cost of ground-source heating is unlikely to be so unpredictable because it relies mainly on solar energy, with some electrical energy needed to run the pumps and compressors. Its price should be steady and much lower in general. Price changes may be due to the cost of materials used in the construction of the system. If the pipes are plastic, future scarcity of hydrocarbons may increase the cost of a system; but volatile cost fluctuation would not be expected. The fluctuating cost of electricity to run pumps and compressors is the largest factor in the cost of earth energy.

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15. a.



- b. A photon of violet light delivers the most energy to the photovoltaic cell because this photon has the higher frequency and, therefore, transfers more energy.

16. Answers will vary. Contact your teacher for a sample analysis of photovoltaic cells.

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17. a. It is important to reduce the energy that is lost as waste heat during the transmission of electrical energy. The energy lost as waste heat is dependent upon the strength of the electric current in the transmission cables. To keep the current in the transmission cables low, the transformer can boost the transmission voltage to 250 000 V or higher.

- b. A step-up transformer is required. The transformer is increasing the voltage produced by the generator to a higher value used for transmission.

18. Answers will vary. Contact your teacher for a sample analysis of hydroelectric power.

19. percentage of power = $\frac{18\,000\text{ MW}}{2.83 \times 10^5\text{ MW}} \times 100\%$
 = 6.36%

20. Power production from the Three Gorges Dam could increase the quantity of energy produced using renewable energy sources, and it could potentially decrease the use of coal for electricity production.

21. Answers will vary. It is highly likely that answers will identify other beneficial factors associated with the project or increased energy supply as benefits that outweigh the adverse consequence. Sample responses to criticisms are provided.

- I. Although many people have been displaced by the project, alternative new housing has been provided for many families. The new facilities represent an improvement in lifestyle for many and the opportunities that exist for employment in the new communities should enable these people to find meaningful work to support themselves and the new communities. For many, the new homes have electricity and other modern features.
- II. The unfortunate pollution of rivers is offset by improvements that can occur to the levels of atmospheric pollution. Providing a large amount of hydro energy can be accompanied with a decrease in the use of coal for energy production. This will reduce emissions and their unfortunate environmental consequences, such as acid deposition and metal leaching.
- III. Data does not exist to show that the dam is the sole reason for the possible extinction of rare fish species. Other factors may be at play, like those that are not within the control of humans. Efforts can also be made to provide suitable habitats for rare species of fish along the river.
- IV. The opportunity presented at the Three Gorges Dam site is rare, allowing for the construction of the largest hydroelectric dam in the world. Technology used in the construction of the dam can provide for allowances for seismic activity. Since the prediction of earthquakes is imprecise, holding back on the opportunities presented at this site would have long-term negative effects on China's development.

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22. The prevailing winds in Alberta tend to blow from west to east. This is a combined result of solar energy heating masses of air, creating convection currents in the atmosphere, and the effects of Earth's rotation. As these westerly winds blow across British Columbia, the various ranges of mountains create barriers to the flow of air. When the winds encounter a significant gap in the mountains, such as the one found at Crowsnest Pass, the wind energy becomes concentrated as it funnels through the narrow opening. In the southwest corner of Alberta, the elevation drops as the mountains give way to the foothills and eventually to the prairies. This drop in elevation causes atmospheric effects that further intensify the energy of the wind. Situated just east of Crowsnest Pass, the Pincher Creek area is ideally positioned to take advantage of these favourable wind conditions.
23. Answers will vary. Contact your teacher for a sample analysis of wind energy.

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24. a. The activities in the illustration that indicate that using biomass is not completely carbon-neutral include the trucks hauling the waste wood to the biomass generation station and the logging trucks hauling the logs to the forestry-operations facility. The trucks that do this kind of hauling typically run on fossil fuels and will produce emissions of $\text{CO}_2(\text{g})$. To be carbon-neutral, these trucks would have to somehow run on energy produced by the biomass generating station or have the equivalent of their $\text{CO}_2(\text{g})$ emissions absorbed by the reforested area.
- b. Biomass energy could also be harvested from crops grown for the sole purpose of providing biomass fuels, from the waste plant material from other crops, and from the waste material from livestock and people.
25. Answers will vary. Contact your teacher for a sample analysis of generating electricity with biomass.

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26.

Aspects of Ecological Sustainability	Ethanol	Biodiesel
based on a renewable energy resource	✓	✓
maintains the quantity of surface water	unsure	unsure
maintains the quality of surface water	unsure	unsure
does not contribute to acid deposition	✓	✓
does not contribute to the presence of persistent organic pollutants in water, soil, or air	unsure	unsure
does not contribute to the presence of heavy metals in water, soil, or air	✓	✓
recycles liquid and/or solid waste products	unsure	unsure
does not contribute to deforestation or habitat destruction	unsure	unsure
does not contribute to greenhouse gas emissions	✗	✗
does not contribute to emissions of ozone-depleting materials	✓	✓
does not contribute to emissions of particulate matter	✗	✗
does not contribute to photochemical smog	✗	✗
does not threaten the survival of species at risk	unsure	unsure
does not contribute to the destruction of fragile ecosystems	unsure	unsure
does not contribute to the release of ionizing radiation	✓	✓
does not contribute to the mass of radioactive waste produced	✓	✓

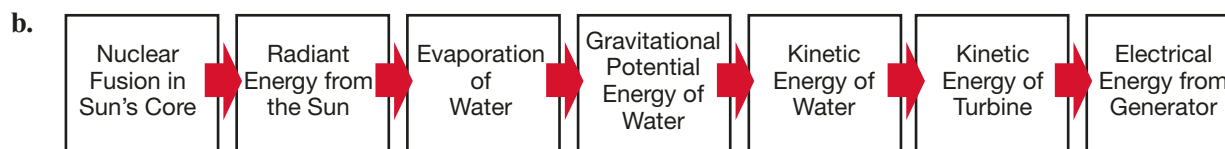
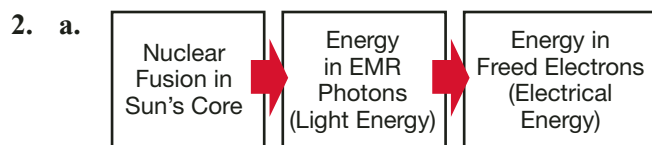
The table indicates that biofuels can be a sustainable energy source only if the crops used to provide the initial material to make the biofuels are produced using sustainable practices. Converting natural areas into farmland and using pesticides, herbicides, and fertilizers are all unsustainable practices.

27. $\text{H}_2\text{S}(\text{g})$ is toxic, and care must be taken to prevent inhalation when handling the biogas. $\text{H}_2\text{S}(\text{g})$ can also dissolve in water to form hydrosulfuric acid, which may react with metal or other materials in the biogas collection and delivery system. When biogas is combusted, $\text{H}_2\text{S}(\text{g})$ will react to form $\text{SO}_2(\text{g})$, which can further react with water in the atmosphere to produce acid deposition.

2.2 Questions, page 555

Knowledge

1.
 - a. Passive solar energy is the thermal energy derived from the Sun’s radiant energy, absorbed by structural materials, and transferred without the use of mechanical devices to other areas by conduction, convection, and radiation.
 - b. An earth energy system is a heating system that uses fluid circulating through piping within the ground, which acts as a solar collector. When used for heating, the system uses the ground to absorb radiant solar energy and then converts that energy into thermal energy, which is carried by the fluid to a building.
 - c. Biomass is a renewable energy source derived from living and recently living biological material.
 - d. The hydrogen economy is an alternative energy system to the carbon economy. In the hydrogen economy, a high priority is placed on the use of renewable-energy technologies. Electricity is generated using renewable resources—solar, hydro, and wind—and energy needed for transportation is provided by hydrogen that is produced in a sustainable manner.



3. Answers will vary. Two possible answers are given.
 - Laundry can be dried outdoors instead of using a clothes dryer.
 - The curtains can be opened on a south-facing window on a sunny winter day.
4. The limitations of solar-energy technologies include the following:
 - Solar-energy technology is still more expensive than conventional fossil fuel sources.
 - The Sun only shines during part of the day.
 - Cost-effective and efficient batteries capable of holding a sufficient charge have yet to be developed.
 - Solar-energy technologies tend to be inefficient at converting solar energy into electrical energy.

The benefits of solar-energy technologies include the following:

- Solar energy is a renewable, inexhaustible source of energy.
- There are no harmful emissions.
- The technology to utilize solar energy is improving.

Applying Concepts

5. Earth energy systems transport heat using a fluid circulating through a closed-loop network of pipes. The human circulatory system transports heat as well as oxygen, carbon dioxide, nutrients, and wastes through a similar closed-loop system of blood vessels. Both the earth energy system and the human circulatory system maximize surface area using long lengths of thin tubing instead of vessels that are thicker and shorter. A larger surface area allows for a more-efficient exchange of energy (heat) in the case of the earth energy system and a more-efficient exchange of energy (heat) and matter (oxygen, carbon dioxide, and other substances in blood) in the case of the human circulatory system.

6. The following summarizes some of the strategies that a family can use to move closer to sustainable development:
 - Become less dependent upon fossil fuels, like coal, by using less electricity by
 - using compact fluorescent light bulbs
 - replacing worn-out appliances with energy-efficient models
 - avoiding appliances that use standby power
 - turning off the lights when you leave the room

 - Become less dependent upon fossil fuels, like petroleum, by
 - using re-useable shopping bags instead of plastic bags
 - travelling by foot, bicycle, or public transit instead of by automobile
 - replacing your vehicle with a model that uses less petroleum

 - Become less dependent upon fossil fuels, like natural gas, by
 - ensuring that your home is well insulated and the windows have tight seals
 - turning down the thermostat a few degrees in the winter
 - replacing a worn-out furnace with a high-efficiency model

 - Produce less solid waste by
 - avoiding products that come with excessive packaging
 - composting garden trimmings and kitchen scraps
 - participating in paper, metal, and plastic recycling programs

 - Waste less water by
 - avoiding excessive watering of the lawn and garden
 - replacing or repairing leaky faucets

7. Responses are dependent upon the completed “Determining Sustainability of Technologies” checklist for each energy source. Sample answers are given that reflect one possible set of outcomes.
- a. The following table describes the outcome of my evaluation for each of these sources of energy.

Sustainability Categories and Weightings	Source of Energy					
	Coal	Nuclear Fission	Photo-voltaic	Hydro-electric	Wind	Biomass
Ecological Sustainability Weighting = 50	17.2	35.9	43.8	39.1	48.4	35.9
Societal Sustainability Weighting = 25	10.9	17.2	15.6	17.2	14.1	7.8
Economic Sustainability Weighting = 25	16.7	16.7	8.3	18.1	9.7	13.9
Overall Sustainability Weighting = 100	44.8	69.8	67.7	74.4	72.2	56.6

- b. As described in the table, the source with the overall highest score for sustainability was hydroelectric power. Close behind were nuclear fission, photovoltaic cells, and wind energy. Both nuclear fission and hydroelectric power had a very similar pattern, scoring reasonably well in all three categories with hydroelectric power scoring slightly higher in terms of ecological sustainability. Photovoltaic cells and wind energy did not have the same degree of balance. These sources scored higher in the ecological category but much lower in the economic sustainability category due to the inefficiency of converting the energy and the intermittent nature of the energy from the source.

Electricity from biomass fuels was scored next to last in terms of overall sustainability. Although this source scored better than both photovoltaic cells and wind energy in terms of economic sustainability, its score for societal sustainability was the lowest of all and its ecological score was also low. The main cause for concern was the potential for emissions to be released into the environment. These emissions could have negative effects on human health.

The source of energy with the lowest ranking is coal, due primarily to its very low score in the ecological sustainability category. The combustion of coal results in the emission of numerous substances that are harmful to the environment. Despite the fact that coal scored favourably in the economic sustainability category—mostly because it is a relatively inexpensive fuel—the fact that I chose to weight the ecological category higher than the economic category meant that coal was ranked last in terms of overall sustainability.