CHAPTER 20 SUSTAINABLE ENERGY

Chapter Overview

This chapter explains renewable energy sources. Solar, hydroelectric, wind, ocean, biomass, geothermal, and fuel cells are described in detail. How these energy sources function and their availability is essential information for the AP exam. Advantages and disadvantages of harnessing, producing, and storing each energy source are important to understand. Costs and benefits of each are also important to know.

Topics and Key Concepts

Energy Resources and Consumption

- Discuss how active and passive solar power may be used to generate electricity in individual and commercial settings.
- Summarize various methods by which a consumer can reduce energy use in a home.
- Outline the benefits of cogeneration.
- Describe the use of fuel cells.
- Explain how electricity can be derived from the various types of biomass.
- Appraise the environmental benefits and drawbacks to using wind and hydroelectric energy generation.
- Discuss how electricity can be harnessed using geothermal energy.
- Analyze the key geographic features necessary to harness tidal energy.

Key Terms

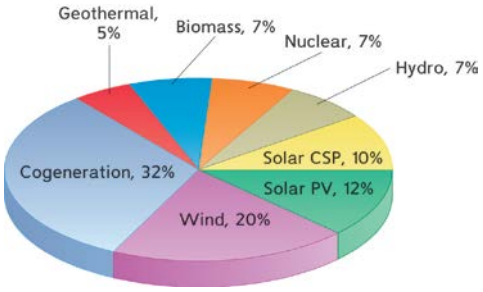
active solar system
biofuels
biomass
cellulosic ethanol
cogeneration
concentrating solar power (CSP)
system
fuel cells
geothermal energy
green pricing
light-emitting diodes (LEDs)
methane
negawatts
ocean thermal electric conversion (OTEC)
ocean wave energy
passive heat absorption
passive houses
photovoltaic (PV) cells
power tower
smart meter
tidal station
wind turbines

Pacing Guide

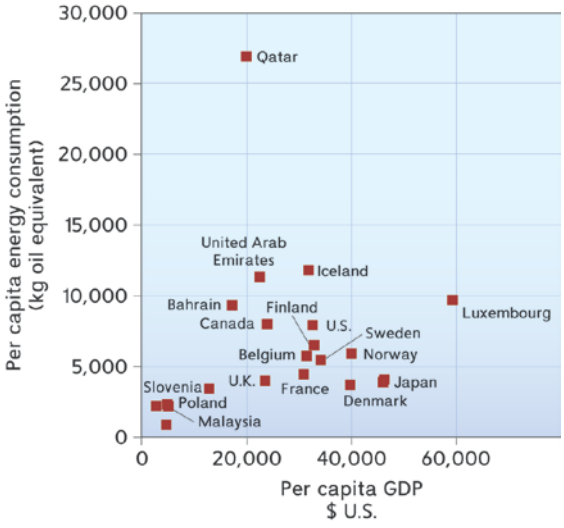
Spend 5-7 days on this chapter. Make sure that the students understand that there are both costs and benefits to any energy source. Also, be sure that the students are adept at energy calculations, using scientific notation without a calculator. Students must be able to carry out dimensional analysis using energy units and data. One important aspect of these calculations is being able to correctly use scientific notation, as some of the values for energy production and use are extremely large.

Approach and Tips

Transition from the discussion of fossil fuels to alternative energy sources using Figure 20.38. This is a renewable energy scenario for 2050. Discuss whether or not this is realistic. If this is the future, discuss the economic implications of this scenario. Have students compare the percentages of today's energy sources to this idealized model.



When you look at our level of energy consumption and compare it to that of other countries and their standards of living, you see that we could be more efficient in our energy use. Examine the graph in the figure below and discuss what information is being conveyed.



As in the previous chapter, students should be able to explain the mechanics of using an alternative energy supply in a step-by-step manner. Previous AP exams have used nuclear power plants, passive solar energy designs, and cogeneration as topics for questions.

Conservation and efficiency are two key concepts that all students need to understand. Challenge the students to think of methods that can save energy or reduce energy consumption. Energy star appliances can be used as examples of how household appliances can be more efficient. Stress that turning off household electronics can save up to 25% of their monthly energy bill. The efficiency of appliances, as well as that of engines and generators, needs to be discussed. Have students calculate the energy efficiency of common household items. Assign students a specific appliance and have them research the cost over the lifetime of the appliance.

None of the alternative energy sources is expected to replace fossil fuels totally. The ideal approach is to use different sources in combination, as well as to reduce energy consumption by increasing efficiency. Discuss how these goals could make a difference in our energy consumption levels.

Biomass is easily accessible and renewable. Current, 30% of the world's population relies on wood as an energy source. Include a description of how biofuels are processed. Stress the benefits as well as the costs of this type of technology. Students should also examine the economic and societal impact of converting a food crop (such as corn) to ethanol.

Hydroelectric power, geothermal, wind and ocean technologies are all renewable energy resources. Hydroelectric power generates about 20% of electricity worldwide, but it is not without environmental disadvantages. Discuss the fact that wind power is not a new invention; in fact, it has been used for hundreds of years to pump water and grind grain. Modern wind turbines can generate electricity 90% of the year at 35% efficiency. Geothermal energy uses the heat from Earth to generate electricity. Discuss the implications of geothermal on a large scale, such as what is happening in Iceland with small scale geothermal (heat pump) used in residential areas. Describe the different ocean technologies; tidal, wave and ocean thermal electric conversion technologies.

All students should know the fundamental differences between passive and active solar energy systems. Passive solar systems have no moving parts; they gather and hold heat within their structural mass and release the collected heat slowly at night. Many passive solar benefits can be used to cool a house, such as awnings, deciduous trees, or window shades. Students must learn that energy conservation- plugging leaks, programmable thermostats, lowering thermostats,

ceiling fans, low energy windows, superinsulation- are not uses of passive solar technology. They are conservation methods. Active solar systems have fans and/or pumps to circulate fluid or air through the collection system. Emphasize that both of these systems are suitable for residential living.

High temperature solar arrays (parabolic mirrors) can be used to collect and concentrate solar energy for production of commercial electricity. Turbines containing heating absorbing fluids are used to generate electricity. Photovoltaic cells convert sunlight directly into electrical energy and are coming into mainstream use when electric power is needed off-grid. Stress the fact that storing electrical energy in batteries has drawbacks in the amount of energy stored per mass or volume of the battery. Further, most batteries used for this purpose are lead/acid batteries which have a short lifespan and have hazardous components.

An alternative to storing and transporting electrical energy is the fuel cell, which uses chemical reactions to produce electricity. A fuel cell runs on oxygen and hydrogen and produces water, carbon dioxide and radiant heat. Even though it produces carbon dioxide, it is much less than conventional fossil fuel combustion. Discuss the use of the fuel cell in the automobile industry.

Utility companies often promote the use of alternative energy devices or cogeneration and conservation because it is often less expensive for the utility. Students can investigate the policies of the local power company and, if time permits, ask if a representative can address the class.

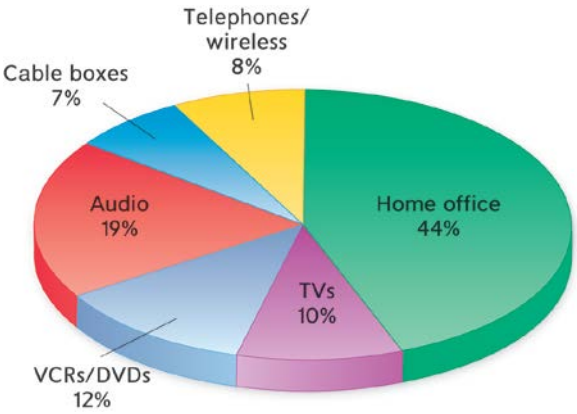
Common Mistakes and Misconceptions

Often, students are not familiar with units used in energy calculations. Familiarize students with units such as kWh and BTU. Students are often confused by kWh and BTU, since these units are multiplied. For example, a BTU's unit lb x °F. Students are not accustomed to units which may be removed independently during dimensional analysis problems. Practice calculations. In addition, students don't realize that there are environmental consequences/disadvantages for renewable energy sources. Whether it is mining a mineral for a component such as sand for a PV cell or flooding behind a dam, there are environmental costs as well as economic disadvantages. Students must also be able to explain what aspect of environmental damage is ameliorated by switching to alternative energy resources.

Activities

Energy Efficiency Critical Thinking Activity

Discuss the implications of the statement "For an average home, standby appliances can represent up to 25 percent of the monthly electric bill" and the representation in Figure 20.4. You may want to include calculations as a part of this discussion. Using an electric bill the students can calculate how much energy and money is used for each of these standby appliances. It is a good idea to get students comfortable with the units used on electric bills, for instance kilowatt hours. Students often do not understand the meaning of these units.



Additional questions for discussion are found on a worksheet at the end of this teacher's manual chapter.

Renewable Energy Resources Activity

In this lesson you will investigate various energy sources and in the end, vote on a new type of energy to be adopted by your peers. The worksheet for this activity is located at the end of this teacher's manual chapter.

Questions for Review

1. What is waste heat? How can it be reduced?
   During electrical generation heat is produced that is usually dissipated. By using the process of cogeneration, the heat can be used for buildings.

2. What are the differences between passive solar and active solar housing? Can solar housing be utilized in northern climates? What adaptations would have to be made in order for the technology to function adequately?

Passive solar homes take advantage of the sun by having windows facing south. It uses overhangs so that it allows sunlight into the home in the winter and reduces the amount of sun into the home in summer. The construction consists of heat absorbing material, such as stone. Active solar housing uses collectors on roof tops and a pump. The problem in northern climates is that there is very little daylight during the winter months. There would have to be an adequate long term storage system.

3. What steps would be involved in selling excess energy back to the utility when using solar energy to generate household electricity?
   It is called reverse metering which is when your meter works in both directions. When you are not using all of the energy that you are producing your meter goes in the reverse direction. When you need more power than you are producing the meter goes in the forward direction.

4. What are the problems of using biofuel as an energy source?
   If corn, soybean, or rape seed is used to produce a biofuel then you have a conflict of food or energy. Other issues involve habitat alteration for agricultural production and all of the issues that surround agricultural production.

5. What are two environmental consequences of hydroelectric power?
   Two environmental consequences are interruption of fish migration and habitat alteration as a result of the change in flow pattern up- and downstream of the dam.

6. What are the issues with using wind as an energy source?
   Wind is intermittent and does not blow steadily in all areas. There is also some controversy over whether or not the wind turbines interfere with bird migration and bats.

7. Does geothermal energy have any limitations? Explain.
   Geothermal energy can only be harnessed in limited areas (e.g. Iceland) with an abundance of geothermal vents and springs. It is not readily accessible.

Practice Questions

Multiple Choice:

Directions for questions 1-5: The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) Fuel cell
(B) Solar energy
(C) Hydroelectric power
(D) Biofuel
(E) Geothermal

1. Uses the heat of Earth

2. Facility can interfere with fish migration

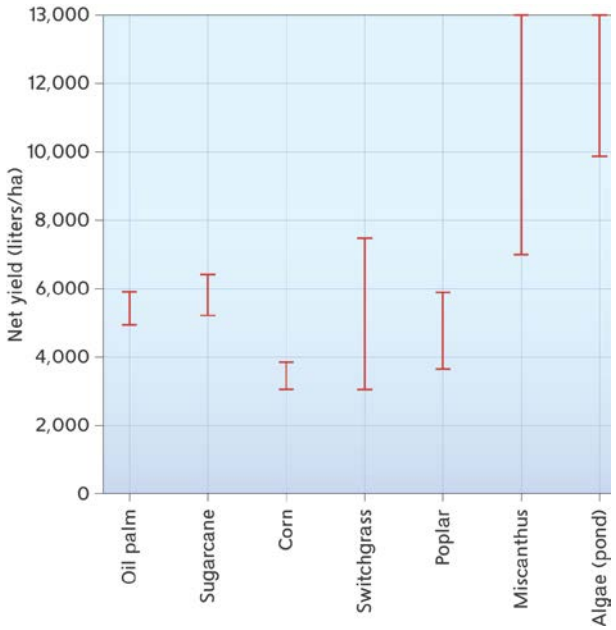
3. Hydrogen and oxygen are the starting materials

4. Can be made from soybeans

5. Iceland's main source of energy

6. Thirty percent of people worldwide use this as a primary energy source.
   (A) wood
   (B) oil
   (C) coal
   (D) solar
   (E) wind

Questions 7-10 use the following graph.



7. Which substance has the lowest yield per hectare?
   (A) switchgrass
   (B) oil palm
   (C) sugar cane
   (D) algae
   (E) corn

8. What is the average yield (liters/ha) for Miscanthus?
   (A) 8
   (B) 9
   (C) 10
   (D) 11
   (E) 12

9. Which two species have approximately the same net yield?
   (A) poplar and corn
   (B) corn and algae
   (C) oil palm and sugarcane
   (D) sugarcane and poplar
   (E) switchgrass and poplar

10. Identify the organism that would cause a controversy of food or energy?
    (A) poplar
    (B) switchgrass
    (C) algae
    (D) corn
    (E) miscanthus

Free-Response Question:

Directions: Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples. When a calculation is required, be sure to show how you arrived at your answer.

1. Wind energy is the fastest growing power source in the United States. A modern wind turbine can produce 5 Mw of power. This is enough to power 2500 homes.

    (a) (i) The community of Knightland consists of 10,000 households. How many wind turbines would be needed to provide energy for this town?
    (ii) If it costs $3 million for each wind turbine, what would be the cost to the community for the turbines?

    (b) Identify and describe TWO economic and/or environmental costs and benefits of building the wind turbines.

    (c) What are TWO limitations of wind power?

    (d) Identify ONE possible problem with the location of the wind farm.

Answers to Practice Questions

Multiple Choice:

1. E
2. C
3. A
4. D
5. E
6. A
7. E
8. C
9. C
10. D

Free-Response Question:

This question is based on 1o points.

1. (a) 2 points total.
   (i) 1 point for the set-up and 1 point for the correct answer.

   10,000 homes x 1 (5Mw) turbine/2500 homes = 4 wind turbines (5 Mw each)

   (ii) 1 point for correct answer of $12 million.

   (b) 4 points total. 1 point for each cost/benefit and 1 point for each description. Costs can include, but not limited to, habitat alteration, expensive to build, loss of biodiversity. Benefits can include, but not limited to, jobs for the community, renewable resource, no greenhouse gas emissions.

   (c) 2 points total. 1 point for each limitation. Limitations can include winds not always blowing, ideally only 60% efficient.

   (d) 1 point for indicating that the area where the wind farm is located may be the home of an endangered species. Also, some people find wind farms aesthetically unpleasing.

Answers to questions in the Student Edition:

Case Study AP Document-Based Question (page 451)

(A) The current scientific consensus is that carbon dioxide emissions will cause a global temperature increase of over 2°C. This increase in temperature will lead to changing weather patterns and increases in extreme weather events. This increase in temperature will also lead to changes in species distributions, and possibly extinctions of certain vulnerable species.

(B) Solar, wind, nuclear, and biomass energy sources are all presented in this case study. Biomass, in the form of timber and biogas, is the most versatile and most consumed energy source in Germany. Nuclear power is seen as the best clean energy source by some in the U.S., but it requires uranium and creates radioactive waste. Due to these dangers and a lack of resources, Germany does not use nuclear energy. Solar and wind energy prices are coming down, and Germany has been an early adopter and leader in this development.

(C) Economic benefits include profits or reduced costs for homeowners who invest in feed-in tariffs or cooperatives, reduced reliance on energy imports, decreased costs over time as technology improves, and increased local jobs in renewable energy. Environmental benefits include cleaner air, water and land, and social justice awareness and opportunities.

Use the Math (page 455)

Answer will vary with starting year, but you want to determine the annual percent increase. Example: ((54.5-30)/((54.5+30)/2))/(2025-2017)*100 = 7.25% per year

Use the Math (page 462)

Between 2000-2014, the percent increase in solar capacity is 11,767%.
(178.0-1.5)/1.5*100
Between 2000-2004, the rate of increase of solar capacity is 22.7% per year.
((4.0-1.5)/((4.0+1.5)/2))/4*100
Between 2006-2010, the rate of increase of solar capacity is 35.1% per year.
((40.0-7.0)/((40.0+7.0)/2))/4*100

AP Connections Review Answers (pages 476)

Multiple-Choice

1. e. Examples of biomass power include dung, peat, and ethanol.

2. c. Land subsidence and groundwater depletion are some environmental costs associated with the generation of geothermal power.

3. b. A passive solar design is using reflective roofing to decrease cooling costs in the summer. Increased insulation to keep warm air in a home in the winter, installing energy-efficient windows to keep hot air out in the summer to decrease air conditioning costs, and planting a tree line of conifers to block wind from reaching a house in northern climes by decreasing winter heating costs are all energy-efficiency methods. Using photovoltaic cells to generate electricity is an active solar design.

4. c. Dams trap sediment, so less is available downstream. Increased downstream temperature, decreased downstream dissolved oxygen, and interrupted fish migration and water flow are all associated with the use of hydroelectricity.

Data Analysis and Free-Response Questions

1A Between 2003 and 2008, the percent increase in renewable energy usage is 20%.
(7.37-6.14)/6.14*100

1B 225 million homes.
1 kW = 3412.142 BTU/hr.
8.46 quadrillion btu in nuclear in 2007.
$8.46X10^{15}/3412.142 = 2.48x10^{12}$ kW
$2.48x10^{12}/11{,}000 = 2.25x10^{8}$ homes

2A Solar, wind, geothermal, biomass, hydropower, and ocean energy are all renewable energy sources. Solar, wind, hydropower, and ocean energy produce no emissions (benefit). Geothermal and biomass still do (drawback), but are cleaner fuel sources than traditional fossil fuels (benefit). Solar and wind can be unreliable or intermittent energy sources and require lots of land for arrays (drawback). Biomass, ocean energy, hydropower are very reliable energy sources (benefit). Hydroelectric dams can be expensive to build and can also cause controversy over water access, as can geothermal energy (drawback). All reduce our reliance on foreign sources of energy and fossil fuels in general (benefit).

2B Renewable energy is cleaner than conventional energy sources, widely available and replenished naturally. Sustainable energy uses renewable energies and energy efficiency technology to maintain humans' energy needs and keep those needs fulfilled into the future.

Energy Efficiency Critical Thinking Activity

*Student*_____

Questions for Discussion:

1. How does energy efficiency come into play when so much energy is wasted when utilizing “instant on” features in household electronics?

2. The typical incandescent lightbulb is only 5 percent efficient. What can you do to improve the efficiency of your household lighting?

The automotive industry is gradually phasing in hybrid engine and alternative fuel technology.

3. What barriers do you see in implementing these hybrids and alternative fuels on a large scale?

4. What workable solution can you propose to facilitate the change?

Renewable Energy Resources Activity

*Student*_____

Introduction:

Renewable resources can be replenished fairly rapidly (from hours to decades) through natural processes as long as it is not used faster than it is replaced. These resources are called flow resources. These flow resources pass through plants, economies, and other systems. Examples of renewable resources come from forests, grasslands, fresh water, fresh air and fertile soil. These resources help to generate energy efficiency and create new energy sources through solar power, wind, wave, tidal, geothermal, biomass, or hydropower.

Procedure:

1. Use your computers to research information about the assigned energy resource. The energy resources assigned will be solar, wind, wave, tidal, geothermal, biomass, or hydropower.

2. You will be placed in groups of four members to research one of the energy resources.

3. As a group, write a one-page summary of the energy source and prepare a presentation for the class. Presentations can be in PowerPoint, video, poster, speech/campaign, etc.

4. The following ideas should be included in your summaries/presentations:

    a. How does this technology work?
    b. How could this energy source be used?
    c. What are some examples of its current use?
    d. What are apparent environmental impacts associated with this?
    e. Are there hidden environmental and social costs?
    f. Is this technology widely accepted today? Why or why not?
    g. Do the costs of this technology make it prohibitive for common use? Why or why not?