

## CHAPTER 19 CONVENTIONAL ENERGY

### Chapter Overview

This chapter describes the different types of energy sources that are nonrenewable: coal, oil, natural gas, and nuclear. Both advantages and disadvantages of each fuel source are discussed. Recent historical events should be explained with specific reference to the chapter information.

### Topics and Key Concepts

#### Land and Water Use

- Describe and compare the environmental damage resulting from coal mining and oil extraction.

#### Energy Resources and Consumption

- Differentiate between power, energy and work.
- Discuss the advantages and disadvantages of using various fossil fuels.
- Describe the advantages and disadvantages of using coal to generate electricity.
- Summarize the actual risks associated with producing electricity from nuclear power.
- Critique the likelihood of using nuclear fusion to generate electricity.
- Diagram a light water nuclear reactor and explain the role of each component in the system.

### Key Terms

bitumven

breeder reactors

Carbon capture and  
storage (CCS)

\*carbon sequestration

chain reaction

control rods

energy

fossil fuels

fuel assembly

hydraulic fracturing

joules

kerogen

liquefied natural gas  
(LNG)

\*Mercury and Air Toxics

Standards

methane hydrates

\*moderator

nuclear fission

nuclear fusion

oil shale

\*peak oil

power

tar sands

watt

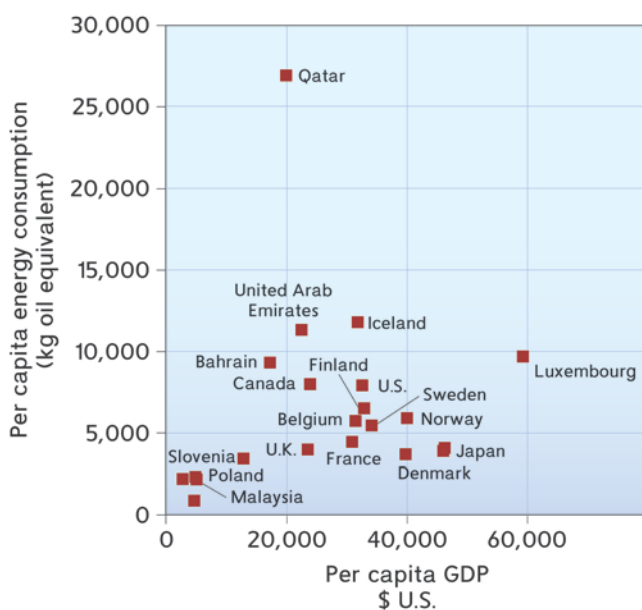
work

## Pacing Guide

Students need to be able to express this knowledge in mathematical terms (scientific notation) without the use of a calculator. Devote one week for this chapter. Make sure students practice energy conversion calculations using dimensional analysis with no calculator. Review again the SI units of giga, mega, kilo, and those units are often used when discussing production of electricity. Students should also know BTU units, as well as the kWh.

## Approach and Tips

Begin the chapter by having the students perform an energy audit for their homes. Discuss the difference between energy consumption in the United States and that of less-developed countries that lack the infrastructure and lifestyle that allows for greater energy need and consumption. Correlate this information to the information presented in the figure below.



Describe the thermal conversion process used in combustion-based or nuclear power plants to generate electricity. Correlate this information with the process of generating electricity using hydroelectric dams. Make the connections that the process is similar. There is a fuel source, or as in the case of dams a mechanical energy source, that eventually leads to spinning a turbine that turns a generator to make electricity. Continue the discussion with an explanation of the transmission and step-down process used to get electricity into homes at a usable level. Practice the energy conversions involved at each step of the process. Include a discussion of the aged US grid system and how energy is lost at each step as electricity is transmitted to a building from a power plant.

Discuss the benefits and drawbacks associated with each of the fossil fuel types, including the different categories of coal, as well as tar sands and oil shales. Students need to know where the major reserves of coal are located (Figure 19.4 in the textbook). They should also know the different types of coal and how coal can be classified by either sulfur content or heat content. Emphasize that the main problems with coal combustion are greenhouse gas emission in the form of carbon dioxide,  $\text{SO}_2$ , and mercury deposition. Using the Deepwater Horizon accident, begin with a discussion of the problems with drilling for oil. Remind the students that oil is nonrenewable meaning that reserves are finite. Stress that carbon emissions are an issue with oil combustion too. Oil shale and tar sands in Canada and the western United States could be extracted, but the wastes, water requirements, and environmental degradation may make this very costly. These resources are more utilized today than in the past.

Using nuclear reactors to generate electricity also has benefits and drawbacks. Students should be able to explain the steps in obtaining fuel and refining it to a usable form, in addition to the problems of waste storage and disposal. The nuclear accident at Fukushima Daiichi Nuclear Power Plant in Japan can be used to explain some of the issues with nuclear power. It is essential to know the basic method used to produce electricity in a light water reactor. Fission of nuclear material is accomplished in a reactor. Students need to know how the reaction is controlled and moderated. The students should know historical events concerning nuclear power, since these events have influenced the nuclear energy industry. The three main events that all students need to know are Three Mile Island, PA, Chernobyl, Ukraine, and Fukushima, Japan.

Stress that we have no storage area in the United States for nuclear wastes at this point in time. All nuclear waste from electricity generation is stored on site, either in pools or in lead lined casks. Explain that Yucca Mountain was proposed several years ago, but due to some controversial information, funding has been halted. Emphasize that decommissioning nuclear plants is proving to be more expensive than it was to build the plants in the first place. Discuss the lifespan of nuclear power plants.

Describe the process of nuclear fusion and explain that this technology has not been perfected. It has not been able to produce electricity at a break-even point.

For all of the types of fuels discussed, students should be able to identify the different components in the power plant and the transmission process. Depending upon the background of the student, this can take as little as one class or as many as four to cover the material in detail.

Resource extraction causes environmental damage, as well as being harmful to human health. Relate the issues of energy extraction to the multiple use policies in national wildlife areas and forests. Students should be able to discuss the benefits and drawbacks of extracting resources from these areas, as well as know some details about the legislation protecting or allowing access to these areas. Students must also explain the drawbacks of thermal pollution, air pollution, and water contamination as applicable to each energy resource.

## **Common Mistakes and Misconceptions**

The most troubling issue that students encounter on energy questions is that they are unable to answer energy calculations correctly. Students must be able to do calculations involving energy units. They must use dimensional analysis or factor label method and be adept at doing calculations using scientific notation. Practice often and without the use of a calculator. Also, students need to know how a power plant works. There have been free response questions on past AP exams asking students to diagram, label, and/or explain a power plant. Students are also expected to delineate specific environmental consequences of harvesting an energy resources, and subsequent environmental damage due to use of the resource.

## **Activities**

### **Coal Analysis Activity**

In this activity, the students will analyze different types of coal. They will calculate % water and investigate burning time of each sample and draw some conclusions about each type of coal investigated. There is a worksheet at the end of this teacher's manual chapter for this activity.

Coal samples can be ordered from the American Coal Foundation at <http://teachcoal.org/energy-and-you/coal-kits/>. Several activities for teachers can also be accessed from the website. To identify the major steps of electricity generation from coal use the diagram from the website.

### **Cookie Mining**

Purchase three different brands of chocolate chip cookies, each will represent a mine. Students will simulate the mining process by purchasing their mine, tools (toothpicks and paper clips), and reclamation events. Each student will profit for the number of chocolate chips extracted and lose profit for the amount of reclamation required. The student will also be exposed to the economic consequences of mining such as learning about external, internal, and ownership costs. A sample of the activity can be found on the last page of this supplement.

**Supplemental Video**

Show the video “30 Days of Coal” by Morgan Spurlock. The video follows Morgan Spurlock as he takes on the role of a coal miner. The video is an attention grabber with students. Discussion about the advantages and disadvantages are conveyed in the video.

**Operation of a Battery Electric Vehicle**

The website below provides lessons and links on describing how an internal combustion engine operates in comparison to a battery electric vehicle.

**Supplemental Websites**

Diagrams of the engines can be found at Explain that Stuff: Electric Cars:

<http://www.explainthatstuff.com/electriccars.html>

howstuffworks “Electric Car”:

<http://auto.howstuffworks.com/electric-car.htm>

howstuffworks “How Car Engines Work”:

<http://auto.howstuffworks.com/engine1.htm>

## Questions for Review

1. Why is coal a viable fuel source for the United States? How is it mined? What is the controversy with mining?

*One of the largest reserves of coal is found in the United States. There are several methods of mining coal. They are mountain top removal, strip mining, and shaft mining. Habitat destruction is probably the biggest issue surrounding coal mining. Acid mine drainage is another issue.*

2. Why are fossil fuels considered problematic?

*Fossil fuels are nonrenewable and are in finite supply. They also contain sequestered carbon. This means that their use adds to greenhouse gases and contributes to global climate change.*

3. What is involved in the decommissioning of nuclear power plants? Why are these steps necessary?

*It must be taken apart and radioactive pieces must be stored with other radioactive wastes. It takes robots to do the work, since it is too dangerous. It is very expensive. These steps are necessary because plants contain corroded, brittle pipes and radioactivity.*

4. What is the difference between fission and fusion reactions? What are the raw materials required for each type of reaction?

*A fission reaction is the splitting of an atom while a fusion reaction is the joining of two nuclei. Fission reactors usually use uranium-235 as the fissionable material. The fuels for a fusion reaction are deuterium and tritium.*

5. How many barrels of oil were spilled into the Gulf of Mexico as a result of the Deep Water Horizon explosion? How many barrels of oil were spilled in the Exxon Valdez accident? What percent of the Deep Water Horizon spill was the Valdez oil spill? Hint: You will need to do a calculation to answer this question.

*5 million barrels of oil were spilled into the Gulf of Mexico. This is twenty times that of the Exxon Valdez spill. Therefore:*

$$5 \times 10^6 / 2 \times 10^1 = 2.5 \times 10^5 \text{ barrels of oil}$$

$$2.5 \times 10^5 / 5 \times 10^6 \times 100 = 5\%$$

## 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) Nuclear fission
- (B) Coal
- (C) Natural gas
- (D) Oil
- (E) Tar sands

1. The cleanest burning fossil fuel.
2. The trans-Alaskan pipeline carries this.
3. Found in the Appalachian Mountains in West Virginia.
4. The Deepwater Horizon was extracting this.
5. Three Mile Island produces electricity by this method.
6. In a nuclear reactor, it is usually made of either boron or cadmium.
  - (A) Control rod
  - (B) Reactor core
  - (C) Containment building
  - (D) Switch
  - (E) Turbine
7. Which area of the world has the highest percentage of proven natural gas reserves?
  - (A) Africa
  - (B) South America
  - (C) North America
  - (D) Russia
  - (E) Middle East

8. A material that contains kerogen is
- (A) soil
  - (B) coal
  - (C) uranium-235
  - (D) oil shale
  - (E) natural gas
9. All of the following are contained in emissions from burning coal EXCEPT
- (A) oxygen
  - (B) soot
  - (C) carbon dioxide
  - (D) SO<sub>x</sub>
  - (E) mercury
10. Identify the nonrenewable resource.
- (A) Soil
  - (B) Wood
  - (C) Water
  - (D) The sun
  - (E) Uranium-235

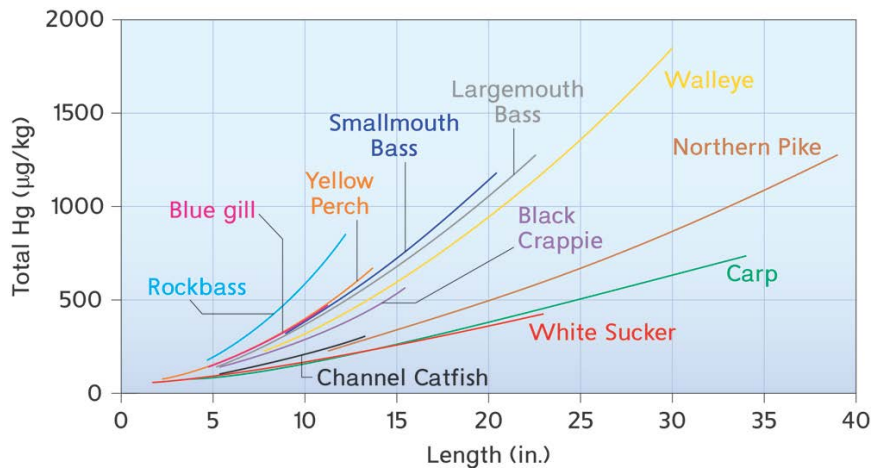
Free-Response Question:

*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. Coal, oil and natural gas are conventional energy resources. They are nonrenewable and create many environmental issues.
- (a) Choose ONE of the three resources and explain TWO environmental consequences of using that resource to generate electricity.
  - (b) For each of the TWO consequences listed in part (a), describe ONE method that could eliminate the consequences.



- (c) The graph below depicts freshwater fish species in the United States and the level of mercury in these fish.



- (i) The walleye and northern pike are large lake dwelling species. Why do you think their levels of mercury are high?
  - (ii) The carp is a large fish but doesn't have the same amount of mercury content as the fish mentioned in part (i). Why do you think this is true?
  - (iii) Which of the three resources is most likely responsible for the mercury contamination in the water?
- (d) Nuclear power currently provides less energy in the United States than renewable energy sources.
- (i) Why has nuclear energy not gained in popularity?
  - (ii) What is NIMBY and how does it apply to the nuclear power industry?

## Answers to Practice Questions

### Multiple Choice:

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

### Free-Response Question:

This question is based on 10 points.

1. (a) 2 points total. One point for each environmental consequence given. Only the first two will be scored.  
Such consequences include, but are not limited to, greenhouse gas emissions, habitat alteration as a result of resource extraction, other emissions that correspond to the appropriate resource.
- (b) 2 points total. 1 point for each method. Methods include, but are not limited to, using alternative fuel sources such as renewable sources, burning less of the resource, conservation.
- (c) (i) 1 point for indicating that these fish are large predatory fish and that biomagnification is causing the increase in Hg.  
(ii) 1 point for indicating that although these fish are as large as the two mentioned in part (i), they probably don't eat the same food source. Therefore, biomagnification is not as prevalent.  
(iii) 1 point for stating that coal produces Hg emissions.
- (d) (i) 1 point for stating that nuclear accidents or lack of storage of waste are both reasons for a decline in the nuclear industry. Also, the student may indicate the popularity of the green movement towards renewable energy resources.  
(ii) 2 points total. 1 point for indicating that NIMBY means not in my back yard and 1 point for explaining that no one wants to live near a nuclear power plant

## Answers to questions in the Student Edition:

### Case Study AP Document-Based Question (p. 427)

- (A) The closing of coal mines benefits the environment because if less coal is mined, then less coal is burned. Burning coal emits carbon dioxide, a greenhouse gas. It can also lead to acid rain, and burning dirty coal can lead to even more pollution. Coal mining ruins wildlife habitat and can scar the landscape, but areas can recover once the mines are closed.
- (B) Some of the advantages of coal is that it is abundant, inexpensive compared to other types of fuel, versatile, reliable, able to be stored, and is easy to transport. The mining of it creates jobs and reduces our dependence on oil. Its availability and use is independent of weather. One disadvantage of coal is that the burning of it produces carbon dioxide and other harmful substances like nitrous oxide, sulfur dioxide, arsenic, and ash. The mining of it is harmful to the environment and can be dangerous to the miners' health and lives. It is a non-renewable source of energy and is quickly depleted.
- (C) Answers will vary and could include some of the following: solar panels need sunlight to produce power, but other forms of renewable energy, like biofuels, are independent of weather. Many renewable energy sources are abundant. The installation and operation of renewable energy sources creates jobs. Most renewable energies are somewhat expensive when compared to coal, oil, and gas, but increased technology is bringing the price of renewable energy down.

### Use the Math (p. 439)

The high estimate for shale gas emissions is that it produces about twice as much carbon per million Joules of energy produced as does coal. The differences in IR absorption of methane compared to CO<sub>2</sub> indicate that the effects from shale gas emissions could be hundreds of times greater than coal gas emissions.

Shale gas  $45 \times 20 + 16 \times 1 = 916$  relative infrared absorbing capacity

Coal  $10 \times 20 + 30 \times 1 = 230$  relative infrared absorbing capacity

## AP Connections Review Answers (pages 447-448)

### Multiple-Choice Questions

1. c. Natural gas is the cleanest burning of the fossil fuels.
2. c. The disease associated with the mining of uranium is lung cancer due to radon exposure.
3. d. Tankers leaking is a problem associated with oil transport.
4. b. The secondary water circuit is heated and spins the turbine to generate electricity.
5. a. coal power plants provide the greatest proportion (33%) of U.S. electricity.

6. e. ozone is not released from auto emissions, rather  $\text{NO}_x$  is released and changes into ozone in the atmosphere.

### **Data Analysis & Free-Response Questions**

1a The most common energy source in American homes is natural gas.

1b

- i. 97.75 million Americans use electricity to heat their homes  $[(0.23 * 150,000,000) + (0.42 * 125,000,000) + (0.43 * 25,000,000)]$ .
- ii. 158 million Americans use natural gas to heat their homes  $[(0.60 * 150,000,000) + (0.48 * 125,000,000) + (0.32 * 25,000,000)]$ .
- iii. In 15 years there would be approximately 178.6 million Americans using natural gas. Single-family homes and multi-family homes would go up by 7.5% each, or 67.5% single-family, and 55.5% multi-family, and 32% mobile homes (unchanged).  $[(0.675 * 150,000,000) + (0.555 * 125,000,000) + (0.32 * 25,000,000)]$

2a Benefits of building the dam include a local source of electricity for homes, flood protection, the creation of water recreational areas, and sanctuaries for wildlife like migratory birds. Costs of building the dam include the expensive infrastructure, relocating families, lost fishing and farming opportunities, barriers created that hurt migratory fish populations, restrictions on water use that could result in higher monetary costs for families, and the environmental effects of decreased water flow and transport of sediment and nutrients to downriver ecosystems. Dams can also potentially trigger earthquakes in areas that are seismically active.

2b Air pollutants that are emitted from a conventional fossil fuel-burning power plant include particulate matter, lead, nitrogen oxides, carbon monoxide, volatile organic compounds, and sulfur dioxide. These air pollutants have a variety of effects from inducing asthma to causing nerve damage and cancer.

## Coal Analysis Activity

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Student \_\_\_\_\_

### Purpose:

To observe and analyze different types of coal for water content and length of burn

### Materials:

Small samples of peat, lignite, bituminous, and anthracite coal. (These can usually be purchased inexpensively through a science supplier or you can call a local power plant and they may be willing to give you small pieces.)

Bunsen burner with gas connections, tongs, crucible, ring stand, and clay triangle

### Procedure:

1. Break off a small piece of each type of coal (sometimes putting the coal into a paper towel and stepping on it works best).
2. Using the tongs, burn each sample in the flame of the Bunsen burner and record the information in Data Table 1.
3. Mass the crucible.
4. Obtain a small piece of coal and mass it and your crucible.
5. Heat the coal on high in the crucible for 4 minutes.
6. Allow the crucible to cool and mass the crucible with the coal.
7. Repeat steps 4-6 with each of the other types of coal. Record the data in Data Table 2.

Data:

Data Table 1

| Type of Coal | Ease of Ignition | Flame Color | Smell | Length of Time Burned |
|--------------|------------------|-------------|-------|-----------------------|
| Peat         |                  |             |       |                       |
| Lignite      |                  |             |       |                       |
| Bituminous   |                  |             |       |                       |
| Anthracite   |                  |             |       |                       |

Data Table 2

| Type of Coal | Mass of Crucible | Mass of Crucible and Coal | Mass of Coal | Mass of Crucible and Dry Coal | Mass of Dry Coal | Percent Water in Coal |
|--------------|------------------|---------------------------|--------------|-------------------------------|------------------|-----------------------|
| Peat         |                  |                           |              |                               |                  |                       |
| Lignite      |                  |                           |              |                               |                  |                       |
| Bituminous   |                  |                           |              |                               |                  |                       |
| Anthracite   |                  |                           |              |                               |                  |                       |

Analysis:

1. Show your calculations for the percent water in each type of coal.

$$\frac{\text{Coal} - \text{Dry Coal}}{\text{Coal}} \times 100 =$$

2. Make a bar graph to compare the percentage of water in each type of coal.
3. Is there any relationship between moisture content and length of burning?
4. Which type of coal would be best for heating? Which for electricity? Which for burning in a fireplace?

## Cookie Mining

### Procedure

1. You have \$1,000,000 available. You desire to invest the money in a mine.
2. Buy a mine:

|                 |           |
|-----------------|-----------|
| a. Store brand  | \$250,000 |
| b. Chips Ahoy   | \$300,000 |
| c. Chips Deluxe | \$400,000 |
3. Place your mine on graph paper and trace its outline. Record the number of squares covered by the mine (partial squares count as whole squares).
4. Buy your mining equipment.

|                    |           |
|--------------------|-----------|
| a. Flat toothpick  | \$100,000 |
| b. Round toothpick | \$275,000 |
| c. Paper clip      | \$350,000 |
5. Record the cost of your mining equipment.
6. Mine the chips out of your cookie- you may NOT touch the cookie with your fingers. The paper and the tool are the only things that can touch the cookie. The maximum mining time is 5 minutes with a cost of \$50,000 per minute.
7. Tally the number of whole chips you obtained (put the smaller pieces together to equal whole chips). Each whole chip is worth \$100,000.
1. Reclaim your mine by using your tools (no fingers) to put all of the property back into the original circle.
2. Draw another circle (in a different color) around the reclaimed mine and count the squares covered. You are charged \$50,000 for each square over the addition of squares.
3. Clean up.

Name \_\_\_\_\_ Date \_\_\_\_\_ Period \_\_\_\_\_

## Cookie Mining Worksheet

Mining Start up Funds = \$1,000,000

A. Land acquisitions costs = price of cookie

Name of cookie \_\_\_\_\_ \$ \_\_\_\_\_

Size of mine = size of cookie

Squares covered pre-mining (used for reclamation) \_\_\_\_\_

B. Equipment costs

Flat toothpick \_\_\_\_\_ X \$100,000

Round toothpick \_\_\_\_\_ X \$275,000

Paper clip \_\_\_\_\_ X \$350,000

Total equipment costs \$ \_\_\_\_\_

C. Mining/Excavation costs = chip removal

Number of minutes \_\_\_\_\_ X \$50,000

Total excavation costs \$ \_\_\_\_\_

D. Mining Valuation

Number of chips mined \_\_\_\_\_ X \$100,000

Gross profit \$ \_\_\_\_\_

E. Reclamation

Squares covered outside original outline X \$50,000

Total reclamation costs \$ \_\_\_\_\_

F. Profit/Loss

Start up Funds \_\_\_\_\_

Less total mining costs (A, B, & C) \_\_\_\_\_

Less total reclamation costs (E) \_\_\_\_\_

Plus gross profit (D) \_\_\_\_\_

Total profit / Loss \_\_\_\_\_



Name\_\_\_\_\_Date\_\_\_\_\_Period\_\_\_\_\_

Conclusion Questions

1. What type of cost did the \$50,000 per minute represent? Explain.
  
2. Which mine contained more resources (minerals)? Which mine should have contained more minerals?
  
3. Which part of the procedure simulated reclamation? Explain.
  
4. What functioned as the overburden?
  
5. What functioned as the tailings? How would these be removed in the actual mining industry?
  
6. Why were you charged if the reclaimed mine took up more space than the original mine?
  
7. What were the ownership costs for this activity? What types of costs were left out?
  
8. Which cookie was the easiest to mine? Why?
  
9. Which tool (or combination of tools) was/were most efficient? Explain. (confer with other group members)

Name\_\_\_\_\_Date\_\_\_\_\_Period\_\_\_\_\_

| Ahoy                  | Deluxe           | Store               |  |
|-----------------------|------------------|---------------------|--|
| 21 Jay Flat Clip 25   | 22 Jared 2 Round | Jerad 2 Round       |  |
| 19 Lucas Flat Clip    |                  | 26 Emily Clip Round |  |
| 14 Miriam Flat Clip   |                  |                     |  |
| 25 Krystal Round Clip |                  |                     |  |
| 19 Alysa Round Clip   |                  |                     |  |
| 20 Marshal Clip       |                  |                     |  |
| 24 Quinn Round        |                  |                     |  |
| 16 Sarah Flat Clip    |                  |                     |  |
| 14 Tyler Flat Clip    |                  |                     |  |
| 14 Levi 2 Round       |                  |                     |  |
| 24 Zac 2 Round        |                  |                     |  |
| 10 Bianca Flat Clip   |                  |                     |  |
| 22 Dane 2 Round       |                  |                     |  |
| 13 Cutter Flat Clip   |                  |                     |  |
| 14 Rebecca Clip       |                  |                     |  |

| Deluxe                | Ahoy                   | Store                |
|-----------------------|------------------------|----------------------|
| 34 Kendall Clip Round | 14 Alex Flat Round     | 10 Carolyn Flat Clip |
| 26 Hal Round          | 14 Taylor Clip Round   |                      |
| 20 Timmy Flat Clip    | 15 Jennifer Clip Round |                      |
| 26 EZ Flat Clip       | 8 Dylan Clip           |                      |
| 25 Calvin Round Clip  | 11 Austin Round        |                      |
|                       | 18 Christian Round     |                      |
|                       | 17 Joey Flat Round     |                      |
|                       | 20 Marissa Flat Clip   |                      |
|                       | 22 Elissa Flat Clip    |                      |
|                       | 17 Lindsey Flat Clip   |                      |
|                       |                        |                      |
|                       |                        |                      |
|                       |                        |                      |
|                       |                        |                      |
|                       |                        |                      |
|                       |                        |                      |