Energy Conversions

Grade Level: AP Environmental Science

Problem Defined: Through critical thinking, students will answer the following questions. How can unit conversion through dimensional analysis inform us about the amount of energy being used? How does this relate to energy usage at home? Does energy saving outweigh environmental impacts?

Objectives: Students will be able to
- Perform unit conversion calculations through dimensional analysis.
- Recognize the difference in price and energy usage of different types of home light bulbs.
- Describe a method to reduce their ecological footprint by using energy efficient products at home.

Materials and Estimated Costs For Lesson:

<table>
<thead>
<tr>
<th>Materials and Technology Specifically Used By Students</th>
<th>Estimated Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incandescent Light Bulb (pack of 4)</td>
<td>$5.99</td>
</tr>
<tr>
<td>CFL Light Bulb (pack of 4)</td>
<td>$9.95</td>
</tr>
<tr>
<td>LED Light Bulb (pack of 4)</td>
<td>$16.95</td>
</tr>
<tr>
<td>Laptop</td>
<td>$195.00</td>
</tr>
<tr>
<td>Radio</td>
<td>$38.16</td>
</tr>
<tr>
<td>Watts meter (5 meters)</td>
<td>$94.55</td>
</tr>
</tbody>
</table>

Standards: AP Environmental Topics (College Board):

V. Energy Resources and Consumption (10–15%)
A. Energy Concepts
   - (Energy forms; power; units; conversions; Laws of Thermodynamics)
B. Energy Consumption
   1. History
      - (Industrial Revolution; exponential growth; energy crisis)
   2. Present global energy use
   3. Future energy needs
C. Fossil Fuel Resources and Use
   - (Formation of coal, oil, and natural gas; extraction/purification methods; world reserves and global demand; synfuels; environmental advantages/disadvantages of sources)
D. Nuclear Energy
   - (Nuclear fission process; nuclear fuel; electricity production; nuclear reactor types; environmental advantages/disadvantages; safety issues; radiation and human health; radioactive wastes; nuclear fusion)
E. Hydroelectric Power
Day 1: Energy Basic Mathematical Equations
- Teacher will explain the two fundamental laws of thermodynamics and basic energy mathematical equations.
- Students will collaborate in groups of three to complete The Energy Basic Notes and Review. (Review attached: A1 & A2)
- Teacher will use checklist to assess student mastery of subject matter while groups show their process to complete energy equations through oral communication in front of the class. (Checklist attached: A3)

Day 2: Energy Consumption Lab
- Students will collaborate in groups of four and use energy equation to complete the Energy Consumption Lab. In which they will be able to analyze and interpret the cost and energy usage data in three different types of light bulbs, a computer, and radio. (Lab attached: A4 & A5)
- Students will be assessed through a written lab write up.

Day 3: AP Free Response Energy Calculation Assessment
- Students will complete summative assessment 2004 AP Free Response Energy Calculation Quiz. (Quiz attached: A6)
**Energy Basics:**

**Energy:** The basic unit of energy is a Joule (J). Other units are calorie, kilojoule, British Thermal Unit (BTU), and therm.

1000 J = 1 kJ

1st Law of Thermodynamics:

1000 cal = 1 kcal

1 cal = 4.184 J

2nd Law of Thermodynamics:

1 BTU = 1.05 kJ

1 therm = 100,000 BTU

Power: Power is the rate at which energy is used. (P = \( \frac{E}{t} \)) Unit: Watt

1 W = 1 J/s (1 Watt = 1 Joule per second)

Practice:

1. How much energy, in kJ, does a 75 Watt light bulb use then it is turned on for 25 minutes?

2. The Kilowatt Hour, or kWh, is not a unit of power but of energy. Notice that kilowatt is a unit of power and hour is a unit of time. \( E = P \times t \) (rearranged from above). A kilowatt hour is equal to 1 kW delivered continuously for 1 hour (3600 sec).

Assume your electric bill showed you used 1355 kWh over a 30-day period.

a.) Find the energy used, in kJ, for the 30 day period.

b.) Find the energy used in J/day.

c) At the rate of $.0749/kwh, what will your electric bill be for this month?

3. A 100 Watt light bulb is 20% efficient.

a.) How much energy does it use in 12 hours of operation?

b.) How much energy does the bulb convert to light during 12 hours?

c.) Convert total energy use to kWh
4. An electric clothes dryer has a power rating of 4000 W. Assume a family does 5 loads of laundry each week for 4 weeks. Assume each dryer load takes 1 hour.
   a.) Find the energy used in J and kWh.
   b.) Find the operating cost for 4 weeks. Assume cost is $.0758/kWh

5. Refrigeration is costly in terms of energy usage. A single-door, manual defrost refrigerator uses 600 kilowatt hours/year (abbreviated kWh/yr). A large, 20 cu ft two-door automatic defrost refrigerator uses 1880 kWh/yr. How many kcal/yr do each type of refrigerator use? 1 kWh = 860 kcal.

6. Assume you use an air conditioner for a total of 137 days, 24 hours per day, at a rate of 7.25 kWh per hour. Assume the cost per kWh is $.0825 and 1 kWh = 3400 BTUs.
   a.) Calculate the total number of kWh used per year.
   b.) Determine the cost of air conditioning for one year.
   c.) How many kcal are used per year?
   d.) How many BTUs are used in one year?

7. Suppose your electric lights use 400 watts per hour and average four hours per day, every day for one year.
   a.) How many kWh per year does this represent?
   b.) If replacing the lights with a fluorescent bulb would save 60 w per night, what savings in kWh does this represent in one year? In your opinion do overall savings outweigh any and all environmental impacts?
   c.) If the fluorescent bulb costs $18 but lasts for 10 years, would you consider it a wise investment over incandescent bulbs? Explain your answer.

A3: Student Assessment Checklist
Objective to be met by students during presentation:

3 minute presentation:

Explanation of problem to be solved:

Correct use of energy conversion:

Specific units used:

Math is correct:
After learning about your individual ecological footprint you have decided to do something to reduce it. One thing you have decided to do is to reduce your energy consumption. You have decided to change all your lights bulbs in your house to the most efficient type. Before you can do this you must first decide what light bulb consumes the least amount of energy.

In order to determine which light bulb is better you will need to fill in the table below using the wattmeter, unit conversion through dimensional analysis, and other information at each station.

**Prelab Hypothesis:**

**Procedure:**

a) Pay attention to the heat from each bulb after plugging in (do not touch the incandescent bulb and don’t look directly at the light!) Which bulb felt the hottest? The coolest?

b) Let the bulb run for 1-2 minutes before recording # of watts/hr.

c) You will need to calculate cost/month and total cost after visiting all 4 stations.

<table>
<thead>
<tr>
<th></th>
<th>Incandescent</th>
<th>CFL</th>
<th>LED</th>
</tr>
</thead>
<tbody>
<tr>
<td># of lumens</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost of Bulb</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of watts/hr (from meter)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lifetime of bulb (hours)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$/kwh</td>
<td>$0.08</td>
<td>$0.08</td>
<td>$0.08</td>
</tr>
<tr>
<td>Time used a day</td>
<td>8 hours</td>
<td>8 hours</td>
<td>8 hours</td>
</tr>
<tr>
<td>Cost per month (electricity)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>wattage x hours used ÷ 1000 x price per kWh = cost of electricity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td># of bulbs for 20,000 hours of light</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total cost for 20,000 hours (bulb cost for 20,000 hours + energy cost)</td>
<td></td>
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</tr>
</tbody>
</table>

1. Which of the bulbs is the best one to use your home? Why?
2. Due to the average home in the U.S. having approximately 45 light bulbs, how much money would be saved per 20,000 hours if they used LED instead of incandescent?

A5: Energy Consumption Lab

3. How much would be saved if everyone in the U.S. did the same (~ 125 million homes)?

4. Due to the increased number of bulbs required for lighting, what are other costs that should be considered (both monetary and environmental) for the production of each bulb type?

**Station 4: Computer**

Your mom gets mad at you because she keeps telling you to shut down your laptop when you are finished using it and you are irritated because you know it is basically the same if you just close the lid. Use the laptop and watts meter at station 4 to determine if it is the same thing.

a) Plug the computer and turn on the power. Wait about 20-30 seconds and estimate the number of watts it’s using (the # of watts will jump around so get a rough estimate). Record this number below. This is the number of watts/hour.

b) Now, close the lid and wait 30 seconds. Record the estimated number of watts being used.

c) Finally, power off the computer and record the number of watts being used.

d) Solve for cost to run for 24 hours for one month and record below.

<table>
<thead>
<tr>
<th></th>
<th># of watts (per hour)</th>
<th>$/kwh</th>
<th>Cost to Run 24 hours for a month</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer on</td>
<td></td>
<td>$0.08</td>
<td></td>
</tr>
<tr>
<td>Computer closed</td>
<td></td>
<td>$0.08</td>
<td></td>
</tr>
<tr>
<td>Computer shut down</td>
<td></td>
<td>$0.08</td>
<td></td>
</tr>
</tbody>
</table>

**Station 5: Radio**
You are constantly being threatened to have to help pay the electric bill if you keep leaving your radio on all day. If your parents charge you the cost of your radio electricity that is being used pretty much 24 hours a day, 365 day a year how much would you owe them? Use the watts meter and radio at station 5 to determine the number of watts and then convert to kWh. Determine kWhs used in a year and assume the cost is $0.08/kWh.

AP Free Response Energy Calculation Quiz

West Fremont is a community consisting of 3,000 homes. A small coal-burning power plant currently supplies electricity for the town. The capacity of the power plant is 12 megawatts (MW) and the average household consumes 8,000 kWh of electrical energy each year. The price paid to the electric utility by West Fremont residents for this energy is $0.10 per kWh. The town leaders are considering a plan, the West Fremont Wind Project (WFWP), to generate their own electricity using 10 wind turbines that would be located on the wooded ridges surrounding the town. Each wind turbine would have a capacity of 1.2 MW and each would cost the town $3 million to purchase, finance, and operate for 25 years.

a. Assuming that the existing power plant can operate at full capacity for 8,000hrs/yr, how many kWh of electricity can be produced by the plant in a year?

b. At the current rate of electrical energy use per household, how many kWh of electrical energy does the community consume in one year?

c. Compare your answers in a and b and explain why you would or would not expect the numbers to be the same.

d. Assuming that the electrical energy needs of the community do not change during the 25-year lifetime of the wind turbines, what would be the cost to the community of the electricity supplied by the WFWP over 25 years? Express your answers in dollars/kWh.
e. Identify and explain TWO environmental benefits to West Fremont of switching from coal to wind power and TWO environmental costs to West Fremont of switching from coal to wind power.