Is it “Worth It” to Change your Light Bulbs?

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Brainstorm!

An incandescent,light bulb in your home has burned out and you have no light bulbs stock-piled to replace it! Should you replace it with an incandescent, CFL, or LED light bulb?



Group brainstorm: What factors would you take into account in deciding which type of light bulb to buy for your home?

Possible Factors:

The Investigation:

Using the Watt meter, measure the watts that the light bulb draws when it is turned on. Note that the incandescent, CFL, and LED bulbs in your set are all supposed to have the same brightness, which is marketed as “watt-equivalent.” How does the wattage of each light bulb actually compare?

Also note how hot each light bulb gets. First just hold your hand near the bulb to get a rough sense. Then look at the light bulbs using the infrared camera on the temperature gun to get a better idea of the temperature differences. How does the temperature of the bulb relate to the amount of power that the bulb uses?

Why does Wattage matter?

A Watt is a unit of **power** which describes the rate of energy use. Specifically, a Watt is equal to 1 Joule / second, where a Joule is a unit of energy. For older folks, we are familiar with the 100 Watt light bulb. When this bulb is on, it is using

100 Watts of power = 100 Joules per second =100 Joules/second.

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Units of Energy

1. a. On the accompanying PECO energy bill, what are the units of energy for electrical energy?

   b. From the table and graph, determine how much energy was used in the current month (January - February 2012 which is the last month on the graph). What are the units?

   c. What month used the most electricity on that graph? How much (include units)? Why would that month's electric usage be so high?

   d. What was the average monthly electric usage? What was the total electric usage over the past year? Again, give units.

If you know the power a light bulb draws when it is turned on, you can calculate how much energy it uses by using the formula:

$$\text{Energy} = \text{Power} \times \text{Time}$$

The unit of energy you see most frequently on electric bills is the kilowatt-hour (**kWh**). Don't be fooled into thinking this is a rate because it has "hour" in its name! Notice that is simply "Power x Time" (kW x h), a unit of energy! Let us do some examples to get used to this unit of energy and see that energy has a nice geometric interpretation.

2. a. If a household is using 3 kW (kilowatt) of power continuously from 1pm to 5 pm, how much energy is used?

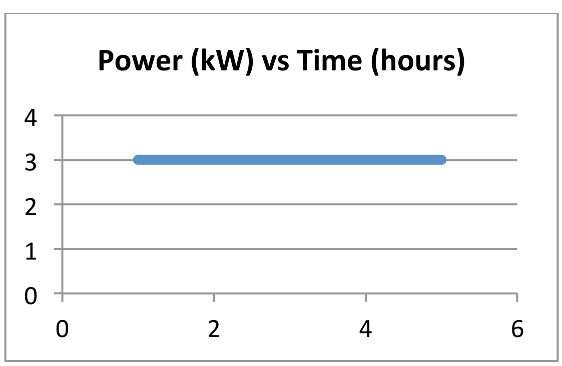

Figure 1. Energy usage with constant power.

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b. What is the area under the power curve (Figure 1) for time going from 1 to 5? What are the units for this area? The units for area will be the product of the units on the horizontal axis and the units on the vertical axis.

3. a. If the household uses 2 kW of power from 1pm to 3pm, then 4 kW from 3pm to 7pm and 1 kW from 7 pm to 9 pm, how much energy does it use?

b. What is the area under the power curve (Figure 2a) for time going from 1 to 9? Note that this will be the sum of the areas under the different pieces of the graph. What are the units for this area? One can also look at this area using a bar graph (Figure 2b) of power vs. time.

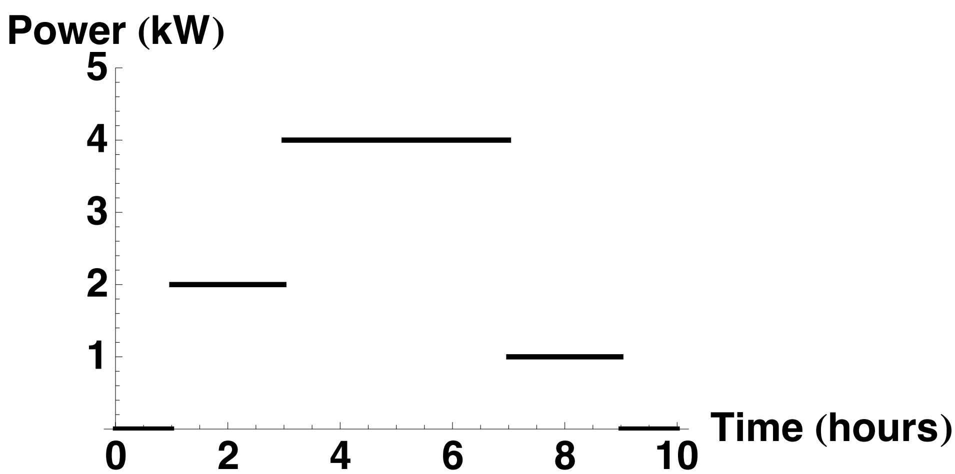

Figure 2a. Power usage with piecewise constant power function.

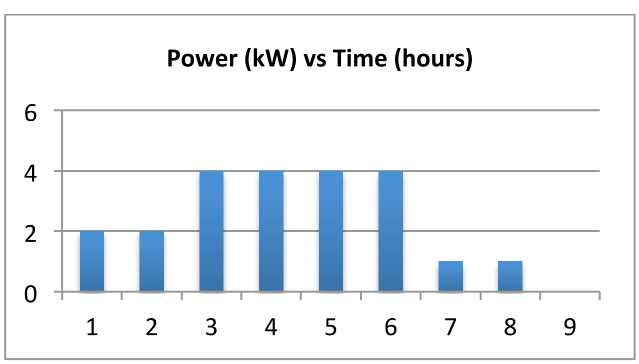

Figure 2b. Power displayed with bar graph.

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c. Geometric Interpretation of Energy:
For a piecewise linear power functions P(t), the energy used is given as the

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of the power graph.

d. Extension: If the power function P(t) is not piecewise linear but instead is a continuously varying function of time, how would the energy be related to the graph?

In physics, one often uses the Joule as the unit of energy. Remember that a Watt is a Joule per second = Joule/second; so when we multiply Power x Time (seconds), the units of time cancel out, leaving us with Joules, our unit of energy!

4. How many Joules are in one kWh?

Cost of Electricity

5. PECO charges $0.17 per kWh of energy use in a home. Your old incandescent light bulb draws 75 W of power when on. If you leave your light bulb on for 120 hours in a month, how much will this light bulb contribute to your energy bill? (See solution later in the handout).

6. **Extension Problem: On Your Own:** Estimate how many light bulbs are in your home and how long they are kept on throughout the month. Using the wattage of the incandescent, CFL, and LED bulbs, calculate the cost of using each type of light bulb in your home for a month.

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Let us return to our original question: Which light bulb would you buy?

Give a mathematical justification. You can look up information on the Internet (or use data that is given in the handout). Are there factors that went into your decision that could not be analyzed using math?

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Calculating Energy Cost:
PECO charges \$0.17 per kWh of energy use in a home. Your old incandescent light bulb draws 75 W of power when on. If you leave your light bulb on for 120 hours in a month, how much will this light bulb contribute to your energy bill? (See solution on next page).

Step 1: Calculate total kWh of energy use.

$$75\ \cancel{W} \times \frac{1\ kW}{1000\ \cancel{W}} \times 120\ h = 9\ kWh$$

Step 2: Calculate cost

$$9\ kWh \times \frac{\$0.17}{1\ kWh} = \$1.53$$

Useful Information about Light bulbs:

100 Watt Equivalent Bulbs

Type	Cost \$	Power Watt	Estimated Lifetime hrs.	Lumens/Appearance
Incandescent	1.5	100	1,000	1490 L/ 3000 K
CFL	4	26	10,000	1600 L/ 4100 K
LED	22	19	25,000	1680 L/ 2700 K

Electricity cost (in Philadelphia): \$.17 per kWh.

Carbon Footprint: It is estimated that to generate one kWh of electricity produces .69 Kg of CO2.

http://www.epa.gov/cleanenergy/energy-resources/calculator.html

This is an overall national average. The conversation factor would vary state by state depending on how electricity is generated in that state.

Did you include carbon footprint as one of the factors in your justification of which type of bulb to buy?

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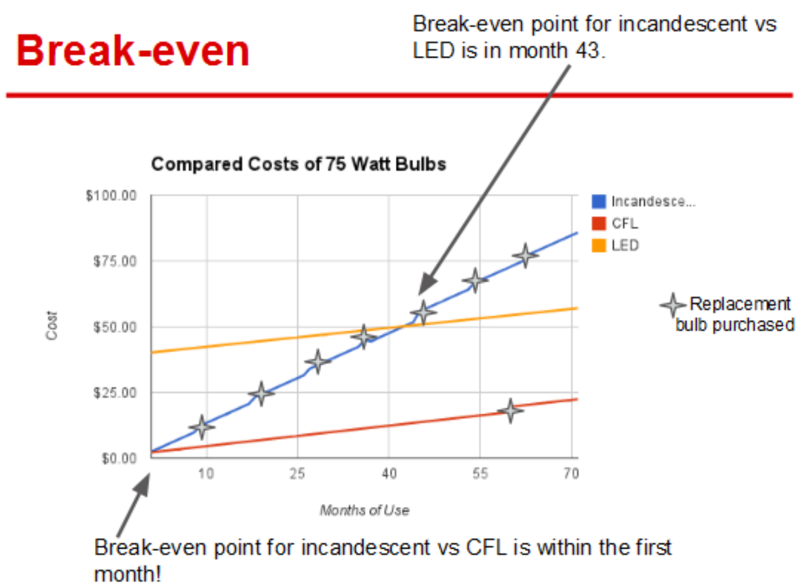
Ways of Investigating Cost:

In past light bulb labs, participants have investigated the cost of using each bulb in a variety of ways, including creating spreadsheets and graphs to solve for the "break even" point of buying the more expensive CFL or LED bulb. Check out the graph below that also takes into account when you have to buy a new bulb! Or they have figured out the costs for buying and operating the bulbs over a common time period such as the longest lifetime of any of the bulbs.



Brainstorm Revisited: Below is a list of factors that past participants who have done this investigation have come up with. Notice many of the factors that could go into the decision that do not relate to cost!

- Initial cost of bulb
- Life of bulb
- CO_2 footprint
- Ease of changing bulb (where it is located)
- Length of time to reach full brightness
- Wattage (and associated cost)
- Temperature of bulb
- Proper recycling of CFL bulbs
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Meter Information

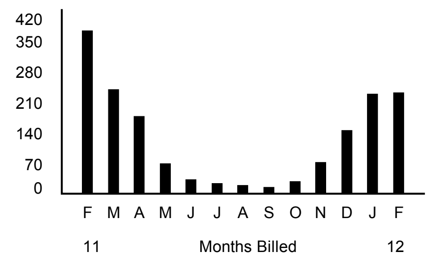
Read Date	Meter Number	Load Type	Reading Type	Meter Reading Previous	Meter Reading Present	Difference	Multiplier X	Usage
02/06	016462079	General Service	Total Ccf	6201 Actual	6432 Actual	231	1	231
02/06	065518976	General Service	Tot kWh	69268 Actual	70447 Actual	1179	1	1179

Total Ccf Used 231
Total kWh Used 1,179

Gas Residential Heating Service - Current Period Detail — Service 01/05/2012 to 02/06/2012 - 32 days

Customer charge					$11.75
Natural Gas Supply Charges	231	Ccf	X	$0.58312	134.70
Distribution Charges	231	Ccf	X	0.37606	86.87
Balancing Service Charges	231	Ccf	X	0.03434	7.93
Gas Cost Adjustment Charges	231	Ccf	X	0.01167	2.70
State Tax Adjustment					-0.24
Total Current Charges					**$243.71**

13-Month Usage (Total Ccf)



Your Usage Profile

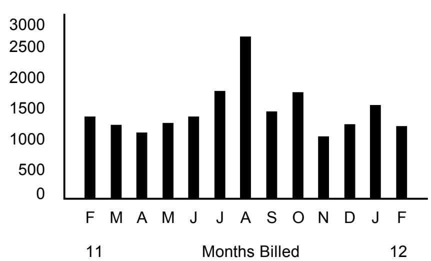
Period	Usage	Avg Daily Usage	Days	Avg Daily Temp
Current Month	**231**	**7.2**	**32**	**39**
Last Month	227	7.0	32	42
Last Year	372	11.6	32	29

Avg Ccf per Month	106
Total Annual Ccf Usage	1,279

Electric Residential Service - Current Period Detail — Service 01/05/2012 to 02/06/2012 - 32 days

Customer charge					$7.20
Generation Charges	1,179	kWh	X	$0.09180	108.23
Transmission Charges	1,179	kWh	X	0.00740	8.72
Wind Energy Service Charge	300	kWh	X	0.02540	7.62
Distribution Charges	1,179	kWh	X	0.06000	70.74
State Tax Adjustment					-0.04
Total Current Charges					**$202.47**

13-Month Usage (Total kWh)



Your Usage Profile

Period	Usage	Avg Daily Usage	Days	Avg Daily Temp
Current Month	**1,179**	**36.8**	**32**	**39**
Last Month	1,519	47.4	32	42
Last Year	1,332	41.6	32	29

Avg kWh per Month	1,442
Total Annual kWh Usage	17,305

DO NOT MAIL THIS PORTION WITH YOUR PAYMENT