Illuminating Light Bulbs

PwC's *Earn Your Future*™ Curriculum

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Introduction

A single light bulb does not use very much electricity in one day, but multiplied over years the cost of electricity for that bulb can really add up. This lesson asks students to consider the financial and environmental costs between the common incandescent light bulb and newer LED bulbs when viewed over long periods of time.

Lesson description

This lesson relies on a pre-made spreadsheet to help students better understand the financial and environmental differences between these two types of bulbs over long periods of time. The lesson begins by challenging students to consider the lifecycle costs of light bulbs and how a bulb with a less expensive purchase price may actually be more costly in the long run. This is followed by a discussion about electrical efficiency and the conversion of energy into different forms. Students will then use a spreadsheet that has been preloaded with equations to facilitate a side-by-side comparison of how incandescent and LED bulbs would affect them financially as well as how these choices affect the environment. A Handout helps guide them through manipulating the spreadsheet. If computer resources are unavailable, a Handout exploring the same information is provided which can be completed without the spreadsheet.

Grade(s)

9-12

Lesson time

45-50 minute class period

Pre-visit prep

- Review the 5-minute prep section to familiarize yourself with the background and vocabulary.
- Contact the classroom teacher to ensure that the materials required will be available to you. Materials are listed under the “Materials” section below.
- Print enough copies of Handout 1 – Incandescent vs. LED Bulbs for each student to have one. Alternatively, if students will be working groups, enough copies for each group to have one.
- Print one copy each of Handout 3 –Incandescent Bulb Image and Handout 4 –LED Bulb Image, if needed.

Student learning objectives

Upon completing the lesson, students will be able to:

- Explain the differences in cost and efficiency between incandescent bulbs and LED bulbs
- List the units of measurement for light output and electrical current
- Explain the financial and environmental implications of energy efficiency

Teacher tips

- Pause often to ask if there are questions. Answer relevant questions clearly.
- Classroom management tip: With students working in groups, there will be plenty of talking between students; remind students 5 minutes before concluding an activity to begin to wrap up.

Materials

- Handout 1 – Incandescent vs. LED Light Bulbs
  - One copy for each student.
- Handout 2 – Incandescent vs. LED Light Bulbs Answer Key
- Handout 3 – Incandescent Bulb Image
- Handout 4 – LED Bulb Image
- Comparing Bulbs Spreadsheet
- Computer access for all students, or an overhead projector
- If computer access is unavailable, Handouts 1a and 2a may be substituted for Handouts 1 and 2. Handouts 1a and 2a cover the same material but do not require the use of the spreadsheet.

5 minute prep

Teacher background

An individual light bulb uses a relatively small amount of electricity. But when this amount of electricity is multiplied over the number of bulbs in a house or school, the type of light bulb used can have significant financial and environmental impacts. The most common type, **incandescent light bulbs**, have been around in some form since the early 1800's. Incandescent bulbs create light by passing electricity through a thin filament of metal. Tungsten is the most common material used as filament. The electricity heats the filament to a high temperature, until it glows **(incandescence**). Because most of the energy used to create light in an incandescent bulb actually goes into creating heat—only about 5% of the energy used is converted into visible light—they are very **inefficient**. While their operating cost is high relative to other types of light bulbs, they are very inexpensive to purchase. On average they only cost about $0.37 to buy, making them an attractive, low-cost option. But their inefficiency makes them more expensive in the long-run. If one adds up the cost of using incandescent bulbs over a long period, their operating cost compared to newer, more advanced types of bulbs is staggering. The compound effect of millions of the inefficient bulbs has prompted legislation to ban them. A phase-out of the most common incandescent bulbs is scheduled for 2014 in the US.

One of the most efficient new types of bulbs is the **LED**, or **light-emitting diode**, bulb. LED bulbs produce light in a very different way than incandescent bulbs. LEDs use a small piece of an inorganic semi-conductive material (typically gallium) which converts the energy in electrons into light. This phenomenon is called electroluminescence. An LED bulb can produce the same amount of light as a 60 watt incandescent bulb with only 9 watts of electricity. The downside to LED bulbs is that they are rather expensive. The average LED bulb costs around $35. The upside is that while an incandescent bulb only lasts about 1,000 hours, an LED bulb has a lifespan of 50,000 hours. The high up-front cost is more than offset by the bulb's long lifespan and electrical efficiency.

Because incandescent bulbs are so common, and they are rated by the number of **watts** of electricity they consume, it is commonly believed that watts are a unit of light output. **Lumens** are actually the unit that measures the brightness of a light source. For instance, a 60W incandescent bulb produces 800 – 900 lumens of light. An LED bulb can produce 800 lumens on only 9W of electricity. The electricity that is sold to consumers is measured in **kilowatt-hours (kWh)**. A kWh is a one kW stream of electricity for one hour. (One **kilowatt** is 1,000 watts.)

Most electricity on the US is generated from the burning of fossil fuels. In 2011, coal accounted for 42% of total supply and natural gas for 25%. The burning of coal is a relatively dirty process, meaning that coal does not combust very thoroughly, and produces a large volume of combustion byproducts. One of these byproducts is carbon. When coal is burned the carbon trapped inside is released in the form of carbon dioxide (CO_2). Carbon dioxide is composed of one carbon atom and two heavier oxygen atoms. CO_2 is over three times heavier than a lone carbon atom, which explains how burning one pound of coal actually creates more than one pound of CO_2 in the atmosphere. Carbon dioxide is the principle gas contributing to global warming. It does occur naturally but because of practices such as burning fossil fuels for electricity, atmospheric levels have been drastically elevated. Incandescent bulbs carry a higher environmental price tag because more fuel must be burned to supply the higher amounts of electricity they require, resulting in the release of more CO_2 into the atmosphere.

Lesson activities

Warm-up – The cost of a bulb (3-5 minutes)

1. Begin by telling students they must choose a light bulb to purchase for their house, which will they choose: one that costs $.35, or one that costs $35?

    a. Ask students to raise their hand to indicate which bulb they would choose.
    b. Most will choose the $.35 bulb.

2. Explain that while this seems like the obvious choice, the $35 bulb is actually less expensive in the long-run.

    a. Ask if anyone can explain how this is possible.

3. Have the class brainstorm all of the costs associated with a light bulb.

    The purchase price; the cost of the electricity to run it; the environmental costs associated with the production of the bulb and electricity.

4. With all of these costs in mind, once again ask how it is possible that a $35 bulb is less expensive than a $1.50 bulb.

    Explain that the key is the bulb's efficiency.

    a. Ask the class to explain what they know about 'efficiency' as it relates to electronic devices.

    When an electronic device does the same amount of work, but uses less electricity, it is more efficient.

5. Explain that electricity is not free; it has environmental and financial costs. It costs money and its production generates pollution—which is cost to the environment. Students will consider how small personal choices in your home can have big monetary and environmental benefits.

Activity 1 – An illuminating discussion (5-10 minutes)

Lead the class in a discussion covering the differences between incandescent and LED bulbs and the units of measure for electricity and light using the following outline as a guide. Use the photos of an incandescent and LED bulb in Handouts 3 and 4 if needed.

1. Ask the class what they are trying to buy when they turn on a light switch.

    a. How do they know how much light a bulb will produce?

    They will likely say by the number of watts a bulb is rated.

    b. Use this as a bridge to open a brief discussion explaining that:

        - Watts are actually a unit of measure for electrical energy.
        - The brightness of a light is measured by a unit called lumens.
        - For reference, a 60 watt incandescent bulb produces 800 – 900 lumens of light.

    c. Does anyone know how an incandescent bulb produces light?

    Incandescent bulbs create light when electricity runs across a thin, wire filament inside the bulb. The friction of the electrons running across the wire changes the energy of the electricity into light and heat. When an incandescent bulb burns out, it is because the thin filament breaks and electricity can no longer be passed through.

d. Ask the class if anyone has touched an incandescent light bulb after it has been on for a bit. *It's hot!*
e. When they turn on a light switch, are they trying to buy heat?
f. What does the heat an incandescent bulb produces say about its efficiency?

Since a portion of the energy an incandescent bulb uses doesn't go toward producing light, but instead produces heat, these bulbs are inefficient. Heat is a byproduct.

2. Ask the class if anyone has heard of an LED bulb and if so, could they explain how it works to the class. These are the salient points:

- LED stands for Light Emitting Diode
- LEDs produce light by 'glowing' when electricity is passed through a very small piece of an inorganic compound called gallium.
- The phenomenon is known as 'electroluminescence.'
- An LED bulb can produce 800 – 900 lumens with only 9 watts of electricity.
- LEDs do not get hot when in use.

a. What can we sat about the efficiency of LEDs compared to incandescent bulbs?

3. Ask if anybody has seen the electric bill for their house. What unit is electricity sold in?

a. Highlight the following to help students complete the next activity:

- Electricity is sold in kilowatt-hours; abbreviated kWh.
- One kW is equal to 1,000 watts.
- One kWh is equal to the amount of work done by 1,000 watts operating for 1 hour.

> It may help to explain it as a *stream* of 1,000 watts for 1 hour.

Activity 2 – Comparing incandescent and LED light bulbs using a spreadsheet (25-30 minutes)

1. Explain that while we tend not to think of light bulbs as consuming huge amounts of resources—financial or natural—over time their impacts can add up.
2. Students will now get a chance to see how these financial and environmental costs compare.
3. Introduce the spreadsheet and pass out one copy of Handout 1 – Incandescent vs. LED Light Bulbs to each student. Alternatively, the spreadsheet and Handout can be done in groups or as an entire class on a projector depending on available computers.

a. Briefly review what a spreadsheet is and how it is used before the students begin.
b. Circulate among students to answer any questions.
c. Provide the students with about 20 minutes to complete the exercise.

4. Once everyone has finished, review the Handout having students share their answers. If time is short, focus on the Comparisons section of the Handout.

Activity 2a – Comparing incandescent and LED light bulbs (25-30 minutes)

Activity 2a is an alternative to Activity 2 in the event that computer resources are unavailable. The content covered in Activity 2a is identical to Activity 2 but the handout can be completed without the use of the spreadsheet.

1. Explain that while we tend not to think of light bulbs as consuming huge amounts of resources—financial or natural—over time their impacts can add up.
2. Students will now get a chance to see how these financial and environmental costs compare.
3. Pass out one copy of Handout 1a – Incandescent vs. LED Light Bulbs to each student. The handout can be completed in its entirety then reviewed as a whole class or you may wish to have students review their answers to particular sections before moving on.
4. Once everyone has finished, review the handout having students share their answers. If time is short, focus on the Comparisons section of the handout.

Wrap up – Final thoughts (3-5 minutes)

1. Wrap-up the lesson by leading a brief discussion about their findings. The following are potential review discussion questions.

    a. Was anyone surprised by how much it costs to operate light bulbs?
    b. Define lumen and watt.
    c. What would students buy with the money they saved?
    d. Were they surprised by how much coal it takes to produce electricity?
    e. Based on what they just learned, what is an easy way they could lower their environmental impact?
    f. Do they need to change every bulb in their house to LED in order to reap the financial and environmental benefits?

    They do not. Every bulb they switch has a positive impact. The more the better, but even switching just one bulb makes a difference.

Evaluation/assessment of student learning

Student learning will be assessed through:

- Participation in group discussions
- Manipulation of a spreadsheet
- Completion of a Handout corresponding to the spreadsheet

Ideas for post-lesson assessments

- Students create their own spreadsheet for another electrical devise and use math skills to figure out the equations that would be needed to calculate the values they would like to investigate.

Extensions/enrichments

- Have the students conduct a similar lifetime analysis of an electronic appliance at home using its initial cost and the cost of the electricity required to operate it.
- The class can undertake a 'light audit' of their school. Have the students determine the number of bulbs in the school, the type of bulbs, their electricity usages, and the approximate number of bulb-hours (# of bulbs x daily number of hours school is lit). Then, play with the values of the numbers in the bulb-hours equation to determine things like how turning off lights when classes leave the rooms would affect the total power usage.

Vocabulary

Efficiency: As it relates to electronics, describes the proportion of a unit of electrical energy goes to performing work

Electroluminescence: An optical phenomenon where a material produces light in response to an electrical current being passed over it

Incandescence: The optical phenomenon where a material glows in response to being heated to a high temperature

Incandescent Bulb: A bulb consisting a filament—typically tungsten—and protective glass globe; electrical current passing through the filament causes the filament to heat up and glow

Kilowatt: Equal to 1,000 watts of electrical power

Kilowatt-hour: A unit measuring an electrical current. One kWh is equal to a 1 kW stream of electricity running for 1 hour

Light-emitting Diode: A small piece of a semi-conductive material which converts the energy in electrons into light when an electrical current passes through

LED Bulb: A type of light bulb which uses light-emitting diodes to produce light

Lumen: A unit of measure for the brightness of a light source

Watt: The watt is a derived unit of power in the International System of Units; measures the rate of energy conversion or transfer

Sources

- Comparison Chart: LEDs vs. Incandescent vs. CFLs
  http://www.designrecycleinc.com/led%20comp%20chart.html
- Earth Easy: LED Comparison Charts
  http://eartheasy.com/live_led_bulbs_comparison.html
- EPA: Clean Energy Comparison
  http://www.epa.gov/cleanenergy/energy-resources/refs.html
- Con Edison: Light Bulb Comparison Lesson
  http://www.coned.com/KIDS/pdf/coned_lightbulbs.pdf

Handout 1 – Incandescent vs. LED light bulbs

Name_____**Date**_____

Directions: Use the information provided for each question and the spreadsheet to complete the questions. Show your work for any questions that require math.

Helpful Hints: A 'cell' on a spreadsheet refers to one individual box. When entering information into the spreadsheet, be sure to only enter values into the cells which are shaded yellow. The spreadsheet is designed to produce answers when numerical values are entered—do not enter units of measurement into the cells.

1. The average national price for one kWh was $.09 in 2010. Enter .09 in highlighted cell for **Price of Electricity – kWh**.

Incandescent bulb basics

1. A typical 4-pack of 60W incandescent bulbs costs around $1.50. How much does 1 bulb costs? Round your answer to the nearest cent. Enter your answer in the designated cell: **Price Per Bulb -- $**.
2. A 60W bulb uses 60 watts of electricity in one hour. How many kilowatts (kW) is 60W? (1kW = 1,000W). Solve the equation and enter this number in the designated cell: **Electricity Usage – kWs**.
3. An incandescent bulb usually lasts for about 1,000 hours before burning out. Enter 1,000 in the cell designated for **Lifetime of bulb – hours**.

Incandescent light bulbs over time

1. The lifetime cost bulb is the purchase price combined with the cost of electricity to run it over its lifespan. What is the lifetime cost of 1 incandescent bulb? Report your answer from the spreadsheet.
2. How much would it cost if the incandescent bulb remained on for 1 year? Report your answer from the spreadsheet.

    a. If 1 bulb lasts 1,000 hours, how many bulbs would be required for a year's worth of continuous light? Solve the equation here.

3. About how many hours per day are the lights on in your house? Enter this number in the cell for, **Hours per Day the Lights are On**. How much does it cost to run 1 incandescent bulb for this number of hours? Report your answer from the spreadsheet.
4. About how many light bulbs are there in your house? Enter this number in the cell for **Number of Bulbs in House**. How much does it cost to light your house using all incandescent bulbs for 1 day? Report your answer from the spreadsheet.
5. How much does it cost to light your house with incandescent bulbs for 1 year? Report your answer from the spreadsheet.
6. Under the heading **Household Cost for x Years** you can determine how much it costs to light your house for any number of years by changing the value you enter into the cell for **Number of Years**.

    a. How much does it cost to light your house for 5 years? Report your answer from the spreadsheet.
    b. For 10 years? 20 years? 50 years? Report your answers from the spreadsheet.

7. Almost 50% of the US' electricity comes from burning coal. If all of the electricity to light your house came from coal, how many pounds would you need to light your house for 2 years? (Change the value in the cell for **Number of Years** to determine this value.) Report your answer from the spreadsheet.

    a. How much coal would be needed for 5 years? 20years? Report your answers from the spreadsheet.

8. Burning fossils fuels emits carbon dioxide (CO_2) into the air, the primary greenhouse gas contributing to global warming. How much carbon dioxide is emitted to light your house using incandescent bulbs for 2 years? Report your answer from the spreadsheet.

    a. How much is emitted in 5 years? 20 years? Report your answer from the spreadsheet.

LED bulb basics

1. The price of electricity remains $.09.
2. The average price of an LEB bulb is $35.00. Enter 35 into the cell designated for **Price Per Bulb – $.**
3. An LED bulb can produce the same amount of light as a 60W incandescent using only 9W of electricity. How many kWs is 9W? Solve the equation and enter this number in the designated cell: **Electricity Usage – kWs**.
4. A typical LED bulb will last for 50,000 hours. Enter 50,000 into the cell designated for **Lifetime of Bulb – hours.**

LED light bulbs over time

1. What is the lifecycle cost of 1 LED light bulb? Report your answer from the spreadsheet.
2. How much would it cost to provide continuous LED light for 1 year? Report your answer from the spreadsheet.

    a. If 1 bulb lasts for 50,000 hours, how many years of continuous light could 1 bulb provide? Solve the equation here.

3. How much does it cost to run 1 LED bulb for as many hours as your house is lit each day? Report your answer from the spreadsheet.
4. How much does it cost to light your house with all LED bulbs for 1 day? Report your answer from the spreadsheet.
5. How much does it cost to light your house with LED bulbs for 1 year? Report your answer from the spreadsheet.
6. How much does it cost too light your house with LEDs for 5 years? Report your answer from the spreadsheet.

    a. For 10 years? 20 years? 50 years? Report your answers from the spreadsheet.

7. How many pounds of coal would need to be burned to light your house for 2 years using LEDs? Report your answer from the spreadsheet.

    a. For 5 years? 20 years? Report your answers from the spreadsheet.

8. How much carbon dioxide (CO_2) would be produced to light your house with LED bulbs for 2 years? Report your answer from the spreadsheet.

    a. How much would be emitted in 5 years? 20 years? Report your answers from the spreadsheet.

Comparisons

1. Despite being far more efficient, the lifetime cost of the LED bulb is quite a bit higher than that of the incandescent. Why?

    a. How many incandescent bulbs would it take to last as long as 1 LED? Solve the equation here.

2. How much money would be saved in 1 year if your house switched to LED bulbs from incandescent?

    a. How much would be saved in 5 years? 10 years? 20 years?

3. How much CO_2 would be kept out of the atmosphere if your house switched to LEDs from incandescent in 2 years?

    a. How much would be kept out of the atmosphere in 5 years? 20 years?

4. The price of electricity has fluctuated over time and may rise in the future. If electricity prices climbed to $.20 per kWh, do LED bulbs become a better or worse investment than when electricity was $.09? (To change the price, replace .09 in the cell for **Price of Electricity – kWh** with .20)

    Hint: Would you save more or less money at this higher price?

5. LED bulbs are more considerably more expensive than incandescent bulbs to purchase. Despite this, are they a smart investment?

Handout 2 – Incandescent vs. LED light bulbs answer key

Name_____**Date**_____

Directions: Use the information provided for each question and the spreadsheet to complete the questions. Show your work for any questions that require math.

Helpful Hints: A 'cell' on a spreadsheet refers to one individual box. When entering information into the spreadsheet, be sure to only enter values into the cells which are shaded yellow. The spreadsheet is designed to produce answers when numerical values are entered—do not enter units of measurement into the cells.

1. The average national price for one kWh was $.09 in 2010. Enter .09 in highlighted cell for **Price of Electricity – kWh.**

Incandescent bulb basics

1. A typical 4-pack of 60W incandescent bulbs costs around $1.50. How much does 1 bulb costs? Round your answer to the nearest cent. Enter your answer in the designated cell: **Price Per Bulb -- $.**

   Answer: 1.50/4 = .375; rounded to nearest cent = .38

2. A 60W bulb uses 60 watts of electricity in one hour. How many kilowatts (kW) is 60W? (1kW = 1,000W). Enter this number in the designated cell: **Electricity Usage – kWs.**

   Answer: 60/1,000 = .06 kW

3. An incandescent bulb usually lasts for about 1,000 hours before burning out. Enter 1,000 in the cell designated for **Lifetime of bulb – hours.**

Incandescent light bulbs over time

1. The lifetime cost bulb is the purchase price combined with the cost of electricity to run it over its lifespan. What is the lifetime cost of 1 incandescent bulb? Report your answer from the spreadsheet.

   Answer: $5.78

2. How much would it cost if the incandescent bulb remained on for 1 year? Report your answer from the spreadsheet.

   Answer: $50.72

   a. If 1 bulb lasts 1,000 hours, how many bulbs would be required for a year's worth of continuous light? Solve the equation here.

   Answer: 365 days x 24 hrs = 8,760; 8,760/1,000 = 8.76 bulbs

3. About how many hours per day are the lights on in your house? Enter this number in the cell for, **Hours per Day the Lights are On**. How much does it cost to run 1 incandescent bulb for this number of hours? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

4. About how many light bulbs are there in your house? Enter this number in the cell for **Number of Bulbs in House**. How much does it cost to light your house using all incandescent bulbs for 1 day? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

5. How much does it cost to light your house with incandescent bulbs for 1 year? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

6. Under the heading **Household Cost for x Years** you can determine how much it costs to light your house for any number of years by changing the value you enter into the cell for **Number of Years**.

   a. How much does it cost to light your house for 5 years? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   b. For 10 years? 20 years? 50 years? Report your answers from the spreadsheet.

   Answer depends on students' selection of value.

7. Almost 50% of the US' electricity comes from burning coal. If all of the electricity to light your house came from coal, how many pounds would you need to light your house for 2 years? (Change the value in the cell for **Number of Years** to determine this value.) Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   a. How much coal would be needed for 5 years? 20years? Report your answers from the spreadsheet.

   Answer depends on students' selection of values.

8. Burning fossils fuels emits carbon dioxide (CO_2) into the air, the primary greenhouse gas contributing to global warming. How much carbon dioxide is emitted to light your house using incandescent bulbs for 2 years? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   a. How much is emitted in 5 years? 20 years? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

LED bulb basics

1. The price of electricity remains $.09.
2. The average price of an LEB bulb is $35.00. Enter 35 into the cell designated for **Price Per Bulb – $.**
3. An LED bulb can produce the same amount of light as a 60W incandescent using only 9W of electricity. How many kWs is 9W? Enter your answer into the cell **Electricity Usage – kWs.** Solve the equation here.

   Answer: 9/1,000 = .009kW

4. A typical LED bulb will last for 50,000 hours. Enter 50,000 into the cell designated for **Lifetime of Bulb – hours.**

LED light bulbs over time

1. What is the lifecycle cost of 1 LED light bulb? Report your answer from the spreadsheet.

   Answer: $75.50

2. How much would it cost to provide continuous LED light for 1 year? Report your answer from the spreadsheet.

   Answer: $14.10

   a. If 1 bulb lasts for 50,000 hours, how many years of continuous light could 1 bulb provide? Solve the equation here.

   Answer: 50,000/8,760 = 5.7 years

3. How much does it cost to run 1 LED bulb for as many hours as your house is lit each day? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

4. How much does it cost to light your house with all LED bulbs for 1 day? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

5. How much does it cost to light your house with LED bulbs for 1 year? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

6. How much does it cost too light your house with LEDs for 5 years? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   a. For 10 years? 20 years? 50 years? Report your answers from the spreadsheet.

   Answer depends on students' selection of values.

7. How many pounds of coal would need to be burned to light your house for 2 years using LEDs? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   a. For 5 years? 20 years? Report your answers from the spreadsheet.

   Answer depends on students' selection of values.

8. How much carbon dioxide (CO_2) would be produced to light your house with LED bulbs for 2 years? Report your answer from the spreadsheet.

   Answer depends on students' selection of values.

   a. How much would be emitted in 5 years? 20 years? Report your answers from the spreadsheet.

   Answer depends on students' selection of values.

Comparisons

1. Despite being far more efficient, the lifetime cost of the LED bulb is quite a bit higher than that of the incandescent. Why?

   Answer: Because the LED bulb's life includes 50,000 hours of electrical use whereas the incandescent bulb's life only includes 1,000 hours of use.

   a. How many incandescent bulbs would it take to last as long as 1 LED? Solve the equation here.

   Answer: 50,000/1,000 = 50 bulbs

2. How much money would be saved in 1 year if your house switched to LED bulbs from incandescent?

   Answer depends on students' selection of values.

   a. How much would be saved in 5 years? 10 years? 20 years?

   Answer depends on students' selection of values.

3. How much CO_2 would be kept out of the atmosphere if your house switched to LEDs from incandescent in 2 years?

   Answer depends on students' selection of values.

   a. How much would be kept out of the atmosphere in 5 years? 20 years?

   Answer depends on students' selection of values.

4. The price of electricity has fluctuated over time and may rise in the future. If electricity prices climbed to $.20 per kWh, do LED bulbs become a better or worse investment than when electricity was $.09? (To change the price, replace .09 in the cell for **Price of Electricity – kWh** with .20)

   Hint: Would you save more or less money at this higher price?

   Answer: The exact amount of money that is saved with the new higher price depends on several values that are unique to each student, but in every case LED bulbs are a better investment because the amount saved will have increased.

5. LED bulbs are more considerably more expensive than incandescent bulbs to purchase. Despite this, are they a smart investment?

   Answer: Yes. They are a smart investment because although they cost more up front, over their lifetime they save considerably more in electricity bills that their price premium over incandescent bulbs, and use less electricity which preventing less CO2 from entering the atmosphere.

Handout 1(a) – Incandescent vs. LED light bulbs

Name_____**Date**_____

Directions: Use the information provided for each question and the spreadsheet to complete the Handout. Show your work for any questions that require math.

Incandescent bulb basics

Price per kWh of electricity:	$ .09
Price per bulb:	$ .37
Lifespan of 1 bulb:	1,000 hours
Electricity usage of 60W bulb:	.06 kW per hour

Incandescent light bulbs over time

1. How much would it cost if the incandescent bulb remained on continuously for 1 year? [hours in a year x electricity usage of 1 bulb x price per kWh of electricity]

    a. If 1 bulb lasts 1,000 hours, how many bulbs would be required for a year's worth of continuous light? Solve the equation here.

2. About how many hours per day are the lights on in your house?

    a. How much does it cost to run 1 incandescent bulb for this number of hours? [hours x electricity usage of 1 bulb x price per kWh]

3. About how many light bulbs are there in your house?

    a. How much does it cost to light your house using all incandescent bulbs for 1 day? [answer to #2a x number of bulbs]

4. How much does it cost to light your house with incandescent bulbs for 1 year? [answer to #3a x 365]
5. How much does it cost to light your house for 5 years? [answer to #4 x 5]

    a. For 10 years? 20 years? 50 years?

6. Almost 50% of the US' electricity comes from burning coal. Efficiency varies but the average power plant requires .82 pounds of coal to produce 1 kWh of electricity. If all of the electricity to light your house came from coal, how many pounds would you need to light your house for 1 year? [number of bulbs in your house x electricity usage of 1 bulb x hours per day the lights are on x 365 x .82]

    a. How much coal would be needed for 5 years? 20years? [answer to #6 x number of years]

7. Burning fossils fuels emits carbon dioxide (CO_2) into the air, the primary greenhouse gas contributing to global warming. Because CO_2 is composed of one carbon atom combined with 2 oxygen atoms from the atmosphere, burning 1 pound of coal actually produces more than 1 pound of CO_2. Burning 1 pound of coal produces 2.86 pounds of CO_2. How much carbon dioxide is emitted to light your house using incandescent bulbs for 1 years? [answer to #6 x 2.86]

    a. How much is emitted in 5 years? 20 years? [answer to #7 x number of years]

LED bulb basics

Price per kWh of electricity:	$ .09
Price per bulb:	$ 35
Lifespan of bulb:	50,000 hours
Electricity usage of 60W equivalent:	.009 kW per hour

LED light bulbs over time

1. How much would it cost to provide continuous LED light for 1 year? [hours in a year x electricity usage of 1 bulb x price per kWh of electricity]

    a. If 1 bulb lasts for 50,000 hours, how many years of continuous light could 1 bulb provide? Solve the equation here.

2. How much does it cost to run 1 LED bulb for as many hours as your house is lit each day? [hours per day the lights are on x electricity usage of 1 bulb x price per kWh]
3. How much does it cost to light your house with all LED bulbs for 1 day? [answer to #2 x number of bulbs in your house]
4. How much does it cost to light your house with LED bulbs for 1 year? [answer to #3 x 365]
5. How much does it cost too light your house with LEDs for 5 years? [answer to #4 x 5]

    a. For 10 years? 20 years? 50 years? [answer to #4 x number of years]

6. How many pounds of coal would need to be burned to light your house for 1 years using LEDs? [number of bulbs in your house x electricity usage of 1 bulb x hours per day the lights are on x 365 x .82]

    a. For 5 years? 20 years? [answer to #6 x number of years]

7. How much carbon dioxide (CO_2) would be produced to light your house with LED bulbs for 1 years? [answer to #6 x 2.86]

    a. How much would be emitted in 5 years? 20 years? [answer to #7 x number of years]

Comparisons

1. How many incandescent bulbs would it take to last as long as 1 LED? Solve the equation here.
2. How much money would be saved in 1 year if your house switched to LED bulbs from incandescent?

    a. How much would be saved in 5 years? 10 years? 20 years?

3. How much CO_2 would be kept out of the atmosphere if your house switched to LEDs from incandescent bulbs in 1 year?

    a. How much would be kept out of the atmosphere in 5 years? 20 years?

4. The price of electricity has fluctuated over time and may rise in the future. If electricity prices climbed to $.20 per kWh, do LED bulbs become a better or worse investment than when electricity was $.09?

    Hint: Would you save more or less money at this higher price?

5. LED bulbs are considerably more expensive than incandescent bulbs to purchase. Despite this higher price, are they a smart investment?

Handout 2(a) – Incandescent vs. LED light bulbs answer key

Name_____**Date**_____

Directions: Use the information provided for each question to complete the Handout. Show your work for any questions requiring math.

Incandescent bulb basics

Price per kWh of electricity:	$ .09
Price per bulb:	$ .37
Lifespan of 1 bulb:	1,000 hours
Electricity usage of 60W bulb:	.06 kW per hour

Incandescent light bulbs over time

1. How much would it cost if the incandescent bulb remained on continuously for 1 year? [hours in a year x electricity usage of 1 bulb x price per kWh of electricity]

   Answer: (365 days x 24 hours) x .06 x .09 = $47.30

   a. If 1 bulb lasts 1,000 hours, how many bulbs would be required for a year's worth of continuous light? Solve the equation here.

   Answer: 365 days x 24 hrs = 8,760; 8,760/1,000 = 8.76 bulbs

2. About how many hours per day are the lights on in your house?

   Answer depends on students' selection of values.

   a. How much does it cost to run 1 incandescent bulb for this number of hours? [hours x electricity usage of 1 bulb x price per kWh]

   Answer depends on students' selection of values.

3. About how many light bulbs are there in your house?

   Answer depends on students' selection of values.

   a. How much does it cost to light your house using all incandescent bulbs for 1 day? [answer to #2a x number of bulbs]

   Answer depends on students' selection of values.

4. How much does it cost to light your house with incandescent bulbs for 1 year? [answer to #3a x 365]

   Answer depends on students' selection of values.

5. How much does it cost to light your house for 5 years? [answer to #4 x 5]

   Answer depends on students' selection of values.

   a. For 10 years? 20 years? 50 years?

   Answer depends on students' selection of values.

6. Almost 50% of the US' electricity comes from burning coal. Efficiency varies but the average power plant requires .82 pounds of coal to produce 1 kWh of electricity. If all of the electricity to light your house came from coal, how many pounds would you need to light your house for 1 year? [number of bulbs in your house x electricity usage of 1 bulb x hours per day the lights are on x 365 x .82]

   Answer depends on students' selection of values.

   a. How much coal would be needed for 5 years? 20years? [answer to #6 x number of years]

   Answer depends on students' selection of values.

7. Burning fossils fuels emits carbon dioxide (CO_2) into the air, the primary greenhouse gas contributing to global warming. Because CO_2 is composed of one carbon atom combined with 2 oxygen atoms from the atmosphere, burning 1 pound of coal actually produces more than 1 pound of CO_2. Burning 1 pound of coal produces 2.86 pounds of CO_2. How much carbon dioxide is emitted to light your house using incandescent bulbs for 1 years? [answer to #6 x 2.86]

   Answer depends on students' selection of values.

   a. How much is emitted in 5 years? 20 years? [answer to #7 x number of years]

   Answer depends on students' selection of values.

LED bulb basics

Price per kWh of electricity:	$ .09
Price per bulb:	$ 35
Lifespan of bulb:	50,000 hours
Electricity usage of 60W equivalent:	.009 kW per hour

LED light bulbs over time

1. How much would it cost to provide continuous LED light for 1 year? [hours in a year x electricity usage of 1 bulb x price per kWh of electricity]

   Answer: (365 days x 24 hours) x .009 x .09 = $7.10

   a. If 1 bulb lasts for 50,000 hours, how many years of continuous light could 1 bulb provide? Solve the equation here.

   Answer: 50,000 hours/8,760 hours = 5.7 years

2. How much does it cost to run 1 LED bulb for as many hours as your house is lit each day? [hours per day the lights are on x electricity usage of 1 bulb x price per kWh]

   Answer depends on students' selection of values.

3. How much does it cost to light your house with all LED bulbs for 1 day? [answer to #2 x number of bulbs in your house]

   Answer depends on students' selection of values.

4. How much does it cost to light your house with LED bulbs for 1 year? [answer to #3 x 365]

   Answer depends on students' selection of values.

5. How much does it cost too light your house with LEDs for 5 years? [answer to #4 x 5]

   Answer depends on students' selection of values.

   a. For 10 years? 20 years? 50 years? [answer to #4 x number of years]

   Answer depends on students' selection of values.

6. How many pounds of coal would need to be burned to light your house for 1 years using LEDs? [number of bulbs in your house x electricity usage of 1 bulb x hours per day the lights are on x 365 x .82]

   Answer depends on students' selection of values.

   a. For 5 years? 20 years? [answer to #6 x number of years]

   Answer depends on students' selection of values.

7. How much carbon dioxide (CO_2) would be produced to light your house with LED bulbs for 1 years? [answer to #6 x 2.86]

   Answer depends on students' selection of values.

   a. How much would be emitted in 5 years? 20 years? [answer to #7 x number of years]

   Answer depends on students' selection of values.

Comparisons

1. How many incandescent bulbs would it take to last as long as 1 LED? Solve the equation here.

   Answer: 50,000/1,000 = 50 bulbs

2. How much money would be saved in 1 year if your house switched to LED bulbs from incandescent?

   Answer depends on students' selection of values.

   a. How much would be saved in 5 years? 10 years? 20 years?

   Answer depends on students' selection of values.

3. How much CO_2 would be kept out of the atmosphere if your house switched to LEDs from incandescent bulbs in 1 year?

   Answer depends on students' selection of values.

   a. How much would be kept out of the atmosphere in 5 years? 20 years?

   Answer depends on students' selection of values.

4. The price of electricity has fluctuated over time and may rise in the future. If electricity prices climbed to $.20 per kWh, do LED bulbs become a better or worse investment than when electricity was $.09?

   Hint: Would you save more or less money at this higher price?

   Answer: The exact amount of money that is saved with the new higher price depends on several values that are unique to each student, but in every case LED bulbs are a better investment because the amount saved will have increased.

5. LED bulbs are considerably more expensive than incandescent bulbs to purchase. Despite this higher price, are they a smart investment?

   Answer: Yes. They are a smart investment because although they cost more up front, over their lifetime they save considerably more in electricity bills that their price premium over incandescent bulbs, and use less electricity which preventing less CO_2 from entering the atmosphere.

Handout 3 – Photo of an incandescent bulb

Handout 4 – Photo of LED bulb

Illuminating light bulbs

Pre-assessment

1. Which of the following is the unit of measure for the intensity of light?

    a. Volt
    b. Kilowatt
    c. Watt
    d. Lumen

2. LED bulbs use less electricity because they are more _____ than incandescent bulbs.

    a. Efficient
    b. Round
    c. Common
    d. Money

3. An LED bulb will last for

    a. 1,000 hours
    b. 5,000 hours
    c. 12,000 hours
    d. 50,000 hours

4. LED bulbs are better for the environment because they

    a. Are made from recyclable materials
    b. Are biodegradable
    c. Last longer and use less electricity
    d. Cost more to purchase

5. Incandescent bulbs are

    a. More expensive than LED bulbs when life-cycle costs are factored in
    b. Less expensive than LED bulbs when life-cycle costs are factored in
    c. Cost about the same as LED's when life-cycle costs are factored in
    d. The best choice for the environment

Post-assessment

1. LED bulbs use less electricity because they are more _____ than incandescent bulbs.

    a. Efficient
    b. Round
    c. Common
    d. Money

2. Which of the following is the unit of measure for the intensity of light?

    a. Volt
    b. Kilowatt
    c. Watt
    d. Lumen

3. Incandescent bulbs are

    a. More expensive than LED bulbs when life-cycle costs are factored in
    b. Less expensive than LED bulbs when life-cycle costs are factored in
    c. Cost about the same as LED's when life-cycle costs are factored in
    d. The best choice for the environment

4. An LED bulb will last for

    a. 1,000 hours
    b. 5,000 hours
    c. 12,000 hours
    d. 50,000 hours

5. LED bulbs are better for the environment because they

    a. Are made from recyclable materials
    b. Are biodegradable.
    c. Last longer and use less electricity
    d. Cost more to purchase

Pre-assessment answer key

1. d
2. a
3. d
4. c
5. a

Post-assessment answer key

1. a
2. d
3. a
4. d
5. c

Lesson summary

Activity: Warm-up: The Cost of a Bulb
Duration: 3-5 minutes
Materials: none
Summary: Introductory discussion of efficiency in light bulbs, highlighting environmental and financial costs.

Activity: Activity 1: An Illuminating Discussion
Duration: 5-10 minutes
Materials: Handout 3- Incandescent Bulb Image
Handout 4 – LED Bulb Image
Summary: Group discussion highlighting the differences between incandescent bulbs and LED blubs, and the basics of electricity

Activity: Activity 2: Comparing Incandescent and LED Light Bulbs
Duration: 25-30 minutes
Materials:

- Activity option with computer access:
  - Handout 1 – Incandescent vs. LED Light Bulbs Worksheet
  - Handout 2 – Incandescent vs. LED Light Bulbs Answer Key
  - Comparing Bulbs Spreadsheet
- Activity options without computer access:
  - Handout 1a – Incandescent vs. LED Light Bulbs Worksheet
  - Handout 2a – Incandescent vs. LED Light Bulbs Answer Key

Activity: Wrap Up: Final Thoughts
Duration: 3-5 minutes
Materials: none
Summary: Group discussion of student findings from the worksheets, highlighting the environmental and financial benefits of each bulb option.