Lighting in the Library

Overview

The purpose of the Lighting in the Library Activity is to calculate the electricity used to provide lighting in the school library and determine the feasibility of saving energy and money by using energy efficient lighting fixtures.

Your students will assume the role of an energy auditor assigned the task of assessing the current situation and making a recommendation for energy-efficient improvements. This activity requires a trip to the library, an examination of the school's energy bill, and a basic understanding of algebraic concepts as a problem solving strategy.

Level

Grades 8 - 12

Subject

Mathematics, Economics

Concepts

- Efficiency: getting a desired outcome lighting with the least effort and cost
- Energy-efficient lighting fixtures
- Energy conservation
- Cost of electricity

Applicable National Standards

National Math Standards:

- Standard 1: Mathematics as Problem Solving
- Standard 2: Mathematics as Communication
- Standard 3: Mathematics as Reasoning
- Standard 5: Algebra
- Standard 6: Functions

Skills

- Addition, subtraction, multiplication, and division
- Compiling lighting energy and cost data
- Drawing a plan of the library
- Critical thinking
- Problem solving
- Creating and giving presentations

Objective

Calculate the feasibility of replacing older, less efficient lighting in the library with new fixtures that are more efficient and cost less to operate.

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Getting Ready

The exercise is designed in two parts. The first part consists of determining the energy consumption, operating costs, and amount of "greenhouse gases" resulting from the existing lighting fixtures. The second part entails determining the economic feasibility of retrofitting the existing fixtures with three types of energy-efficient lights.

Two primers have been prepared to help you and your students ramp up your energy, environment, and lighting knowledge relatively quickly (see appendix). In addition, helpful hints and some examples specific to each step have also been provided. Before class, use the All About Energy Primer or download a copy of the secondary energy infobook located at: www.aep.com/environmental/renewables/solar/powerPie/pdf/second.pdf/). Each student in the class should have a copy of the following:

- All About Energy Primer or Infobook
- student pages 1-10
- Lighting technology primer
- glossary

Choosing the Room in the School for the Exercise

The exercise is designed for the school library; however it will work for almost any room in the school. If the school library is not available, choose a different common room, preferably one with different kinds of light fixtures with different on/off schedules. Ask the librarian or custodian to help the students determine the on/off schedule for the lights in the library. For example, there is typically one schedule for when school is in session and another for when it is out of session.

Additional Exercises for Advanced Students

Ask the students to see if there are any rooms in the area to be studied where lights are left on for long periods of time and are not occupied. Advanced students might determine the feasibility of installing motion detectors for those rooms as an extra credit exercise. Motion detectors will automatically turn lights on and off. Costs of motion sensors could be determined by calling a local electrical wholesale house and calculating labor at 1/2 hour per switch at a cost of $50 to $75 per hour for an electrician's time. The savings accrue from the number of hours the lights can be turned off. The payback period for the investment in motion detectors can be calculated in the same way as the ***Lighting in the Library*** exercise.

Background

Lighting typically accounts for 15 percent of the total energy bill of educational institutions nationwide. The majority of buildings built before the 1970s have high levels of illumination according to the design standards of the time. Most use older fluorescent fixtures with four tubes, the standard fixture used in schools and office buildings for many years. As a result, most schools spend too much on lighting bills.

Since the late 1980s, many modern fluorescent fixtures have come equipped with the more efficient T8 lamp operated by an electronic ballast. Depending on the task being performed, there are situations where the old four light fixture can be coverted to a two light fixture and still provide the required amount of light. The electronic ballasts were developed to operate fluorescent tubes more efficiently

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Materials

- Pencil, paper, and a ruler
- Tape measure
- One copy per student of the ***Student Guide Primers:***
  - ***Energy Primer or Infobook***
  - ***High School Energy Inventory: Lighting Technology Overview***
- Student pages 1-10
- Glossary

Time

Two 55-minute classroom periods.

and consume less energy when the lights are on. Older, standard ballasts consume up to 20 percent of the total amount of electricity required to operate the lamp. Therefore, a 1.2 multiplier was added to the last equation in Step 5.

Light fixtures in this exercise are typical of those installed in schools built from the 1950s to the 1980s. During this period, the standard light fixture was the 4-tube fluorescent located in the ceiling. Incandescent lighting remains the standard fixture for task lighting. The majority of exit signs use incandescent bulbs. As students will see in this exercise, these fixtures can often be replaced with newer, more efficient types of lighting that cost much less to operate.

At the same time, there are a large variety of light fixtures in schools used across the country. Some schools have been designed to use natural lighting so effectively in common rooms, such as the library, that it will be extremely difficult to reduce their lighting bills. The best way to tell if there is an opportunity to improve the lighting efficiency of a room is to calculate the “lighting index” for the room as done in Steps 9, 14, and 19. If the index is above 1.3 (W/ft^2), there is likely an opportunity to economically reduce lighting energy consumption in the library. If the index is below 1.3, it will be more difficult to do so within a 3-year payback period but there are still many opportunities for savings and enhancing the visual environment that warrant serious consideration. Retrofitting the lighting system in older buildings, especially in institutional buildings that are illuminated above the current lighting design levels, has proven to be one of the most cost-effective energy conservation measures. The savings from lighting retrofits depend on the amount of time the lights are used during the year. For lights that are on a large percentage of the time, simple payback on the cost of replacing them is from one to three years.

Doing the Activity

Ideally, the students would read the primers first (perhaps as homework the night before beginning the activity), and then complete the exercises in subsequent classes. Steps 1-9 should be completed in the first class period. Steps 10-22 can be completed as a combination of in-class time and homework. When the students are done, they will have enough material to prepare a presentation for the school board about their energy-efficient proposal.

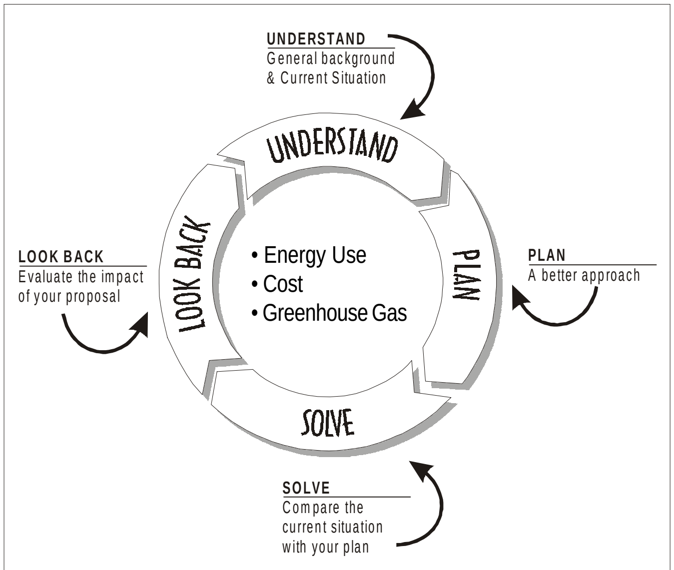
OFFICE OF ENERGY EFFICIENCY
AND RENEWABLE ENERGY

Lighting In the Library
Student Worksheets

OFFICE OF BUILDING TECHNOLOGY,
STATE AND COMMUNITY PROGRAMS

Lighting in the Library

The purpose of this exercise is to determine the amount of electricity used to provide lighting to the school library. During the course of these activities you will need to imagine that you are an energy auditor who needs to make recommendations to the school administration concerning the feasibility of saving energy and money by using energy-efficient lighting. To complete this task, an energy auditor would need to obtain the values of several variables about the location, the current situation, energy-efficient replacement options, and an evaluation of their impacts on the bottom line. This exercise is divided into several steps to help you determine the value of the variables necessary to evaluate the energy consumption, its cost and the resulting greenhouse gas from the lights in your library. We will use the following problem solving application strategy to achieve this objective:



- **UNDERSTAND** the current situation
- **PLAN** a new approach
- **SOLVE** equations to compare the current light design with your new plan
- **LOOK BACK** and compare the bottom line impact of your plan

Part 1 requires a visit to the library to *understand your current situation.* There, you will take an inventory of all of the lights in the room, estimate the schedule the lights are on and off, and using that information, calculate how much it costs to light the library for a year. You'll also estimate the amount of carbon dioxide (greenhouse gas) that is generated to make the electricity for these lights. While you work through the calculations, note the answers on the ***Variable Key on page10*** . This will help you keep track of your answers, and assist you in making accurate bottom line conclusions during the final *look back* steps.

HELPFUL HINTS:

This section will provide you with examples and addtional background which may be useful in completing Part 1.

Why is a sketch important to an energy auditor?

A sketch of the library is required that identifies the locations of the lighting fixtures. The sketch helps the energy auditor or engineer make sure the list of lights is complete, and thus they can accurately calculate energy savings. Furthermore, a sketch is essential for workers hired to make changes to the lighting equipment to be able to identify exactly where this equipment is located. On the sketch, list the type of light fixture with its electricity (power) rating, measured in Watts.

How do I draw a sketch to scale of my library and calculate the area?

Use the sketch paper on page 3 or use a ruler and a blank sheet of paper and draw the largest outline on the piece of paper that will fit within the margins. For example, if the room is 40 feet by 25 feet in size, use a quarter inch scale on the drawing: 0.25 inch on the drawing represents 1 foot of the library. In this case, the measurements of the drawing on the page will be 10 inches by 6.25 inches. Note the scale on the sketch, in this case: 0.25 inches = 1 foot, so you can interpret what you draw at a later date. Draw an arrow facing north so you'll be able to tell which wall is which when you look at the sketch again. The area of a rectangular room is its length times its width.

How do I find out how much my school pays for electricity?

In order to calculate savings from energy efficiency, it is first necessary to calculate how much the school is paying for energy. Electricity costs used for savings calculations are based on the average cost of electricity for the school. This number can be obtained from the school administration by checking the utility bill and equation four.

How do I determine the number of Watts of electric power the light bulbs in my library use?

The power consumption of different types of lighting can be determined by inspecting the lamps and ballasts in the fixtures. If it is impossible to inspect the fixtures themselves, try to determine the wattage of the lamps by asking the person responsible for changing them, such as the custodian. If this is not possible, assume the following watt ratings for the light bulbs below:

- Incandescent lights use lamps that you can examine to determine the rating (e.g. 100 Watts).

- Incandescent exit signs require power only for the lamp; assume they use 40-Watt bulbs.

- Fluorescent lights use either the old standard, 40-Watt F40 lamps or the newer 34 watt energy saver lamps. The ballast regulates current and voltage to ensure proper operation of the fluorescent lamps. All ballasts use a certain amount of energy while operating fluorescent lamps. This energy is called ballast loss and must be included in the calculation. A standard ballast consumes 20 percent of the total power of the fixture. The total power required to operate a fluorescent fixture is the wattage of the tube multiplied by the number of tubes times 20 percent (in other words, times 1.2). See example below. To help you remember to include the ballast loss inside the fluorescent fixture in your calculations, we have written this 1.2 multiplier in the last equation contained in step 5.

Example:

If a fluorescent fixture has four standard tubes, at 40 Watts each plus the ballast, the entire fixture is rated at:

$$(4 \times 40) \times 1.2 = 192 \text{ Watts Fixture}$$

How do I determine the number of hours per week that the lights are on in the library?

The estimated schedule for each fixture is best determined by interviewing people who work in the library, such as the librarians or the custodian. This information combined with the equation in step 3 will help you determine the answer to this important variable.

Example:

School Sessions
For the purposes of illustrating how such a schedule might work, take a hypothetical school library where the lights are on from 7 a.m. to 7 p.m., Monday through Friday. During school sessions, the lights are on 12 hours a day for five days a week totaling 60 hours a week.

School Vacation
During school vacations, the library is open on weekdays from 9 a.m. to 3 p.m. This equals six hours a day for five days a week totaling 30 hours a week. If your school has eight weeks off during the summer, a three-week winter break, a week off for spring break, and a week off for holidays, vacations account for 13 weeks a year. The calculated "on times" for most of the lights in this case would be as follows:

$$(w \times x) + (y \times z) = B$$

where:

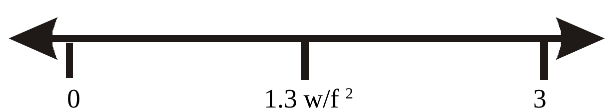
w = hours per week that the lights are on when school **is in** session
x = weeks school **is in** session
y = hours per week lights are on when school **is not in** session
z = weeks during year when school **is not in** session

You would complete the equation as follows

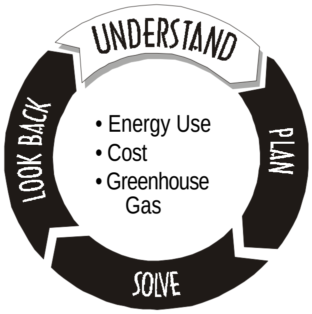
w = 60 x = 39 y =30 z = 13
(60 x 39) + (30 x13) = B
B=2730

What is a lighting efficiency index?

Energy engineers often use a lighting efficiency index such as the one below. When the index is higher than that for similar rooms or buildings, engineers can identify in advance where potential energy savings can be achieved. If the index is greater than 1.3 Watts/ft^2, it indicates that there are probably opportunities for savings. The index is calculated by dividing the total watts consumed by the area. This index is recorded as watts /ft^2. The equations in steps 9, 14, and 19 will help you see where you are and where you could be in relation to this standard.



If the lighting index, (Watts / ft^2) is greater than 1.3, there are probably opportunities for energy savings.

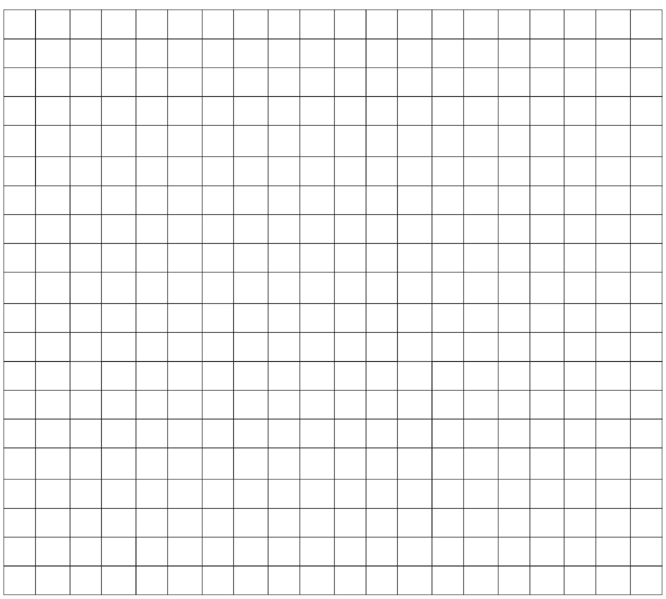


Data gathering and observation

INSTRUCTIONS: In order to get to the bottom line, the energy auditor must get general information about the specific location. The answers to the first four steps will help you complete the calculations necessary to understand your current situation, plan a better approach, solve issues concerning your new approach, and finally, look back at the difference you can make with energy efficiency. To begin, follow the directions for each step. Consult the background information as needed.

STEP 1

Measure the dimensions of the library floor and sketch it to scale below. Be sure to write the length and width on the sketch. Then draw the location and correct number of the incandescent light bulbs, fluorescent tube light bulbs, and incandescent exit sign light bulbs that you see.



STEP 2

Calculate the area (length x width) of the library and write your answer in the variable key next to **A** on page 10.

A= ______

STEP 3

Ask the people that work in the library how many hours per day the lights are on when school is in session and when school is not in session. Use this information and the key below to determine the total hours the lights are used in the library. Write your answer in the variable key next to **B** on page 10.

$$(W \times X) + (Y \times Z) = B$$

B= ______

where:

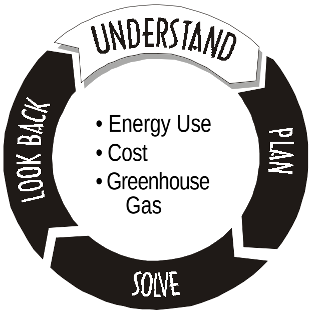
- $w =$ hours per week that the lights are on when school **is in** session
- $x =$ weeks school **is in** session
- $y =$ hours per week lights are on when school **is not in** session
- $z =$ weeks during year when school **is not in** session

STEP 4

Use the equation below to calculate the average cost your school pays per kilowatt-hour. Write your answer in the variable key next to **C** on page10.

$$\frac{\text{Total monthly energy bill in \$}}{\text{Total kilowatt-hours from monthly bill}} = C$$

C= ______



What is the Current Situation?

Instructions: Energy auditors must learn the value of several variables about the current room in order to convince administrators that energy efficiency is a good idea. Steps 5-9 will help you find the value of the following variables about the light bulbs in your library: the number of watts (**D**); the number of kilowatt-hours (**E**); annual electricity cost (**F**); the carbon dioxide greenhouse gas created by the electricity produced (**G**); and the current lighting index (**H**). To begin, follow the directions below and complete the equations. Don't forget to transfer your answers to the variable key on page 10.

STEP 5

In Column 2, write the number of light bulbs you counted for each type listed in column one. Complete each equation. Then, add the answers in column 4 and enter this new watt total in answer block **D** and on page10.

Column 1	*Column 2*	*Column 3*	*Column 4*
Number of incandescent light bulbs with 40 watts	☐	x 40 watts =	☐
Number of incandescent light bulbs with 60 watts	☐	x 60 watts =	☐
Number of incandescent light bulbs with 75 watts	☐	x 75 watts =	☐
Number of incandescent light bulbs with 100 watts	☐	x 100 watts =	☐
Number of exit signs with 40 watt Incandescent light bulbs	☐	x 40 watts =	☐
Number of exit signs with 60 watt Incandescent light bulbs	☐	x 60 watts =	☐
Number of exit signs with 75 watt Incandescent light bulbs	☐	x 75 watts =	☐
Number of exit signs with 100 watt Incandescent light bulbs	☐	x 100 watts =	☐
Number of fluorescent light tubes	☐	x 40 watts x 1.2= (or 34)	☐
		D =	☐

STEP 6

Use the total watts you calculated in step 5 (D) and the total hours the lights are used in a year from step 2 (B) in the equation below to figure out how many kilowatt-hours are consumed by the lights in your library. Write your answer in the variable key next to **E** on page 10.

$$\frac{D \times B}{1000} = E \qquad E= \square$$

STEP 7

Refer to steps 4 and 6 for the value of the variables in the equation below. Then do the math to determine the current annual cost of operating the lights in your library. Write your answer in the variable key next to **F** on page10.

$$E \times C = F \qquad F= \square$$

STEP 8

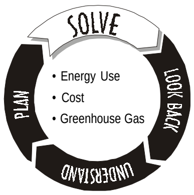
The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4lbs. to 2.8 lbs. per kilowatt-hour, depending on whether or not the electricity is produced from coal, nuclear power, or hydropower (see greenhouse gas article in the energy and environment primer). Use the equation below to estimate the amount of greenhouse gas created when the electricity is made to power the lights in your library. Write your answer in the variable key next to **G** on page10.

$$E \times 2 = G \qquad G= \square$$

STEP 9

Use the following equation to calculate an overall lighting index for the library. This index is the Watts consumed per square foot. Write your answer in the variable key next to **H** on page10.

$$\frac{D}{A} = H \qquad H= \square$$



Summary of Variables Used in the Calculations

A = Area (Length times width) of library =

B = Total hours lights used in a year =

C = Average cost per kilowatt-hour =

D = Total watts consumed by your library lights =

E = Kilowatt-hours consumed by your library lights =

F = Annual cost of operating your library lights =

G = Estimated amount of carbon dioxide (CO_2) greenhouse gas generated during electricity production =

H =Current lighting index for your library =

I = Total watts consumed by your library lights with your new plan =

J = Kilowatt-hours consumed with your new library lighting plan =

K =Annual cost of electrity with your new library lighting plan =

L = Amount of carbon dioxide (CO_2) greenhouse gas with your new library lighting plan =

M = Lighting index with your new library lighting plan =

N = Energy saved in a year with your new library lighting plan =

P = the money saved in a year with your new library lighting plan =

Q= Greenhouse gas prevented in a year =

R = Initial cost of the compact lights you propose =

S =Number compact fluorescent =

T = Initial cost of the (LED) exit signs (chart 1) =

U =Number of (LED) exit signs you propose =

V =Initial cost of the T-8 electronic ballast fluorescent tubes =

W=Number electronic ballast T-8 fluorescent tubes you propose changing =

Y = payback for your plan (years) =

Summary of Abbreviations Used in the Calculations

A	area of a room measured in square feet
Btu	British thermal units
ft^2	square feet
h	hour
kW	kilowatt
kWh	kilowatt-hour
lm	lumen
L	length of a classroom wall
mmBtu	million British thermal units (Btu)
W	width of a classroom
wk	weeks
yr	year
$	U.S. dollars
x	multiplication (also *)
+	addition
-	subtraction
/	division (also "per," as in dollars per year; e.g. $ / yr)