OFFICE OF ENERGY EFFICIENCY
AND RENEWABLE ENERGY

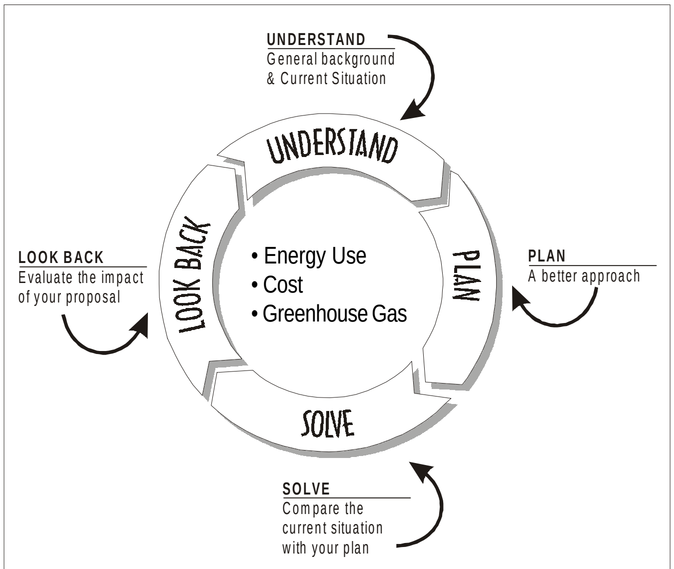
Lighting In the Library

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:

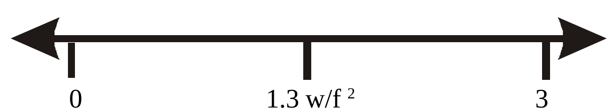
w = hours per week that the lights are on when school **is in** session
x = weeks school **is in** session
y = hours per week lights are on when school **is not in** session
z = weeks during year when school **is not in** session

You would complete the equation as follows

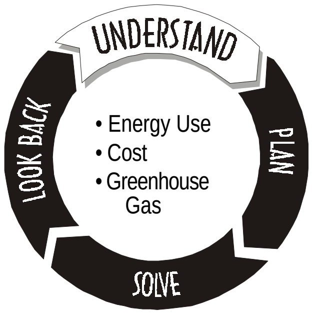
$w = 60$ $x = 39$ $y = 30$ $z = 13$
$(60 \times 39) + (30 \times 13) = B$
$B = 2730$

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= $\boxed{}$

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.

$$(W \times X) + (Y \times Z) = B \qquad B = \boxed{}$$

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

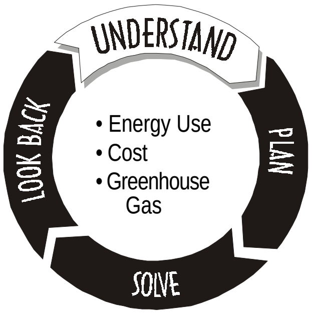
z = weeks during year when school **is not in** session

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.

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

C= $\boxed{}$



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.

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

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.

$$E \times C = F \qquad F = \boxed{}$$

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.

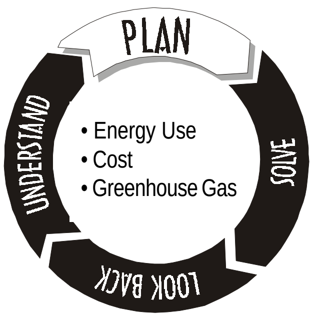
$$E \times 2 = G \qquad G = \boxed{}$$

STEP 9

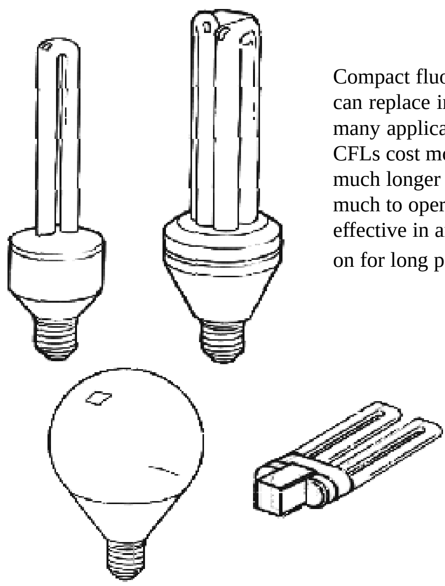
Use the following equation to calculate an overall lighting index for the library. This index is the Watts consumed per square foot. Write your answer in the variable key next to **H** on page10.

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

Determine the Feasibility of Installing Energy Efficient Lighting



In this part of the exercise, you will plan a new approach to lighting your school library. This new plan will use less energy, cost less, and result in less greenhouse gas. Your plan will also include bottom line calculations and decision factors such as: identifying the costs and payback for buying and installing new lighting equipment and making a determination about whether or not the new, more efficient lighting will provide sufficient illumination to the library.



Compact fluorescent lamps (CFL) can replace incandescent lamps in many applications. Although the CFLs cost more initially, they last much longer and cost one fourth as much to operate. They are most effective in areas where the lights are on for long periods.

Background Information

The feasibility of replacing existing lighting with more efficient lighting depends on the cost of replacement versus the savings. The per year savings depend on the type of lighting and the number of hours per year the lights are on. Three types of efficient lighting will be examined here:

- replacing incandescent bulbs with compact fluorescent lamps
- replacing incandescent exit signs with those lit by light emitting diodes (LED)
- replacing the existing F40 lamps and 34 watt energy saver fluorescent fixtures with T8 lamps and electronic ballasts

Replacing incandescent bulbs with compact fluorescent lamps

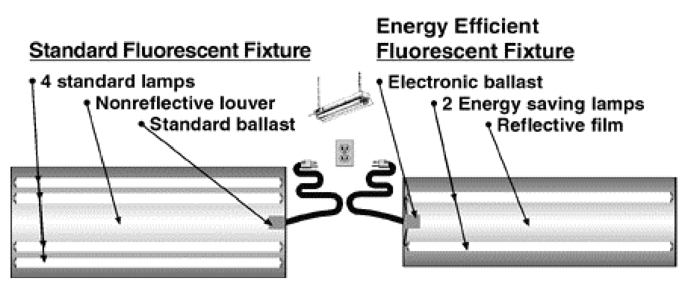
The savings result from increased efficiency: getting more light with less electricity. The efficiency of these fixtures can be measured in terms of lumens per Watt (lm / Watt), and the higher the lumens per Watt rating, the more efficient they are. Generally, fluorescent lamps are much more efficient than incandescent bulbs, producing as much as four times more light (and less heat) with the same electricity input. For example, a 27-Watt compact fluorescent lamp provides 1800 lumens, while a 100-Watt incandescent bulb produces 1750 lumens. The CFL produces almost four times the lumens per Watt of the incandescent bulb.

Replacing incandescent exit signs with those lit by light emitting diodes (LED)

Similar efficiencies can be obtained from exit signs using light emitting diodes (LED), also used in the display areas on a calculator. LEDs are very long lasting and require very little power. For this reason, they work very well in applications such as exit signs that must stay on all the time.

Replace F40 lamps and 34 watt energy saver lamps with T8 lamps and electronic ballasts (retrofit)

Replacing the existing 40w or 34w fluorescent lamps with the more efficient T8 lamp that is operated by an electronic ballast will provide excellent energy savings and also produce a superior quality of lighting which is important in a library environment. It is important that the existing fixtures be well cleaned before the new lighting is installed. Fixtures get dirty with age and are rarely cleaned. Up to 40% of a fixture's efficiency can be lost to dirt, so it is critical that all fixtures are well cleaned when being retrofitted. Replacing the old F40 lamps with the new efficient T8 lamps can save as much as 40% of the energy while providing equivalent or superior levels of illumination and a much better quality of lighting.



New fluorescent fixtures with energy-saver tubes, reflective louvers, and electronic ballasts provide almost as much light as the old, 4-tube fixtures while using less than half the electricity.

Chart 1.

Light Output for Several Types of Energy-Efficient Lamps

Lamp Type	Cost *replace	Lamp Life (h)	Watts	Lumens	Lumens per Watt
Replace incandescent bulbs with compact fluorescent lamps					
Compact fluorescent lamp (CFL)	$14	10,000	27	1800	67
Standard incandescent bulb	$.50	1,000	100	1750	17.5
Replace F40 or 34 watt energy saver tubes with with T8 lamps and electronic ballasts					
F40 or 34 watt fluorescent lamp	$ 5 per tube	20,000	192	11,960	62
T8 lamp and electronic ballast	$ 8.75 per tube	22,000+	106	10,620	
Replace incandescent exit signs with LED exit signs					
Incandescent exit signs		1,000	40		—
LED exit signs	$ 90	20,000	2		—

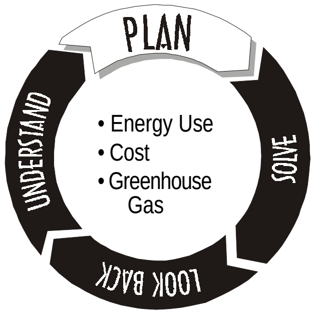
* Cost to replace fixtures in an existing building is higher than to install them in a new building because of higher labor costs to remove and replace fixtures. For example, costs for LED exit signs themselves are as low as $10. The estimates in this chart include labor costs and may vary by 30% or more, depending on location.

PAY BACK

While commercial establishments require a 3-year payback or less for investing in lighting, schools and institutional facilities will generally accept a much longer payback period ranging up to six years. Some of the reasons these longer payback periods are acceptable include:

- The savings will continue many years after the initial investment is recovered since most schools are intended to be in use for 50 years or more
- Educators are concerned both with immediate savings from a new system and lighting quality

Occasionally, the first cost of a new, efficient system will require a simple return of investment that exceeds 5 years; however, the long-term benefits actually prove that the new, more efficient system with the higher first cost is the better investment. Steps 18-22 will provide you with first hand information about the economics for your school.



Plan a New Approach

Instructions: When energy auditors plan a new approach to lighting the library, they consider many factors, including when and how to use daylight, time controls on some lights and which energy-efficient light bulbs will deliver the same or better light but use less energy. In this activity we will concentrate on three common energy-efficient light replacement options. They are compact fluorescent lights, LED exit signs, T8 Fluorescents. In steps 10-14 you will recommend energy-efficient light bulb replacements, and then work to find the answer to the following variables about your new plan: the number of watts **(I)**; the number of kilowatt-hours **(J)**; its annual electricity cost **(K)**; the carbon dioxide greenhouse gas created by the electricity produced **(L)**; and the new lighting index **(M)**. To begin, follow the directions to write and solve the equations below. Then complete the calculations and transfer the value of these variables to your key on page10.

STEP 10

Refer to your library sketch and the equations you completed in step 5 to determine the number of inefficient light bulbs you could replace with the energy-efficient options you read about on your background sheet. Complete the equations below. Then add up the answers to each equation and write this total in the variable key next to **I** on page 10.

____________ **X 27 watts =** ____________
Number of incandescent light bulbs replaced by compact fluorescent lights

____________ **X 2 watts =** ____________
Number of exit signs with incandescent light bulbs replaced LED exit signs

____________ **X 34 watts =** ____________
Number of fluorescent light tubes you can replace with T8

I= ☐

STEP 11

Use the total watts you calculated in step 10 **(I)** 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 new approach you planned. Write your answer in the variable key next to **J** on page10.

$$\frac{I \times B}{1000} = J \qquad J = \boxed{}$$

STEP 12

Refer to steps 4 and 11 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 **K** on page10.

$$J \times C = K \qquad K = \boxed{}$$

STEP 13

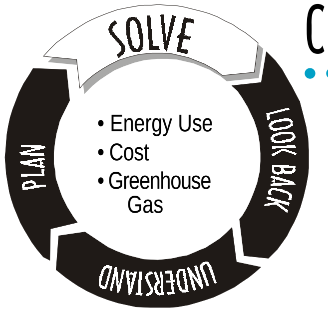
The amount of carbon dioxide greenhouse gas generated during electricity production ranges from 1.4lbs. to 2.8 lbs. per kilowatt-hour (depending on whether or not the electricity is produced from coal, nuclear power, or hydropower). Use the equation below to estimate the amount of carbon dioxide greenhouse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

$$J \times 2 = L \qquad L = \boxed{}$$

STEP 14

Use the following equation to calculate an overall lighting index for the library. This index is the watts consumed per square feet. Write your answer in the variable key next to **M** on page 10.

$$\frac{I}{A} = M \qquad M = \boxed{}$$



Compare Your New Approach with the Current Situation

Instructions: Finally, the energy auditor must compare the current approach and the new plan. If you have not transfered the values of the variables you calculated from the previous pages onto the variable key on page 10, go back and do it now. Then write the equations with the values concerning your school library and do the math.

STEP 15

Calculate the energy savings between the current lights in your library and the new lights you recommended in your plan.

N= $\boxed{}$ **E - J = N**

Where N = the energy saved in a year

STEP 16

Calculate the energy cost savings between the current lights in your library and the new lights you recommended.

P= $\boxed{}$ **F -K = P**

Where P = the money saved in a year

STEP 17

Calculate the greenhouse gas emissions prevented by replacing your current lights in your library and the new lights you recommended.

Q= $\boxed{}$ **G - L = Q**

Where Q = lbs. of carbon dioxide prevented in a year

STEP 18

This exercise is designed to help you identify the payback possible from your proposed lighting changes. Simple payback is defined as the initial cost divided by the first-year dollar savings. To determine the simple payback that would occur if your school adopted your proposed lighting changes, use the equation below. Note: Financial decision-makers usually use a 3-year payback.

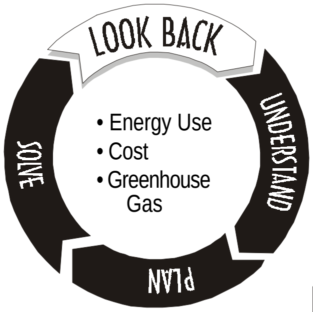
$$\frac{(R \times S) + (T \times U) + (V \times W)}{P} = \underline{\hspace{3cm}} = y$$

year payback

Where:
P= the money saved in a year
R= Initial cost of the compact fluorescent lights (See Chart 1, page 6)
S =Number compact fluorescent lights you propose
T= Initial cost of the (LED) exit signs
U =Number of (LED) you propose
V =Initial cost of the electronic ballast T-8 fluorescent tubes
W=Number electronic ballast T-8 fluorescent tubes you propose

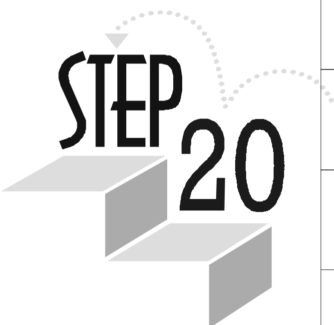
STEP 19

Now compare the index between your current situation, your proposed new lighting plan and the 1.3 w/ft ^{2} standard used by auditors to determine the probability of energy savings. Plot the values for H and M below.



What's The Bottom Line?

Instructions: Use your variable key on page10 to fill in the chart below. Then consider proposing that the school accept your plan for a more energy-efficient, cost-effective, environmentally friendly library. Use the table in step 20 and the results of your work in steps 21-22 in your proposal.



	Energy	**Cost**	**Greenhouse Gas**
Current lights in the Library (variables E,F,G)			
Proposed new plan for the lights in your library (variables J,K,L)			
Savings from your proposal (variables N,P,Q)			

What difference can this make in your school?

If you get the total square footage of your school and complete the equations below you will have a good idea about the impact you can make on your school.

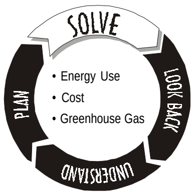
$\frac{N}{A}$ x sq. footage of school = estimated energy saved by applying your plan to the whole school

$\frac{P}{A}$ x sq. footage of school = estimated money saved by applying your plan to the whole school

$\frac{Q}{A}$ x sq. footage of school = estimated CO_2 greenhouse gas prevented by applying your plan to the whole school

Make an Energy Smart Schools presentation.

Discuss your idea and findings with your classmates and teachers and make one combined proposal to your school board and administration team. Research the Energy Smart Schools program offered by the U.S. Department of Energy (www.eren.doe.gov/energysmartschools) and include the many benefits of this program and your findings from this activity as support for making your school or library more energy-efficient.



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)