Energy for Change

A Green Energy Audit Workbook

by Jennie Liss Ohayon

How energy-efficient is your school?

Students work in teams in the Environmental Sciences and Natural Resources Academy of Watsonville High School, California, to conduct a thorough audit of their school.

Here, Gerry Garcia uses a light meter to assess lighting levels in his classroom.

Use this guide to design and carry out a scientific investigation that tracks how your school uses energy and how it might be improved, and then turn in a professional report with your recommendations to school administrators!

Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences
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A Green Energy Audit Workbook

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The data gathering and calculation charts on pages 16 and 17 are modifications of energy audit charts distributed by Strategic Energy Innovations in their Green Building Teacher Workshop, May 18, 2011, at Skyline College, San Bruno, CA, as part of the Bay Area Clean Energy Careers Pathways Project.

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PART 1: What Is an Energy Audit and What Will You Do?

You will work as part of a team to track electricity use at Watsonville High School to understand where there are opportunities to save energy. Each team will look at a different part of the building and will take part in a scientific investigation where your detective work will uncover how your school uses energy and how it might be improved. You might find out that your school has already taken many steps to be energy efficient, but it is very likely you will find that are places to reduce our energy use in the school and help the environment. The process used to evaluate opportunities for energy savings is called an **energy audit**.

In this energy audit, you will do the following:

1. Collect data through an energy audit of your school. First you will check whether your school is using T8 or T12 fluorescent lights, using flicker checkers. Then you will do a lighting level audit, using light meters.

2. At each step, you will calculate how much energy is being used, and analyze ways that energy usage could be reduced.

3. Present your findings. Think about different ways that you can educate your peers and your community about reducing energy use and improving your school's carbon footprint. This might include:

   a) A short report that includes recommendations that you will then distribute copies of to the administration and teaching staff.

   b) Posters that you can put up around the school to inform your peers (for example, in the computer labs)

   c) A short informational write-up (a blurb) that we can post on one of our program web pages.

Name____Date__________________

PART 2: Understanding Energy Units and Conversions

All the lights and appliances around you in the school consume energy. Power is the rate at which energy is transferred and, for electricity, is measured in units called watts. Many devices are said to have a specific wattage. For example, a standard incandescent light bulb is 60W. You can often look on the cord or the actual appliance, or use a special device to calculate how many watts the appliance uses or how power-hungry the specific device is (e.g., a 60W incandescent light bulb is four times as power-hungry as 15W compact fluorescent light bulb). You can calculate how many kilowatt hours **(kWh)** of energy are consumed if you know how long you keep the appliance or light on.

Important equations that relate power and energy are:

Power = Energy ÷ Time   or   Energy = Power x Time

What is the difference between Watts and watt-hours?

4. Watts refers to how power-hungry a specific device is.

5. Watt-hours refers to the total energy used over time or the number of watts consumed in an hour.

You just need to multiply watts times the hours used in order to get watt-hours. For example, that 60W incandescent light bulb that is turned on for 2 hours uses 120 watt-hours.

⇨ How many watt-hours (WH) does a 15W compact fluorescent light bulb use if it is turned on for 5 hours?

_____________WH

Instead of watts or watt-hours, you will often see kilowatts (**kW**), or kilowatt-hours (**kWh**), as the unit of measurement. Kilo means 1000, so you just need to divide watts or watt-hours by 1000 to get kW or kWh.

⇨ What is a 60W light bulb in kilowatts? How many kilowatt-hours (kWh) are used if it is left on for 2 hours?

a)__________kW   b)_______kWh

⇨ What about that 60W light bulb left on for 100 hours?   _____________kWh

PART 3: Introduction to Energy Conservation and Efficiency

Energy is all around us, causing wind, providing light and helping plants create food from water and carbon dioxide. Did you know your body continuously gives off heat equal to that of a 100-watt light bulb? The sun provides Earth with most of its energy. For example, energy originally from the sun is stored in coal, which is a product of ancient plant material.

Energy is always conserved. (That is the **First Law of Thermodynamics**!) The total amount of energy, as it moves from place to place or changes form, stays constant. It is neither created nor destroyed, but only **converted** from one form into another.

However, every time energy gets transformed or converted, some it, and eventually all of it, becomes unavailable for further use. (That is the **Second Law of Thermodynamics**). With each energy conversion, there is an increase in thermal energy in the environment, which becomes dispersed, randomized as heat, and "lost" in the surrounding environment (and eventually ends up in space). Basically energy is getting lost to the atmosphere! This is called **entropy.**

These laws of physics cannot be changed, but we humans also waste tremendous amounts of the energy we generate. Of all the energy used in the United States, about 16% is converted to practical energy while 84% of it is wasted! Most of the energy is lost as heat to the surrounding atmosphere. You are guaranteed to "lose" some energy, but if you are educated and careful, you can choose methods of transfer that are the most "efficient."

The concept of **efficiency** refers to the percentage of energy that can be transferred from one step to the next, or converted from one form into another useful form to do what is intended (for example, converting the power of a waterfall into electricity, and electricity into light) compared to how much is lost as heat (or thermal energy). Most modern conversion devices (that convert energy from one form into another) are inefficient. That means that the amount of useful energy that results from the conversion process (i.e., converting electrical energy into light energy) is much less than the initial amount of energy.

Light Bulbs

A light bulb is an energy conversion device whose purpose is to convert electrical energy to light energy. During the conversion process, all the energy that enters the light bulb is turned into other forms of energy. But not all energy is converted to useful light energy. An incandescent light bulb has a wire filament inside of it and when electricity passes through it, it heats it up as much as it emits light. Thermal energy is therefore also generated in the process, which is often referred to as wasted heat since this energy is not put to use. With each energy conversion some of the energy becomes unavailable for further use.

With a light bulb, 100 units of electrical energy are not converted to 100 units of light energy. If you use incandescent light bulbs, 90-95% of the energy is used for the heat the light bulb generated rather than light! The efficiency of incandescent light bulbs is therefore 5-10%. Incandescent bulbs are still widely used today (look around your home).

As an alternative to the incandescent light bulb, the **compact fluorescent light bulb** (CFL) has been developed for use in homes.

Instead of heating thin wire filaments (like in the incandescent we just learned about), the CFL uses tubes that are coated with fluorescent materials that emit light when stimulated by an electric current.

A 20-watt compact fluorescent light bulb and a 75-watt incandescent light bulb emit the same amount of light, but the CFL will feel cooler as more electrical energy is being converted into light and less is being wasted as thermal energy. CFLs have efficiencies between 15 to 20 percent, so they are three to four times more efficient than most incandescent bulbs. A 20-watt CFL bulb compared to a 75-watt incandescent light bulb saves about 550kWh of electricity over its lifetime, which is equivalent to about 500 pounds of coal. 500 pounds sounds like a lot, but what does it really mean? That is approximately the energy needed to drive a Toyota Prius hybrid across the country two and a half times (from New York to San Francisco).

Typically at least 10% of a high school's energy use can be easily reduced though either improving **energy efficiency** or through **conservation**. These are not exactly the same thing. Conservation refers more to a change in your behavior in the system you have (e.g., making sure electronics are turned off when not being used). Improving energy efficiency, on the other hand, would mean changing actual system parts.

Name____**Date**_________________

FOLLOW-UP QUESTIONS

1. If you find energy waste at your school, what are some examples of **conservation measures** that might be taken?

2. What are some examples of actions your school could take that could improve **energy efficiency?**

3. List 5 problems with increasing greenhouse gases (e.g., CO2, SO2) in the atmosphere.

   a)

   b)

   c)

   d)

   e)

4. **Calculating Real Costs.** You go into a store to purchase a light bulb and find a standard 60-Watt incandescent bulb for $0.63 and a 15-Watt CFL for $9.55.

The lifespan for the incandescent bulb is 1,000 hours, while the life span for the CFL is 10,000 hours. Both produce the same amount of light. Energy in your area costs 5.7 cents per kilowatt-hour (that is the rate the utility company charges). You want to buy the CFL because you know it is better for the environment, but you hesitate because it is over 20 times the price. How do you calculate the real cost of each bulb, taking into account lifespan and the energy consumed to operate the light?

Energy Cost = energy use (kWh of bulb * 10,000 hours) * energy rate

Bulb Costs = number of bulbs needed to last 10,000 hours * price of one bulb

Total Real Cost = Energy cost + Bulb costs

a) Real Cost of a 60-watt Incandescent Bulb:

First figure out the <u>Energy cost</u>: energy <u>use</u> multiplied by energy <u>rate</u>. **Look carefully at the units of measurement for each step, so you convert correctly, and remember to include units in each of your answers.**

1) How many kilowatt-hours are used if you leave the bulb on for 1 hour? _______kWh

2) Multiply by 10,000 hours of use: __________kWh

3) Multiply total kWh by the rate you will be charged: ______kWh x $______/kWh = $_______
rate energy cost

4) Multiply the price of one bulb by the number of bulbs you need to last 10,000 hours:

$___________ x ___________ = $___________
price of one bulb number needed total bulb costs

5) Add energy costs to bulb costs: $________ + $________ **= Total Real Cost: $_______**

b) Real Cost of a 15-watt CFL (quicker this time!) First calculate the energy cost, and begin by figuring out how many kW the bulb is.

1) Energy cost: _______kW x 10,000 hours x $______/kWh = ___________
rate total energy cost

2) Bulb costs needed to last 10,000 hours: $__________
total bulb costs

Energy costs + bulb costs $________ + $________ **= Total Real Cost: $_________**

c) What is the difference in total cost between the incandescent and the fluorescent light bulbs?

d) What is the difference in energy use between the bulbs over a span of 10,000 hours?

You are now ready to conduct an energy audit of your school!

PART 4: Designing Your Audit

Read through the introductory section of Parts 5 and 6, and read the General Observations checklist in Part 7.

Where? Work with a small group to brainstorm a list of rooms and spaces in your school you think should be audited for energy use. What spaces and uses in your school do you think should be checked? Do you think the energy use there might be off-balance? Or will groups spread out through the school and cover each space thoroughly and systematically? Design an audit for one room or section of your school that your group can conduct. Remember that you may not be able to conduct an audit while a room is being used for a class!

What to measure? Begin with the lighting level of the room, using light meters and creating an illumination map (Part 6), and then move through the checklist of room conditions, appliances, and fixtures on the General Observations worksheet (Part 7). Which issues will you focus on?

How to measure it? You will need a light meter to check the lighting level; and, if you decide to check the type of linear fluorescent lamps, you'll need a flicker checker. If you want to know how much energy appliances use, you will need a Kill-a-Watt device. To collect your data in a useful way, you may need additional copies of the data sheets in this workbook, or to design datasheets of your own to capture other information.

PART 5a: Audit for Overhead Linear Fluorescent Lamps

Introduction

Objective: To calculate the annual energy consumption and operating cost for the overhead linear fluorescent lights (LFL) in a designated room.

Background: Lighting is one of the main consumers of energy in our school. Often we can produce significant energy savings by **retrofitting** our lighting system. In this case, retrofitting refers to changing the T12 **linear fluorescent lamps,** and the magnetic **ballasts** required to operate them, with T8 lamps, which run on electronic ballasts. A T12-T8 upgrade does not require a significant change-out of all existing lighting fixtures, so this upgrade is often one of the key recommendations made by energy auditors.

The standard lights for interior overhead lighting are linear florescent lights. Fluorescent lights are sized according to their diameter. Overhead lighting is typically done with T8 or T12 lamps. A T8 lamp (the "T" refers to tubular) has a 1-inch diameter (measured as 8/8 of an inch). A T12 lamp has a diameter of 1.5 inches (12/8 of an inch).

Fluorescent lights need a ballast to function. Ballasts help the lights start up and regulate the electrical current that goes into the fluorescent lights. Both the lamps and ballasts use energy. Ballasts use 6-12 % of the energy and the lamps use the rest.

There are two types of ballasts: magnetic and electric. <u>T12 fluorescent lamps use magnetic ballasts, while T8 lamps use electronic ballasts.</u> T12 lamps with magnetic blasts produce a flicker and a humming noise, while T8 lamps normally do not. T8 lamps use much less energy. See the chart below (Master Light List) for required fixture watts; you can see that T8 lamps of the same length as a T12 lamp use less energy.

We can detect the older magnetic ballasts with a "flicker checker". Flicker checkers are tops that have a radial pattern that shows whether the frequency of the flicker is low and perceivable (magnetic ballasts) or if frequencies are too high to perceive (modern electronic ballasts). You can use them to see if your classroom has inefficient electromagnetic ballasts or more efficient electronic ballasts. When we spin the flicker checker, if we see concentric rings that means that the light has an electronic ballast. A broken-up pattern means that the light has a magnetic ballast.

GLOSSARY

Ballast- regulates the flow of electrical current going through a fluorescent lamp.

De-lamping- removes one or more lamps from a light fixture

Energy- the capacity of a physical system to perform work. You must have energy to accomplish work. Energy can exist in several forms such as heat, kinetic or mechanical energy, light, potential energy, or electrical.

Energy Conservation- a reduction in the amount of energy consumed by a process or system, usually referring to a change in social behavior (e.g., making sure electronics are turned off when not being used or avoiding unnecessary purchases).

Energy Efficiency- using less energy to provide the same level of energy service. Energy efficiency, for example, could be changing to a more efficient lighting system in which the amount of light delivered is the same, but the amount of energy consumed is reduced.

Entropy- a measure of how much energy spreads out in a process. According to the concept of entropy, in any transformation of energy from one form to another, useful energy is lost irreversibly as it becomes dispersed in the system.

Foot-candles- a measure of the amount of light output. One foot-candle equals one lumen hitting one square foot of surface area.

Illuminance- the amount of light that covers a surface

Light meter- a device to measure illuminance

Linear Fluorescent Lamps (LFL)- the standard light tube in interior overhead lighting.

Lumens- a measure of light output.

Power- the rate at which energy is transferred

Retrofit– the addition of new or upgraded parts to an old, outdated assembly that does not require a change of an entire system.

Work- refers to an activity involving a force and movement in the direction of the force.

PART 5b: Audit for Overhead Linear Fluorescent Lamps

Methods

Use the Chart Calculation Key, the Master Light List, and Chart #1 to record your findings about the kind of fluorescent lamps, ballasts, and the energy being used in the room. As part of your audit, you will calculate the energy consumption, cost, and the emissions for three greenhouse gases (carbon dioxide, sulfur dioxide and nitrogen oxides)[1]. The Chart Calculation Key explains which data to put in which boxes on the chart. The Master Light List will allow you to determine the fixture wattages (the rate at which energy is consumed) for lamp type. If the room has lights that are on multiple circuits (i.e., different banks of lights in the room are turned on by different switches), use a different row in the chart for each circuit.

Then use Chart #2 to produce the data needed for a comparative analysis. If you have found older T12 lamps are being used, calculate number of lamps and energy use in the room if T8s were used. On the other hand, if you found T8 lamps are already being used, plug in the data for T12 lamps in those fixtures. Use this chart and the Retrofit Savings Analysis worksheet to calculate the energy savings and the emissions reductions if the school were to replace T12s with T8s; or conversely, calculate how much the school is saving by already using T8 lamps.

CHART CALCULATION KEY

A= Identify the type (T8 or T12) and length of lamp (24”, 36”, etc).

B= Count the number of lamps in the fixture

C= Refer to the Master Light List chart for fixture watts.

D= Total number of fixtures in the room

E=(C*D)/1000 [Divide by 1000 to convert to kilowatt hours]

F= Estimate the number of hours a year lighting is on in the classroom based on when school is in session.

G=E*F

H=G*$0.13 [$O.13 is the average cost of electricity per kilowatt-hour].

I=G*0.524 CO_2

J=G*5.8 grams of sulfur dioxide (SO_2)

K=G*2.5 grams of nitrogen oxides (NO_2 and NO_3).

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[1] "The greenhouse gas emissions will vary in accordance to the energy supply. In California it is estimated that electricity sources emit 0.524 lbs CO2 per kWh. Other states, however, can emit more or less. For example, in North Dakota, the state average for emissions CO2 per kWh is estimated to be 2.24 lbs/kWh."

Master Light List

T12 Lamps		
Lamp Length	Lamps Per Fixture	Fixture Watts
24”	1	28
24”	2	56
24”	3	62
24”	4	112
36”	1	32
36”	2	65
36”	3	115
36”	4	136
48”	1	40
48”	2	72
48”	3	112
48”	4	142
72”	1	76
72”	2	122
72”	1	28
72”	3	202
96”	4	244
96”	1	77
96”	2	128

T8 Lamps		
Lamp Length	Lamps Per Fixture	Fixture Watts
24”	1	15
24”	2	28
24”	3	41
24”	4	57
36”	1	23
36”	2	42
36”	3	62
36”	4	84
48”	1	25
48”	2	54
48”	3	73
48”	4	94
96”	1	57
96”	2	98
96”	3	167
96”	4	219

AUDIT FOR OVERHEAD LINEAR FLUORESCENT LAMPS

CHART 1: EXISTING LAMPS

Name/Group Name: **Room:**

Date:

Existing Overhead Lighting Audit						Current Energy Consumption and Cost	
Lamp Type	Lamps per Fixture	Watts per Fixture	Fixtures Total	Total kW	Operating hours/ Year	Total kWh/ year	Energy Cost/year ($)
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
		TOTALS:					

Greenhouse Gas Emissions			
	CO_2 emissions/ year (lbs)	SO_2 emissions/ year (grams)	NO_2 and NO_3 emissions/ year (grams)
	I	**J**	**K**
TOTALS:			

ENERGY & COST COMPARISON ANALYSIS

FOR OVERHEAD LINEAR FLUORESCENT LAMPS

Chart 2: Data Projection

Data Projection Based on Alternate Lamps (T8 if you found T12 in Audit; T12 if you found T8 in Audit)						**Energy Consumption and Cost**	
Lamp Type	Lamps per Fixture	Watts per Fixture	Fixtures Total	Total kW	Operating hours/ Year	Total kWh/ year	Energy Cost/year ($)
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
		TOTALS:					

Greenhouse Gas Emissions		
CO_2 emissions/ year (lbs)	SO_2 emissions/ year (grams)	NO_2 and NO_3 emissions/ year (grams)
I	**J**	**K**

TOTALS: (last row)

Name____Date__________________

RETROFIT SAVINGS ANALYSIS

Based on Installing T8 Linear Fluorescent Lamps

1. Annual Energy Savings

________________ - ________________ = ________________________________

(G Total for T12) (G Total for T8) (Annual Energy Savings in kWh/yr)

2. Percentage Savings

________________ / ________________ = ________________________________

(kWh/yr savings) (G Total for T12) (Percentage Energy Savings)

3. Annual Energy Cost Savings

________________ - ________________ = ________________________________

(H Total for T12) (H Total for T8) (Annual Cost Savings in $)

4. CO_2 Emissions Prevented

________________ - ________________ = ________________________________

(I Total for T12) (I Total for T8) (Annual lbs CO_2 prevented)

5. SO_2 Emissions Prevented

________________ - ________________ = ________________________________

(J Total for T12) (J Total for T8) (Annual grams SO_2 prevented)

6. NO_2/NO_3 Emissions Prevented

________________ - ________________ = ________________________________

(K Total for T12) (K Total for T8) (Annual grams NO_2/NO_3 prevented)

7. Let's estimate that the annual energy savings that we found for switching a T12 to a T8 lighting system in this single room represents 0.5 % of the savings that could be found for improving the lighting system in the entire school (including all the classes, gym, library, offices, etc).

a) How much total annual energy savings (in kWh) could there be if the entire school retrofitted the lighting system?

b) Let's estimate that the total annual energy savings (in kWh) that Watsonville High School accomplished by retrofitting our lighting system is a number that other schools could also achieve. There are approximately 100,000 public schools in the United States. If 100,000 public schools had the same annual energy savings, what would be the total savings across the country?

c) A nuclear power plant will generate on average 12.4 billion kilowatt-hours (kWh) each year. If all of the schools across the country took measures to reduce energy consumption and there was the total annual savings we found in 7b, how many years of reduced school energy use would be equivalent to closing a nuclear power plant for a year?

PART 6a: Lighting Level Audit

Introduction

Many buildings are over-lit, which means that more light is generated than is needed. Areas can have too little lighting or too much lighting depending on the activities being performed in the space (e.g., a laboratory will need more light than a hallway). In this part of the energy audit, we will see if we can de-lamp an area to bring down the light levels to the recommended level for the type of space activity. **De-lamping** removes one or more fluorescent tube from a fixture and can be an effective way to save energy while still providing adequate lighting.

Light output is measured in **lumens**. A lumen is the measure of light output right at the lamp. Light must travel, however, from the lamp to the desktop, the floor, or some other surface. Many things can diminish the light as it travels from the lamp to the surface area where it is needed, including dust in the air or the lamp's fixture. So we use the measure of **illuminance** to tell us how much light is actually getting where we want it.

We will use a **light meter** to measure illuminance (the amount of light that arrives at a surface) to identify opportunities for removing lamps. Illuminance is measured in **foot-candles**. One foot-candle equals one lumen hitting one square foot of surface area.

RECOMMENDED LIGHT LEVELS	
Type of Space/Activity	**Illuminance (in Foot Candles)**
Hallways	5-8
Restrooms	5-8
Reading printed material	30
Reading pencil writing	70
Drafting, benchwork	100
Lip reading, chalkboards	150
Art rooms	70
Note-taking	70
Laboratories	100
Demonstration Area in Classroom	150
Shops (Operating Machinery)	100
Library (Studying, Typing)	70

PART 6b: Lighting Level Audit

Methods

1. Consult instructions on how to operate your light meter.

2. Create an illumination map on the next page that shows the overhead banks of fluorescent light fixtures, and the areas of need (focus areas) for certain activities.

3. Turn on all the overhead lighting. Does the illumination appear to be uniform throughout the entire room? **(yes/no)** Take multiple readings (at least 4) around the room and write them into your map.

4. Concentrate on focus areas and see if the school can conserve. If the lights are on multiple circuits, turn off the circuits one by one, and take a new reading each time in the same places you measured before, using the codes below (A, B, C, D) to label your measurements on your map. Use the chart below to record your visual impressions. Is there still adequate light in areas where it is needed? Check the box if the area is OK, and mark it with an X if you think it is too dim.

Label each area	A = first circuit off	B = second circuit off	C = third circuit off	D = fourth circuit off
Area 1				
Area 2				
Area 3				
Area 4				

5. Compare your measurements in Step 3 to the recommended light levels for the room. How many foot-candles is the room over or under with all the lights on for each area (think about what activity takes place in each of those areas)"?

	All lights on	Recommended level	How much over or under?
Area 1			
Area 2			
Area 3			
Area 4			

6. Now compare light levels in Step 4 to recommendations. Can some circuits be turned off and still deliver appropriate levels of light?

Group Name: ___________________________ **Room:** ______________________**Date:** _________

CREATE AN ILLUMINATION MAP. Draw a rough floor plan of the room and over it the banks of fluorescent light fixtures. You can include things like the location of doors, windows, and table arrangements. Put the light meter readings in the correct spaces on the map.

6. Could the room be rearranged so that some lamps could be turned off? Describe your idea, identifying spaces, furniture, and the number of circuits that would be needed to supply that light (Attach a drawing if necessary):

Group Name: ____________________ **Room:** ____________________ **Date:** _________

PART 7: General Observations & Recommendations

OBSERVATIONS:

1. Describe number and location of any incandescent bulbs in the room.

2. Do the overhead lamps have older magnetic ballasts or the newer electronic ballasts? (Attach data sheet)

3. Are there multiple wall switches (i.e., circuits) to turn on different groups of lighting? If we used only certain circuits, would that provide enough lighting?

4. Can the classroom be rearranged to reduce overhead lighting requirements? If so, how?

5. Are overhead fixtures dirty and blocking light?

6. Could blinds be open to allow for daylight and overhead lighting reduced?

7. Are lights on when the room is unoccupied? For how long?

8. Are there unnecessary electronic devices (refrigerators, lamps, etc)? Describe:

9. Is electronic equipment (e.g., TV, VCR) plugged in when not needed? Describe:

10. What appliance is consuming the most energy? How much is it costing each year? (Use the kill-a-watt to measure energy use, then calculate cost at $0.13/kWh)

11. Can you find out the room temperature?

12. Are windows properly insulated? Explain:

13. Other observations:

Group Name: __________________________ Room: ______________________Date: _________

RECOMMENDATIONS

Based on your findings, what are the main recommendations that you would make to improve energy efficiency and conservation in this room/area of the school?

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