Lesson 6: Conduct a School Energy Audit

Adopted/Revised From
National Energy Education Development Project, U.S. Department of Energy

Grade Level
6-12

Objectives
- Identify different ways in which energy is used in the school
- Examine different ways energy use can be reduced in the school
- Create a plan to reduce school energy use

Overview
Students conduct a school energy audit.

Materials
- One or more flicker checkers per class
- One or more light meters per class
- One or more power monitors per class

Estimated Cost of Materials
$40 per group

Computer Required?
No

Duration
1-3 class periods

Primer References
2.0 Energy Conservation and Efficiency

Related Articles
- "Students Find Big Savings in School Energy Audit" – Rocky Mountain News
- "High Schools That Create Conservation Culture Save Big on Energy" – Today at Colorado State
- "PSD Saves Big with Conservation Culture" – Poudre School District
- "Mesa County Valley School District 51 Grand Junction, Colorado Case Study" – Southwest Energy Efficiency Project

Engagement

1. What is energy conservation?
2. What is energy efficiency?
3. Why is reducing energy use important?

4. What are some ways we use energy in the classroom? In the school?
5. What are some ways we can reduce our energy use at school? (heating and cooling, lighting, appliances)

Investigation

Now we're going to examine our school to determine ways we can reduce our energy use:

1. Show all students how to record data in the Heating and Cooling activity sheet:
    - The column labeled "X" refers to the number of items (i.e. windows, thermostats) fitting the given description (i.e. thermostat is adjusted to save energy). The column labeled "of Y" refers to the total number of items (i.e. windows, thermostats) located during the audit.
    - "Percent in need of upgrade" refers to the percent of items not meeting the described description as mentioned above (i.e. 2 out of 3 thermostats aren't adjusted).
    - "% savings potential" is an estimate how much energy might be saved from upgrading each item (as a % of the entire school's energy use) and is a given. When multiplied times the percent of items in need of an upgrade, students can calculate the "total % savings potential".
    - Therms, dollars, and CO_2 are calculated from the total % savings potential and costs per upgrade are used to calculate payback periods.
2. Show all students how to use a ballast flicker checker and a light meter by referencing the instructions after this lesson plan and watching the online videos here: http://www.ext.colostate.edu/energy/k12.html
3. Also show them how to record data in the Lighting activity sheet:
    - The column labeled "Number" refers to the number of items (i.e. bulbs, light fixtures) requiring an upgrade (i.e. because the bulb is incandescent or is on when not needed). The flicker checker should be used to find older, inefficient lights with magnetic ballasts. The light meter should be used to determine if light levels exceed those recommended in the light meter instructions after this lesson plan.
4. Show all students how to use a Kill-a-watt meter to measure wattage when equipment is both on and off by referencing the instructions after this lesson plan and watching the online video here: http://www.ext.colostate.edu/energy/k12.html
5. Also show them how to record data in the Appliances activity worksheet as described on the worksheet itself.
6. Show all students how to record information in the Behavior activity worksheet as described in the worksheet itself. Note that ratings should be given after conversations with school staff including custodians as well as other groups (HVAC, Lighting, Appliances).
7. Divide students into 4 groups: 1 group for each of the Appliances, Lighting, HVAC, and Behavior activities. Groups may then wish to sub-divide in order to audit the school more efficiently.
8. Hand out all power monitors to the Appliances group and all flicker checkers and light meters to the Lighting group (likely not enough for each student to have a monitor/flicker checker). Also hand out relevant instruction sheets for the materials.
9. Hand out copies of the relevant activity sheets to each student.

10. Students can audit as much of the school as you permit for the time given.
11. After a designated time period, students should gather back in the classroom to complete the activity sheets.
12. Once all groups complete the activity sheets, complete the Summary activity sheet together as a class in order to see the comprehensive results of the school energy audit.
13. Alternatively, the activity sheets could be completed as homework and the Summary activity sheet can be completed the following day.

Class Review

1. Ask the groups to share the results of their experiments by filling in the summary sheet.
2. Which energy efficiency and conservation measures from each group had the shortest payback periods?
3. Answer the questions on the summary sheet together as a class.

Elaboration

Now we have to check our results and against how other schools use energy:

1. Have students read the Primer references and Related Articles listed above.
2. As a class, discuss how the school audit verified and/or differed from how typical schools use energy.
3. Based on the case study and related articles, draw up a plan for the school to reduce its energy use.

Instructor Notes

- Teachers should familiarize themselves with how to use a power monitor, flicker checker, and light meter by using the devices and referencing the information provided in the curriculum before conducting the lesson.
- For all activities, advise students as to whether or not they are to enter any classrooms, the utility room, the school kitchen, etc. to expand the scope of the audit.
- Arranging for this as well as for custodial staff to be available for an interview by the Behavior team before the lesson is begun is advisable.
- Teachers may also want to contact their school district's energy manager (if applicable) for a consultation prior to the audit.
- Estimated savings provided in the activity sheets is provided for educational purposes only and may not accurately reflect savings associated with listed measures at a given school.

Extensions and Variations

- Any one of the four activities (HVAC, Lighting, Appliances, Behavior) can be conducted as an independent lesson plan for the entire class.
- Students can conduct the walk-through audit (or portions of it) at different times throughout the day in order to find more energy inefficiencies.
- Present class findings to school administrators and/or the school board.
- Use the results to prod school administration to consider a professional audit.
- Hold a fundraiser to raise money to implement selected energy efficiency measures.
- Implement all no-cost energy conservation measures.

- Have students conduct home energy audits.

References/For More Information
Colorado Governor's Energy Office K12 Program:
http://www.colorado.gov/cs/Satellite/GovEnergyOffice/CBON/1251599962874

Colorado Association of District Energy Managers' Energy Fast Facts and Checklist:
http://www.casdem.org/resources/checklist.pdf

Conduct a School Energy Audit: Heating, Ventilation, and Air Conditioning (HVAC)

HVAC items in blue indicate that an exchange of information with the Behavior group is needed.

Annual school therms/ccfs*:

HVAC Item	X	of Y	Percent in Need of Upgrade	% Savings Potential	Total % Savings Potential **	Potential annual therms reduced ***	Potential annual dollar savings	Potential annual CO2 reduction (lbs.)	Cost per upgrade	Total cost of upgrades	Payback period (years)
Thermostat located in temperature-neutral location (i.e. not near heating/cooling source)				2.0%					$60		
Thermostat is adjusted to save energy during unoccupied hours				5.0%					$80		
Supply and return air vents for forced air not blocked				1.0%					$0		
No daylight visible around edges of closed doors, windows (to avoid drafts)				0.5%					$1		
Window coverings to block sun where needed				0.5%					$150		
Domestic hot water temperature set at 110 °F				0.5%					$0		
Boiler installed on or after the year 2000				15.0%					Extremely variable		
Exterior doors and windows closed				1.0%					$0		
Effective weather stripping on exterior doors to prevent drafts				1.0%					$15		
Deciduous plants to shade southern & western sides of building				2.0%					$200		
					Total						

Assumptions
Natural gas prices are $0.60/therm
One BTU (British Thermal Unit) = 100,000 therms = 100,000 ccfs
One therm = 11.7 lbs. CO2

* Use your actual or sample natural gas school bill to determine this number (if annual bills aren't available multiply a monthly sample times twelve to get total therms/year)
**Multiply "Percent in Need of Upgrade" times "% Savings Potential"
***Multiply "Total % Savings Potential" times "Annual School Therms"

Questions

1. Which energy conservation and efficiency measures had the shortest payback periods? The longest?

2. How much money could be saved over the course of the year if all energy conservation and efficiency measures were implemented?

3. How much would it cost to implement all energy efficiency and conservation measures?

4. What is the total percent reduction possible in natural gas use?

5. What is the total percent energy reduction possible in BTUs?

Conduct a School Energy Audit: Lighting

Lighting measures in blue indicate that an exchange of information with the Behavior group is needed.

Lighting Measure	Number	Wattage saved with measure	Hours/ month (each)**	Potential monthly kWh reduced	Months in operation/ year	Potential annual kWh reduced	Potential annual dollar savings	Potential annual CO2 reduced (lbs.)	Cost per measure	Total cost of measure	Payback period (years)
Replace lamps and magnetic ballast with efficient lamps and electronic ballast (per flicker checker)		74							$50		
Replace incandescent bulb with compact fluorescent bulb		76							$2		
Turn hall and other light fixtures off when not needed		117 if magnetic ballasts; 43 if electronic ballasts							$0		
Remove a lamp from a light fixture because more light is provided than needed (per light meter)		29 if magnetic ballasts; 11 if electronic ballasts							$0		
Remove lights from drink and vending machines		117							$0		
Turn athletic field lights off in daylight hours		400*							$0		
Replace older-looking (compact fluorescent) Exit sign with LED Exit sign		11							$100		
					Total						

*Per lamp

**Enter an average number of hours the various types of lights are on per month or a default of 200

Assumptions

The electric rate can be either $0.08/kWh or your actual rate, if known

One BTU (British Thermal Unit) = 3,413 kWh

One kWh = 1.4 lbs. CO_2

Questions

1. Which lighting conservation and efficiency measures had the shortest payback periods? The longest?

2. How much money could be saved over the course of the year if all lighting upgrades were implemented?

3. How much would it cost to implement all lighting upgrades?

4. What is the total percent reduction possible in electricity use?

5. What is the total percent energy reduction possible in BTUs?

Conduct a School Energy Audit: Appliances

Appliances in blue indicate that an exchange of information with the Behavior group is needed.

	CURRENT*						POTENTIAL****								
120 V LOAD**	Watts - on	Watts - off	Hours on/ day	kWh/ month - on	kWh/ month - off	kWh/ year***	Watts - on	Watts - off	Hours on/day	kWh/ month - on	kWh/ month - off	kWh/year	Potential annual kWh reduced	Potential annual dollar savings	Potential annual CO2 reduced (lbs.)
projector															
computer															
computer monitor															
personal space heaters															
personal or group mini-refrigerators															
Total															

*To enter "Current" data, use a power monitor to measure appliance wattage when the appliance is "on" and "off" and enter results in appropriate columns. Estimate "hours-on/day" and calculate results for other columns.

**Most power monitors only work with 120 volt appliances so check voltage carefully before attempting to measure appliance electricity use.

***Multiply "kWh/month - on" times 9 and "kWh/month - off" times 12 and add the results

****See below to enter "Potential" data:

For "Watts-on", use a power monitor to measure wattage by using certain appliances (i.e. fans) at lower settings and enter that number; otherwise enter the "Current" on wattage.

For "Watts-off", enter "0" if the appliance can be unplugged, plugged into a "smart strip", or plugged into a power strip that can be turned off; otherwise enter the "Current" off wattage.

For "hours-on", enter your best estimate of the lowest number of hours this appliance can be run to save energy per day; otherwise enter the "Current" hours on/day.

Assumptions

If measuring a refrigerator, do so during the "on" part of its cycle and during the "off" part of its cycle. Use a default of 5 hours per day for its "Hours on/ day"
The electric rate can be either $0.08/kWh or your actual rate, if known
One kWh = 1.4 lbs. CO_2
A new, high efficiency refrigerator uses only 60% of the energy your current refrigerator uses
A "smart" power strip that eliminates "phantom loads" costs $40
Three appliances could be plugged into one "smart strip"
One BTU (British Thermal Unit) = 3,413 kWh

Questions

1. What appliance-related energy conservation and efficiency measures can the school take?

2. What would be the total cost of using smart strips and how long would it take to get your money back (years)?

3. What is the total percent reduction possible in electricity use?

4. What is the total percent energy reduction possible in BTUs?

5. How much money could the school save every year by installing a new, high efficiency refrigerator? If possible, look online to find the cost of a high efficiency fridge the same size as the one currently installed and calculate the payback period in years.

Conduct a School Energy Audit: Behavior

Interview custodial staff and school employees as appropriate to fill out the following behavior-related energy checklist. A score of 1 indicates "strongly agree" while a score of 5 indicates "strongly disagree".

	Score (1-5)	If 3 or above, provide reason	Current responsible party	Comments
HVAC				
Exterior doors and windows closed when running heating or cooling system				
Thermostats adjusted during unoccupied hours (manually or automatically - including use of a building automation system)				
LIGHTING				
Non-essential hallway and common area lights off or dimmed when not needed and/or when daylighting is adequate				
Non-essential gymnasium lights off or dimmed when not needed				
Athletic field lights off when not needed				
Classroom lights off when not needed				
Administrative office lights off when not needed				
APPLIANCES				
Limited or no use of personal space heaters				
Limited or no use of personal or group mini-refrigerators				
Computers turned off when not in use				
Computer monitors turned off when not in use				
Projectors turned off when not in use				
OTHER				

Questions

1. Exchange information with the HVAC, Lighting, and Appliances groups. How many kWh or therms can be reduced by making each behavior change?

2. How many BTUs can be reduced from behavior changes?

3. How much money could be saved per year through behavior changes?

4. How many lbs. of CO_2 can be reduced through behavior changes?

5. Which actions would be the simplest to take and which would be the most difficult? Why?

<u>Conduct a School Energy Audit: Class Summary</u>

Category	Total potential annual therms reduced	Total potential annual kWh reduced	Total potential annual dollar savings	Total potential annual CO2 reduction (lbs.)	Total cost of all upgrades	Payback period (years)
HVAC						
Lighting						
Appliances						
All combined						
Behavior only						

Questions

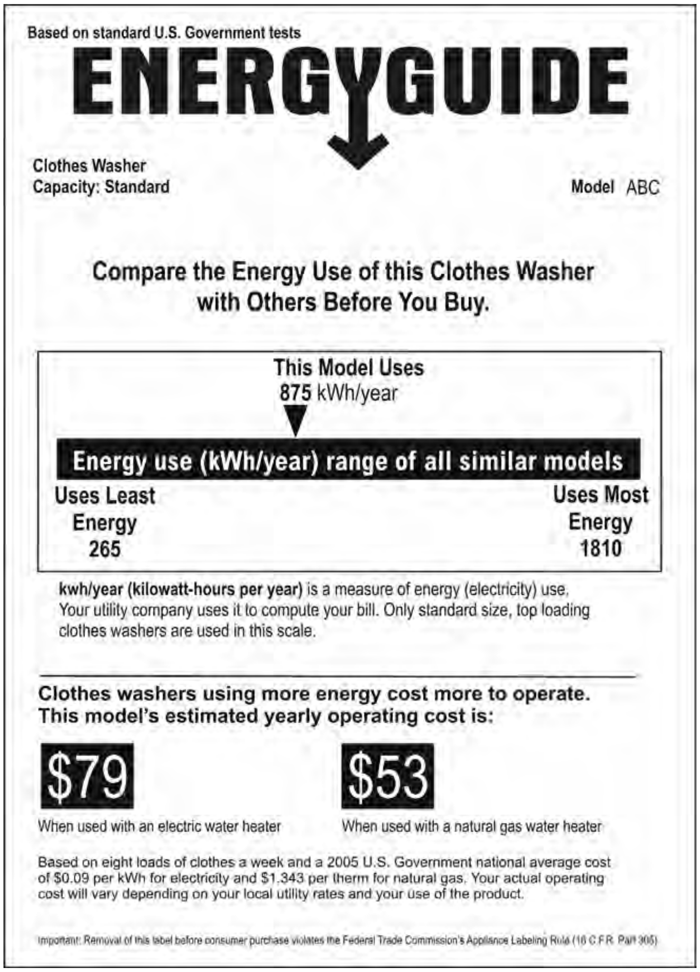
1. Which category of energy upgrades has the lowest cost?

2. Which category of energy measures has the greatest potential savings?

3. Which category of energy measures has the quickest payback period?

4. What is the average cost to reduce one ton of CO_2/year?

Reading Energy Guide Labels



The Federal government requires that appliance manufacturers provide information about the energy efficiency of their products to consumers so that they can compare the life cycle cost of the appliances, as well as the purchase price. The life cycle cost of an appliance is the purchase price plus the operating cost over the projected life of the appliance.

The law requires that manufacturers place EnergyGuide labels on all new refrigerators, freezers, water heaters, dishwashers, clothes washers, room air conditioners, central air conditioners, heat pumps, furnaces, and boilers. The EnergyGuide labels list the manufacturer, the model, the capacity, the features, the amount of energy the appliance will use a year on average, its comparison with similar models, and the estimated yearly energy cost. For refrigerators, freezers, water heaters, dishwashers, and clothes washers, the labels compare energy consumption in kWh/year or therms/year.

For room air conditioners, central air conditioners, heat pumps, furnaces, and boilers, the rating is not in terms of energy consumption, but in energy efficiency ratings, as follows:

EER: Energy.Efficiency.Rating (room air conditioners)
SEER: Seasonal.Energy.Efficiency.Rating (central air conditioners)
HSPF: Heating.Season.Performance.Factor (with SEER heat pumps)
AFUE: Annual.Fuel.Utilization.Efficiency (furnaces and boilers)

From: National Energy Education Development (NEED) Project – www.need.org

For the purpose of the Conduct a School Energy Audit lesson, students can score an appliance based on its age if the Energy Guide label is not available.

Using a Flicker Checker

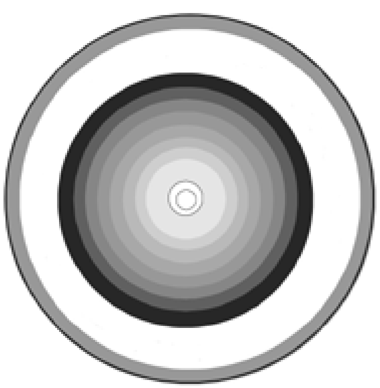
A fluorescent bulb produces light by passing an electric current through a gas using a ballast. The ballast is an electromagnet that can produce a large voltage between the two parts. It is this voltage that gives the electrons of the gas molecules the energy inside the tube. A magnetic ballast has an iron ring wrapped with hundreds of turns of wire. The current from the electrical outlet runs through the wire in the ballast. The wire also is a resistor to some degree, so there is some heat produced. There is also a little heat given off by the gas.

A fluorescent bulb with a magnetic ballast converts about 40 percent of the electricity into light and 60 percent into heat. An electronic ballast has a microchip, like that found in a computer, instead of the coils of wire. This ballast is about 30 percent more efficient in turning electrical energy into light than a magnetic ballast. Some heat is produced in the gas, but not in the ballast itself.

The reason that the Flicker Checker can tell the difference between the magnetic and electronic ballasts is because of the way the current is delivered to the gas. In any outlet in the United States that is powered by an electric company, the electricity is sent as alternating current— it turns on and off 60 times each second. Because the light with the magnetic ballast has wires attached to the outlet, it also turns on and off 60 times per second. The microchip in the electronic ballast can change that frequency. Light bulbs with electronic ballasts are made to turn on and off between 10,000 and 20,000 times each second.

Using the Flicker Checker

Spin the black and white Flicker Checker on a flat surface located beneath your overhead fluorescent light and away from direct, natural light. Any tabletop should do! If you see smooth, grey rings on the Flicker Checker, the fluorescent fixture contains an electronic ballast. If you see a checkered pattern with hints of color that move from ring to ring, the fixture contains a magnetic ballast. Other indicators of magnetic ballasts; a flickering effect, a buzzing sound and poor quality light. This suggests you have lighting that wastes energy.



Example of a flicker checker showing smooth grey rings typical of electronic ballasts

Flicker checking showing the checkered pattern typical of magnetic ballasts

From: National Energy Education Development (NEED) Project – www.need.org

Using a Light Meter

A light meter is a device used to measure the amount of light in a space, whether natural or artificial. Because using artificial light takes energy, when we provide more light to a space than is needed, we waste energy. We can use light meters to measure how much light we have in a space at a given time and then we can compare our measurements to recommended levels to see if we are wasting energy.

Light can be measured in units such as footcandles, lumens, and lux. One footcandle is the amount of light one candle provides as measured one foot away from the source. In subtle contrast, one lumen is the entire amount of light present in a one foot sphere around a candle. One lux equals one lumen per square meter. One footcandle equals 10.76 lux.

Below are some commonly accepted light levels for different parts of a school. (Note that these levels are lower than recommendations made by the Illuminating Engineering Society of North America.):

AREA	FOOTCANDLES	LUX
Hallways	15 fc	161.4
Classrooms	35-40 fc	376.6 – 430.4
Offices	40-50 fc	430.4 – 538.0

To use your light meter:

1. Remove the cover over the measuring device (if applicable).
2. Turn the meter to the “on” position.
3. Place the meter where light is desired for a given space. For example, light measurements in places like classrooms and offices are usually taken on desks and work stations since that is where the light is needed.
4. Be sure to not hover over the measuring device when trying to taking a measurement as this can artificially lower light level readings.
5. The meter will then display the light level in a unit such as lux.
6. Adjust the “range” switch as necessary (unlikely for school settings) so that no leading zeroes appear in the display.

The light at this workstation is measured where reading commonly takes place.

This meter displays the light level in lux on the digital screen.

The meter reading can then be compared to the suggested levels above to see if a space has more or less light than needed. If more light is being provided than suggested levels above, consider “delamping”, or removing lamps from the space until the suggested light level is reached.

Using a Power Monitor

Power monitors have various functions that allow you to check different aspects of electricity usage. For testing energy use, the most important ones are Watts (W) and kilowatt hours (kWh). The Watts function measures the instantaneous draw (how much electricity a device is using), whereas the kWh gives the measure of electricity usage over time. For example, a 1,000 watt electric heater running for one hour will use one kWh of electricity.

For the purpose of the Conduct a School Energy Audit lesson, the Watts function can be accessed on a Kill-a-Watt EZ power monitor by:

1. plugging the monitor into an electrical outlet
2. plugging an appliance into the monitor
3. hitting the “Up” button four times until the “Watt” function is displayed.

This can be done both when the appliance is turned on and when it is off (to measure “phantom loads”.

Many power monitors also allow for electricity use to be converted into cost. While a default value (i.e. $0.10 per kWh) may be pre-entered on a power monitor, monitor users should enter the rate they are charged by their local utility to get the most accurate cost estimates from the monitor.

Functions of less relevance for energy efficiency include Volts (your reading should be close to 120.0, the standard voltage in US electrical outlets), Amps (the measure of the flow rate of electric current), and HZ/PF (60 hertz cycles per second is the standard for alternating current in US electrical outlets).

Special cases

Some appliances such as fans, space heaters, and hair dryers have multiple settings. You can see the savings potential for using these devices at lower settings by either recording the watts at different settings in different rows, or by recording it in the “potential” column.

Other appliances may have large fluctuations in their draws when actively on. For example, a hair dryer ranged from 240 to 1,000 watts when on high. In this case, take the average of the high and low (620 watts) and enter that into the “on” column.

Still other appliances have such a low draw that they may not immediately register. These may include LED nightlights and carbon monoxide detectors. The electricity usage of these is so small that it may not be worth capturing even over a longer period. It’s most important to get accurate readings for the appliances that use the most electricity such as refrigerators or large screen televisions.

Some appliances such as computers and printers use significantly different amounts of energy when "on" depending on whether they are actively "on" or passively "on". Computers are actively "on" when being used or not in sleep mode. Printers are actively on when printing, not standing by.

It is best to capture the cycling of these active and passive stages over a representative period of time as is done with refrigerators and water heaters. A less accurate means of calculating wattage when "on" would be to record the most common wattage (active or passive) or take the average of the active and passive wattages if they are not too far apart.

Maximizing your "potential"
Use the "potential" columns to compare the cost of using an appliance at different wattage settings. The lower wattage would be entered into the "potential" column (Watts-on) if you currently use the appliance at a higher wattage.

Next, see what you would save by cutting your phantom loads. For each appliance that has a wattage draw even when turned off, enter a "0" in the potential "Watts-off" column. To actually achieve these cost savings, plug each of these devices into a switchable outlet strip and switch it off when you're not using the device or consider the use of a "smart strip" that automatically cuts phantom loads when the device isn't in use.

This stereo uses 15 watts when "off" under a certain display setting.

The "potential" columns can also allow you to compare the cost of running your current appliance with that of a new, more efficient version. To do this, look for the Energy Guide labels or other estimates of electricity use of the new appliance. Divide the annual estimated kWh of the new appliance by 12.