### Science of Buildings

**Building Envelope, Lighting, Plug and Phantom Loads**

**Tara Smith and Sandy Cardon, BSU**

<table>
<thead>
<tr>
<th>Time Frame:</th>
<th>Middle and High School</th>
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<tbody>
<tr>
<td>(2)-(4) 50-minute class periods per section</td>
<td><strong>Standards:</strong> 6th -8th Grade</td>
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<table>
<thead>
<tr>
<th><strong>Goals</strong></th>
<th><strong>Common Core Standards pages 62-66</strong></th>
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<tbody>
<tr>
<td><strong>Science</strong></td>
<td><strong>Reading</strong></td>
</tr>
<tr>
<td>• See specific science guidelines by course subject at the beginning of &quot;Learning and Conserving: Student Guide&quot; from the National Energy Education Development (NEED) Project(^1)</td>
<td>3. Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.</td>
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<td></td>
<td>7. Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).</td>
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<td>8. Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.</td>
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<tr>
<td><strong>Math</strong></td>
<td><strong>Writing</strong></td>
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<tr>
<td>• Fluently divide multi-digit numbers using the standard algorithm.</td>
<td>2. Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.</td>
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<tr>
<td>• Fluently add, subtract, multiply, and divide multi-digit decimals using the standard algorithm for each operation.</td>
<td>7. Gather relevant information from multiple print and digital sources; assess the credibility of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and providing basic bibliographic information for sources.</td>
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<tr>
<td>• Recognize a statistical question as one that anticipates variability in the data related to the question and accounts for it in the answers.</td>
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<tr>
<td>• Understand that a set of data collected to answer a statistical question has a distribution which can be described by its center, spread, and overall shape.</td>
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<tr>
<td>• Recognize that a measure of center for a numerical data set summarizes all of its values with a single number, while a measure of variation describes how its values vary with a single number.</td>
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<tr>
<td>• Summarize numerical data sets in relation to their context, such as by:</td>
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<tr>
<td>o Reporting the number of observations.</td>
<td></td>
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<tr>
<td>o Describing the nature of the attribute under investigation, including how it was measured and its units of measurement.</td>
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**Objectives:**

Students will:

- have a basic understanding of a school's energy consumption and how to read a utility meter
- exhibit proper use of measuring equipment,
- be able to define a kWh, a plug load, a phantom load,
- be able to identify the types of lighting being implemented,
- perform a partial energy audit on their school or another school in the district. The school receiving the audit is referred to as the “host school”.
- mentor host school pupils on energy audits and efficiency
**Background Information:**

The majority of this energy audit guide is based around the "Learning and Conserving: Student Guide" from the National Energy Education Development (NEED) Project\(^1\). NEED has various other energy audit materials available for different applications and grade levels. Please see references section for a list of references and supplemental materials.

**Materials:**

- Light level meter
- Ballast discriminator / flicker checker™
- Kill A Watt™ meter
- Temperature gun
- Power strip
- 100’ tape measure
- Digital distance measurer
- Temperature data logger (optional)
- Digital camera for capturing your students in action!

**Procedure:**

- Your students will begin by reviewing a professional energy audit (optional, recommended for high school students) -- many schools have one on file. Students should ideally review an audit on their own school and/or on the host school. If neither is available, consider obtaining an audit from another school in your district or, if none are available, a publically available school energy audit.
- Have the students fill out Attachment 1: Inquiry Chart\(^2\) for the audit.
- Supply each student with the "Learning and Conserving: Student Guide" from the National Energy Education Development (NEED) Project\(^1\) or the portions of the Student Guide referenced in this guide.
- Using the energy audit (if available), the inquiry chart, NEED's "Learning and Conserving: Student Guide"\(^1\) (NLCSG) and the guiding questions below...
  - Facilitate a discussion with the students on an energy audit plan for either your school or another school in the district. The school that receives the energy audit is referred to as the “host school” for the remainder of this guide.
  - Teach the students how to complete measurements, compile charts/graphs, and interpret collected data. The students will practice using the tools, collecting data, using the charts/spreadsheets, performing calculations, and interpreting data in a test area at their own school before performing their "official” audit.
  - Formulate a plan for mentoring the host school pupils on energy efficiency. Consider the following as you brainstorm with your students:
    - How will your students involve the host school pupils?
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- Will the host school pupils assist your students with the audit?
- Will your students perform the audit and teach the host school pupils about their school’s energy consumption and energy efficiency?
- How will your students demonstrate competency with using tools, charts/graphs/spreadsheets, performing calculations and interpreting data?
- How will your students develop and provide age-appropriate information to the host school pupils they are mentoring?
- Other options/ideas?

Section 1: Building Envelope

The school’s building envelope includes everything that separates the school from the outdoors. For this section, students will gather data from around the school with regards to the building construction and the systems within the building. It is recommended that the maintenance personnel at your school and the host school are contacted in advance to answer questions about the building and provide access to utility rooms within the building, utility meters and utility bills.

Have your students review the background information on pages 2-5 (“Energy and Conservation” – “Heating, Ventilation, and Air Conditioning (HVAC)” sections) and pages 10-16 (“Energy Definitions and Conversions” – “Sample Bill Explanation Key” sections) of NLCSG¹. Using pages 10-12 of NEED’s "Energy Survey Teacher Guide"³ as a reference, have the students arrange for and conduct the appropriate interviews at the host school. Have the students consider the following (additional questions also on page 37 of NLCSG¹):

- What type of roofing material does the school have?
- Is the roof flat or sloped?
- What is the orientation of building (N, S, E, W)? Is there any shading from trees and/or overhangs?
- What type of siding material does the school have?
- What type(s) of windows (single pane, double pane, wood vs. metal frame)?
- Are the windows covered with curtains or blinds?
- Are the windows operable or static?
- Describe the insulation for interior/exterior walls, basement, attic (type, age, R-value)?
- Does the school have an attic?
- Does the school have one story or more than one? (1ᵗʰ floor is insulated by 2ⁿᵈ floor, etc.)
- What type of foundation does the school have? (Basement / crawl space / slab on grade)
- What type of heating/air conditioning system is used?
- What types of thermostats are used? Where are they located (in each classroom? in each wing?, etc.)? How are they controlled (automatic, manual, master control, etc.)?
- What are the typical temperature settings for winter/summer and day/night?
Section 2: Lighting

Have your students review the lighting sections found on pages 7-8 and 17-25 of NLCSG¹ and additional supplemental material included in Attachment 2: Lighting Supplemental Materials. Teach the students how to use the light meter (page 19 of NLCSG¹), how to identify different lamps (pages 7-8 of NLCSG¹), how to use a flicker checker (page 25 of NLCSG¹), how to compile lighting information on the lighting inventory sheet (Attachment 2.5), how to create a reflected lighting plan (Attachment 2.5), how to perform necessary calculations, and how to interpret the collected data. Consider the following questions (additional questions also on page 37 of NLCSG¹):

What types of lights are used in the room?
- Tube Fluorescent
  - T8 vs. T12
- Incandescent
- Compact Fluorescent Light (CFL)
- Light Emitting Diode (LED)
- High Intensity Discharge (HID) -- usually in gyms, shops, parking lots, etc.

According to the lighting recommendations (page 20 NLCSG¹):
- Is the lighting system adequate?
- Is the area over-lit?
- How can over-lighting be addressed?
- Under-lighting?

How are the light fixtures controlled?
- Switch in room?
- 1 switch for all?
- Separate switch for different areas of room? Near windows? Or front & back of room?
- Separate switch affects different lamps within fixture?
- Dimmer switch?
- Photocells near window?
- Occupancy sensors?

How can this lighting system be improved?

Note: make sure the students consider other options besides turning the lights off.
It is necessary to have proper lighting, what else can be improved?

Section 3: Electronics, Appliances, Plug and Phantom/Vampire Loads

Have students review background information on electrical appliances, plug loads and phantom loads (pages 8-9, 26-34 of NLCSG¹), teach the students how to read an electrical nameplate (page 26 NLCSG¹), use the Kill A Watt™ meter (page 31 NLCSG¹), how to collect data (pages 32-34 NLCSG¹), how to perform necessary calculations, and how to interpret the collected data. Use the plug and phantom loads worksheet (Attachment 3) to collect data and perform calculations. NEED's "Plug Load"³ lesson plan covers this topic more in-depth and provides an Excel spreadsheet for plug and phantom loads, if more detail in this section is desired. Consider the following questions with your students (additional questions also on page 37 of NLCSG¹):
• Which appliances/electronics use the largest amount of electricity?
• Which ones use the smallest?
• How can we reduce energy consumption? Remember that Energy (kWh) = Power (measured in kW) X Time (measured in hours).
  o Can reduce demand (replace with lower power unit, perform energy efficiency
    upgrades/maintenance)
  o Can reduce time used (unplug, turn off power strip)
• Which appliances/electronics use energy when turned off and how much energy do they use when
  in the standby power mode?
• Which of the appliances/electronics has a “power saving mode?” i.e. computer, vending machine
  etc.
• How does the power saving mode affect the energy (kWh) usage of these appliances/electronics?
• Do these appliances/electronics use energy even when they are entirely powered down (i.e. turned
  off, but still plugged in)?
• Measure Phantom Loads by measuring the kW usage and the amount of days they are on stand-by
  and/or turned OFF.

Assessment:
Verify that your students understand the technical concepts, are comfortable with taking
measurements, performing calculations, and interpreting data, but are able to simplify the
audit materials to communicate the general topics to a pupil.

If the school has an energy audit on file and your students used the audit as a springboard
for their own audit, have the students compare their measurements and calculations with
those found in the professional audit. Why might these measurements/calculations differ?

The discussion questions, interviews, data collected/analyzed and your students’
experiences mentoring the host school pupils can be used as the basis for an energy
efficiency research project. The students may showcase their research project via a
presentation, paper, video, instruction manual, skit, poster, etc.

Additional Content:
Primary:

Secondary and Intermediate:
http://www.need.org/needpdf/LearningConservingTeacherGuide.pdf
http://www.need.org/needpdf/Monitoring%20Mentoring%20Teacher%20Guide.pdf


**References: Links are current as of June 20, 2012**

All NEED materials may be accessed at [http://www.need.org/](http://www.need.org/):  
[http://www.need.org/needpdf/LearningConservingStudentGuide.pdf](http://www.need.org/needpdf/LearningConservingStudentGuide.pdf)

2 "Inquiry Chart (I-Chart)." *All About Adolescent Literacy.*  


[http://www.need.org/needpdf/PlugLoads.pdf](http://www.need.org/needpdf/PlugLoads.pdf)

Excel Worksheet for Plug and Phantom Loads:  

A2.1 Ohayon, Jennie Liss. "Energy for Change Workbook." *Santa Cruz-Watsonville Inquiry-Based Learning in Environmental Sciences.* 13  


A2.4 Proud, Mike and Estabrooks, Ron. "Lighting Efficiency: A Comparison by Lighting Type". *Smart Energy User* 2 15 August 1996.  
[http://www.wisdompage.com/SEUhtmDOCS/SEU15.htm](http://www.wisdompage.com/SEUhtmDOCS/SEU15.htm)

A2.5 "Lamping Comparison Chart." *Eleek.*  

### Special Thanks:
- Wind for Schools Program (a branch of the US Department of Energy's Wind Powering America initiative)
- Boise State University
- CAES Energy Efficiency Research Institute
- iSTEM
- Dick Jordan, secondary science educator at Timberline High School, Boise, ID
- Idaho Power Company