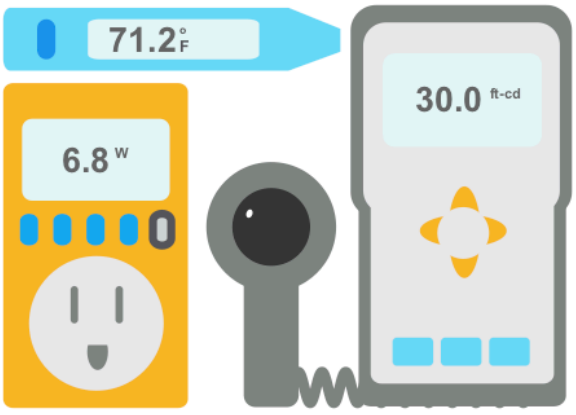
STRATEGIC ENERGY INNOVATIONS

Grade: 9-12

Version 5

August 2019

# Energy Audit Certificate




**Perform a school energy audit and gain hands-on experience to develop skills and awareness in the energy auditing profession**

# Table of Contents

# Curriculum Matrix: School Energy Auditing Certificate

~38 hours of coursework

| Module | | Lesson | | Schedule | Description |
|---|---|---|---|---|---|
| 0 | Intro | 0 | Introductions & Pre-Test | 25 minutes | Introduce unit and give student pre-test. |
| 1 | Why is Saving Energy Important? | 1.1 | Sustainability: Problems and Opportunities | 90 minutes | Intro to energy auditing: Why this is important work? What is the purpose of energy auditing? Students develop, analyze and discuss sustainability definitions and their personal carbon footprint. Students evaluate and compare home energy usage using the local utility's energy tool. |
| | | 1.2 | Climate Change | 225 minutes | Students explore, research, and discuss the causes and consequences of climate change. |
| 2 | Fundamentals of Energy | 2.1 | Energy and Power | 60 minutes | Students are introduced to the fundamentals of electricity: energy, power, current, voltage, and resistance. Students will learn the terminology and symbols relating to electricity and create and test their own electrical circuits. Students will build mini-generators to produce electric current, complete an activity where they diagram and make an electrical circuit, analyze their local fuel mix and analyze energy storage, critical for the solar industry. |
| | | 2.2 | Electrical Circuits | 90-135 minutes | |
| | | 2.3 | Electricity Grid | 135 minutes | |
| | | 2.4 | Energy Storage | 90-135 | |
| 3 | Tackling Energy Waste: Plug Loads and Lighting | 3.1 | Auditing Plug Loads | 135 minutes | Through hands-on assignments, students will conduct an energy audit of plug loads and calculate energy savings based on their recommendations. Students learn to identify inefficient lighting and to recommend appropriate lighting upgrades. Students will conduct a lighting audit, estimate energy and cost savings based on the implementation of their recommendations, and continue to develop an energy audit report. |
| | | 3.2 | Auditing Lighting | 135 minutes | |
| | | 3.3 | Lighting Levels, Lighting Controls, & Conservation Practices | 90 minutes | |

| | | | | | |
|---|---|---|---|---|---|
| 4 | Tackling Energy Waste: Mechanical Systems | 4.1 | Draft Detection & Thermostat Audit | 90 minutes | Students will act as detectives searching for unwanted air leakage and thermostat errors that result in wasted energy and uncomfortable indoor spaces in the school. |
| | | 4.2 | Mechanical Systems Audit | 6.5 hours | Students learn about the types of mechanical systems found in schools, their function, and rating systems including SEER and EER. Students learn to read rating labels on mechanical and electrical equipment to assist with identifying the year of manufacture and capacity. Students mechanical systems, including HVAC, pool pumps, commercial kitchens, building controls, water heating, motors, and renewable generation systems, where they exist. |
| 5 | School-Wide Audit, Rebates, & Reporting | 5.1 | School-Wide Energy Audit | 5.25 hour | Students will use the auditing skills they have developed throughout the Certificate to perform a school-wide walk-through audit of energy use. |
| | | 5.2 | Energy Audit Report & Presentations | 4.5 hours | Students complete their energy audit report and prepare to present to their school community and/or school board. |
| 6 | Green Careers | 6.1 | Green Careers | 90 minutes | Students explore the market sectors and job opportunities available in the green economy after obtaining marketable skills and knowledge by completing this curriculum. Students will complete a self-assessment to aid in identifying their career interests, will develop job search skills and materials, and will then, ideally, speak with professionals in the field. |
| 0 | Conclusion | 0 | Post-test, Peer Evaluation & Next Steps | 45 minutes | Students will take the post-test to evaluate learning retention and skills acquired through the training. Students and instructors share feedback. |

## Lesson 3.2 Overview

**Estimated Time**
2.25 hours

**Standards:**
***NGSS:*** HS-ESS3-2, HS-ESS3-4, HS-PS3-1, HS-ETS1-3
***CCSS:*** *Math* HSN.Q.A.1, HSN.Q.A.2, HSN.Q.A.3, HSA.CED.A.1, HSA.CED.A.4, HSA.REI.B.3,
*ELA Literacy* RST.9-10.3, RST.9-10.4, RST.9-10.7
***CTE:*** Energy, Environmental & Utilities: 2.0, 2.3; 5.0, 5.1, 5.3; A8.0, A8.4

**Objectives:** Students will be able to:
- Identify standard lighting types and their components
- Calculate energy consumption and cost to operate light fixtures
- Identify lighting retrofits and calculate energy savings based on the recommendations

**Handouts**
- 3.2.1 Classroom Incandescent/CFL/LED Bulb Audit & Retrofit Recommendations
- 3.2.2 Classroom Linear Fluorescent Lighting
- 3.3.3 Classroom Exit Signs Audit

**Materials**
- Smartphone with camera
- Computers with Internet
- Tape measure

**Additional Resources**
- How Fluorescent Lamps Work: http://home.howstuffworks.com/fluorescent-lamp2.htm
- School T12 to T8 Retrofit Project: https://www.energy.gov/eere/wipo/weatherization-and-intergovernmental-programs-office

# Lesson 3.2: Auditing Lighting

Lighting accounts for up to 11% of electrical energy consumption for businesses and commercial buildings and 7% of all electricity consumed in the United States.[6] In this lesson, we investigate lighting to identify measures and retrofits that can lead to significant energy savings. Through hands-on assignments, students will conduct a lighting analysis and calculate energy savings based on their recommendations.

## KEY WORDS

**Ballast:** A device that regulates the current going into fluorescent lamps

**Compact Fluorescent Light (CFL):** An energy efficient fluorescent light bulb used to replace traditional incandescent light bulbs

**Light Emitting Diode (LED):** A long-lasting lighting technology often that requires very little energy

**Linear Fluorescent Lamp:** Fluorescent light tubes common for interior overhead lighting in a school or office

**Luminaire:** The lighting industry's term for what is commonly referred to as a "light fixture." A luminaire consists of the housing, power supply (ballast or driver), "lamp" or light source, and optical components, such as reflectors and lenses.

**Rebates/Incentives:** Money or credit offered by utilities, state, or federal governments to help offset the initial investment for the installation of energy efficiency measures

**Walk-through:** The portion of an energy audit in which the auditor observes and collects data on the loads in a home or building

[6] https://www.eia.gov/tools/faqs/faq.php?id=99&t=3

## PREPARATION

- Prior to this lesson, review background material on lighting and lighting retrofits. Read through the handouts and become familiar with calculating lighting energy consumption. Gather materials required for the lesson (see the Materials Matrix in the Introduction Module).

- Prepare to discuss typical lighting types found in overhead lighting and exit signs in buildings. It would be helpful to ask a custodian for replacement lamps. Then, students can record information directly from the bulbs. Fluorescent lamps are fragile and contain mercury, so be careful when handling. Fluorescent bulbs must be recycled at a proper recycling or hazardous waste facility. If the school doesn't already have designated recycling containers contact the local municipal disposal agency or search these websites to find a recycling facility: https://www.epa.gov/cfl/recycling-and-disposal-cfls-and-other-bulbs-contain-mercury OR http://search.earth911.com/.
    - In the case of a broken bulb, proper ventilation is needed. Have people and pets leave the room and air out the room for 5-10 minutes by opening a window or door to the outdoor environment.
    - Shut off the central air heating/air-conditioning system, if you have one.
    - Scoop up glass fragments using stiff paper or cardboard. Use sticky tape, such as duct tape, to pick up any remaining small glass fragments and powder. All fragments should be sealed in a plastic bag before being recycled like intact bulbs.

- Obtain an incandescent lamp and its more energy efficient counterpart, the compact fluorescent light bulb (CFL). It will also be informative for the class if the instructor (or custodian) is able to remove the cover of an exit sign to show the lamps inside the fixture.

- Print the following handouts:
    - Classroom Incandescent/CFL/LED Bulb Audit & Retrofit Recommendations – one per student
    - Classroom Linear Fluorescent Lighting – one per student
    - Classroom Exit Signs Audit – one per student

Recommended Daily Lesson Breakdown:

- Day 1: Lighting Fixtures
    - Setting the Stage: Lighting Energy Consumption
    - Setting the Stage: Incandescent, CFL, and LED
    - Activity 1: Classroom Incandescent, CFL, and LED Survey
- Day 2: Classroom Lighting Audit
    - Setting the Stage: Types of Lighting Fixtures

- Activity 2: Classroom Lighting Audit

➢ Days 3 and 4: Exit Sign, Exterior Lighting, and Gym Lighting Audit

- Setting the Stage: Exit Signs, Gym, & Exterior Lighting
- Activity 3: LED Exit Signs, Exterior Lighting, and Gym Lighting Audit

## SETTING THE STAGE: LIGHTING ENERGY CONSUMPTION

➢ In 2014, about 412 billion kWh of electricity were used for lighting by the residential sector and the commercial sector, including schools, in the United States. This was about 15% of the total electricity consumed by both of these sectors, and about 11% of total U.S. electricity consumption.[7]

- To put 412 billion kWh in perspective, the greenhouse gas emissions from producing that amount of electricity are equal to almost 60,000,000 cars driven for a whole year!

➢ Inform students they will be conducting a lighting audit in the classroom first to learn and test their auditing techniques. Later in the course, they will conduct a walkthrough lighting audit of the school to make recommendations for conservation and retrofits.

➢ The classroom lighting audit will cover lighting fixtures such as incandescent, compact/linear fluorescent (CFL/LFL), and light emitting diode (LED) types as well as exit sign lighting. In the next section, students will learn about different types of lighting as well as how to identify them in the context of a lighting audit.

## SETTING THE STAGE: INCANDESCENT, CFL, AND LED

➢ Incandescent light bulbs are sometimes used in schools. They can be found in desk lamps, floor lamps, exit signs, and sometimes even in ceiling fixtures. [8]

- In the most basic form, incandescent lighting is still much like that invented by Thomas Edison 140 years ago. In the light bulb, electricity flows through a thin wire called the filament. The resistance against electricity flowing through the filament causes it to heat up and glow.
- The light bulb has no oxygen in it, so the filament does not catch fire or burn. It does, however, lose atoms from the intense heat and eventually weakens and breaks, causing the light bulb to burn out.
- Although the incandescent offers some of the best light quality at a low price, it is the least efficient: only 5-10% of the energy consumed by an incandescent bulb produces light; the rest is given off as heat.


Incandescent Light Bulb

[7] https://www.eia.gov/tools/faqs/faq.cfm?id=99&t=3
[8] https://en.wikipedia.org/wiki/Incandescent_light_bulb

- The lifespan of an incandescent lamp is short as compared to other technologies, causing its maintenance costs to be relatively high. Incandescent lamps last approximately 1,000 hours[9], which can mean multiple bulb changes per year for a lamp that is often in use, like an exit sign.

➢ **Compact fluorescent light (CFL)** bulbs use the same technology as linear fluorescent lamps, but they are designed to fit into lamps and other fixtures where incandescent light bulbs are commonly used.

- In a fluorescent lamp, light is created by sending electricity through a gas. This produces visible light, but also some ultraviolet light, which is invisible to the human eye.[10]

- To make the ultraviolet visible, the inside of a fluorescent light bulb is coated with phosphors, which absorb the ultraviolet light and change it to visible light. This brightens the light.


CFL Bulb

- The electricity needed by the lamp is converted and controlled by a ballast.

- Although CFLs cost slightly more than incandescent light bulbs, they save money in the long run because they use only one-fourth the energy of incandescent bulbs, they produce very little heat, and last 6 to 12 times longer[11].

- Fluorescent light quality is suitable for office and school lighting. The lamps are more energy efficient and have a longer lifespan than incandescent lighting.

➢ **Light Emitting Diode (LED) lamps** are comprised of an array of light emitting diodes which use solid-state electronics to create light.

- A LED is a light source which uses semiconductors and electroluminescence to create light. Electroluminescence happens when electrons are passed through certain materials, and the material emits light. Similar to a ballast, the electricity needed by the LED is controlled by a driver.[12]


LED Light Bulb

- A typical LED consumes 80% less energy than a comparable incandescent bulb and 50% to 80% percent less energy than a comparable CFL.[13]

- LEDs contain no mercury, and a recent Energy Department study[14] determined that LEDs have a much smaller environmental impact than incandescent bulbs. They also have an edge over compact fluorescent lights (CFLs) that's expected to grow over the next few years as LED technology continues its steady improvement and becomes more cost-effective.

[9] http://energy.gov/energysaver/articles/how-energy-efficient-light-bulbs-compare-traditional-incandescents
[10] Image Source: http://farm2.staticflickr.com/1086/1393726309_287fc8d340_o.jpg
[11] https://www.nachi.org/energy-lighting.htm
[12] ImageSource: http://commons.wikimedia.org/wiki/LED_lights#mediaviewer/File:Led_lamp.jpg
[13] http://energy.gov/energysaver/articles/how-energy-efficient-light-bulbs-compare-traditional-incandescents
[14] https://www.energy.gov/eere/articles/study-environmental-benefits-leds-greater-cfls

- From an energy stand point, LED lighting is versatile and energy efficient. Although the initial cost is higher than other light sources, the life expectancy is very long and the return on investment from energy and replacement savings makes upgrading to LEDs worth the initial cost.
- Maintenance and replacement costs are reduced because LEDs are estimated to have lifetimes between 25,000 and 100,000 hours[15]. Replacing incandescent light bulbs and CFLs with LEDs is a great way to save energy at your school!
- The development of white LEDs has helped LEDs gain popularity as a replacement for other white light sources. LEDs are currently commonly used for streetlights, indoor growing lights, traffic lights, and other lighting applications with long operational hours, and are increasingly being used to replace incandescent and fluorescent light bulbs as a cost-effective, bright, and quality alternative for overhead and task lighting.
- Compared to other lighting types, LEDs offer a variety of benefits. Some of these benefits include small size, long lamp life, low heat output, energy savings, and durability.[16] LEDs also come in many different colors, shapes, and sizes.
- More detailed information and discussion about the science behind LED technology is abundant on the internet. Visit https://energy.gov/energysaver/led-lighting for more LED facts.

## ACTIVITY 1: CLASSROOM INCANDESCENT/CFL/LED BULB SURVEY

- Provide a copy of the Classroom Incandescent/CFL/LED Bulb Audit & Retrofit Recommendations handout to each student (or to small groups). Explain that they are going to calculate the annual energy consumption and cost to operate the incandescent/CFL/LED light bulbs first in a scenario and then in the room in preparation to conduct this component of the audit for the school.
- Tips for supporting students with word problems: First, read the word problem with students and see if there are any questions. If the students are having trouble getting started on the word problem, ask them to:
  - Circle or highlight all of the important information or rewrite the important information elsewhere on the page.
  - Set-up and complete the equations one at a time.
  - When setting up the equations, use only the units instead of the numbers to figure out what units the final number will be in. Knowing the correct units, students can then go back and figure out the correct numbers to arrive a final answer.
- Have students calculate the scenario problems 1 and 2, and then discuss. Then, students will check to see if there are any incandescent light bulbs in their classroom.

[15] http://energy.gov/energysaver/articles/how-energy-efficient-light-bulbs-compare-traditional-incandescents
[16] http://energy.gov/energysaver/articles/how-energy-efficient-light-bulbs-compare-traditional-incandescents

- Solution to part 1:

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 bulbs | X | 100 W/bulb | X | 8 hrs./day | X | 5 days | X | kW/1000 W | = | 8 kWh |
| 1 bulbs | X | 60 W/bulb | X | 8 hrs./day | X | 5 days | X | kW/1000 W | = | 2.4 kWh |
| | | | | | | | | | | 10.4 kWh |

| | | | | |
|---|---|---|---|---|
| 10.4 kWh | X | $0.12/kWh | = | $1.23 |
| 10.4 kWh | X | 1.2 lbs. $CO_2e$/kWh | = | 12 lbs. $CO_2e$ |

- Solution to part 2:

| | | | | |
|---|---|---|---|---|
| 10.4 kWh | X | 80% | = | 2.08 kWh |
| $1.23 | X | 80% | = | $0.25 |
| 12.3 lbs. $CO_2e$ | X | 80% | = | $2.5 lbs. $CO_2e$ |

➢ For part 3, have students record the watts of each incandescent or CFL bulb they find in the classroom. To find out how many watts the incandescent light bulb uses:

- Turn off the lamp and let it cool for a minute.
- Look on the top of the incandescent bulb. You will see a number and the letter 'W'. For example, 60W means the light bulb uses 60 watts.
- In general, CFLs use 25% and LEDs use 20%[17] of the energy used by an incandescent to produce the same amount of light. To figure out the replacement CFL and LED wattage for an incandescent bulb, you can divide the wattage of the incandescent by 4 and 5, respectively, or refer to the chart below. This chart lists the CFL and LED wattages that are commonly used to replace incandescent light bulbs while providing the same level of illumination. The chart will help students to identify lighting types that may not be easily identified by their shape or the way they look. (For example, linear LEDs have become increasingly popular and resemble linear fluorescents)

[17] http://energy.gov/energysaver/articles/how-energy-efficient-light-bulbs-compare-traditional-incandescents