the gaia project
realistic environmentalism

Project Guide: Energy Audit: Lighting

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Energy Audit: Lighting

A guide to conducting a lighting inventory and tracking improvements as part of a sustainability plan in your classroom.

The Gaia Project is a charitable organization dedicated to providing project based learning opportunities in the areas of energy, environment and sustainable engineering.

We develop projects, provide professional development, technical support and ongoing project support for teachers and students. Our projects aim to incorporate three key principles, which symbolise our focus on realistic environmentalism.

1. **Data Informed Decisions** – We want students to be able to explain why, and quantify the effect of each decision they made along the way to their final solution.
2. **Economic Assessments** – We expect students to be able to assess the cost effectiveness of their solutions, and be able to optimize their projects with limited budgets.
3. **Environmental Impact and Lifecycle Assessments** – We need students to take a holistic view to their projects. This means looking at their projects from cradle to grave, as opposed to just examining the use phase, and acknowledging that greenhouse gas reduction is not the only environmental issue at stake.

For more information, please visit www.thegaiaproject.ca

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Lighting

Lighting is an essential aspect of most buildings. It's in virtually every room, and usually on for a good portion of the day – often when the room is unoccupied, or there is adequate natural lighting available.

It is estimated that about 20% of energy use in buildings is attributable to lighting, and it is one of our least efficient technologies. An incandescent light bulb only converts about 2% of the energy it uses into light. The remaining 98% produces heat.

Even fluorescent lighting, which is significantly more energy efficient, only convert 10% of the energy used into light—a five fold improvement, but still 90% is going to heat.

This means that our lighting really comes from heaters that happen to produce light as a by-product. This doesn't make a whole lot of sense since we don't always want heat at the same time as light (think about summer evenings). Different lighting technologies can have a huge impact on the lighting portion of our energy bill.

Light intensity levels can also be measured to ensure that light intensity is at optimal levels for the task at hand, and not to dim or too bright. Doing so ensures that the energy we use on lighting is actually useful lighting.

Discussing with your class

Ask students whether they think the classrooms are too bright. Are there classrooms with enough light even on an overcast and cloudy day to work? Are there any motion sensor lights in the school?

Also ask students to think about lighting at home—do they leave the lights on all of the time? If so, why? What would make you consider turning off the lights when you leave the room? What type of light bulbs do they use at home?

Essential Resources

Sustainability Plan: The Gaia Project

http://www.thegaiaproject.ca/sites/default/files/teacher-resources/project-guides/sustainability-plan.pdf

Energy Audit: The Gaia Project

http://www.thegaiaproject.ca/projects/sustainability-planning/energy

Inventory

Establishing a lighting inventory is an important first step in assessing lighting energy use. The inventory simply accounts for all the lights in a particular building, their location and their size.

Taking an inventory is as straightforward as counting each light fixture in each room in a building. We should be looking at the type of light fixture, the wattage per bulb, and the number of bulbs in each room.

The wattage of a light bulb can generally be found by looking at the bulb, and reading the writing on the side of it. If some of these bulbs are inaccessible, talk to your custodial staff and see if they have any spare bulbs available for you to look at.

An example of this inventory is shown in Table 1.

Room	Light Type	Wattage per Bulb (W)	Number of Bulbs	Total Wattage (W)
Room 1	Overhead Fluorescent	32	80	2,560
	Desktop Incandescent	60	3	180
Room 2	Overhead Fluorescent	32	40	1,280
	Desktop Incandescent	60	1	60
Gym	Metal Halide	400	40	16,000
Total				20,080

Table 1: Example Lighting Inventory

Time of Use

Just knowing the number and wattage of lights in the school doesn't help much in assessing energy use associated with lighting. The amount of energy used by a bulb obviously depends on how much time it is used for.

Monitoring

The most effective way to determine the amount of time that lighting is used for is to monitor it. This could be by through monitoring it in person (either continuously, or checking in intermittently) – although this is probably not a viable option in the middle of the night.

Fortunately, we have datalogging light meters available (Xplorer GLX). Leaving one of these running in a room for an extended period of time will collect data on the lighting levels present in that room. It should be possible from analyzing that data later to tell when the lights were on, and when they were off.

It may be necessary to verify some readings before leaving the light sensor in place. Find out:

- What are the approximate lighting levels at the sensor location when all the lights are on?
- What about when only the front lights are on?
- Does opening and closing the curtains have a measurable impact on the data?

By answering questions like these beforehand, it becomes easier to tell whether a rise in lighting intensity in a room was due to the lights being turned on, or the curtains being opened.

Survey

A quick way to determine time of use for lighting is to survey the user of those lights. In a classroom for example, it would most likely be the teacher. We would want to know which lights are turned on, and for how many hours a day they are turned on for.

The disadvantage of a survey is that the answers aren't always accurate. This is for a number of reasons, including:

- People tend to answer surveys in the way that they think they are supposed to answer. So when conducting an energy audit, it is likely that people will exaggerate their claims of how little they use their lights.
- The individuals being surveyed often aren't the only ones with control of the lights. They may switch the lights off at the end of the day when they leave to go home, but they have no idea if someone comes in 5 minutes later and turns them back on again.

For this reason, surveys should be used with caution. While it may be impractical to monitor each room, it might be worthwhile monitoring a few rooms and seeing how they compare with the survey responses to determine whether or not the surveys can be trusted.

Energy Use

The next step is to add this data to our table, now shown in Table 2 [see end of document]. We can now calculate the amount of energy use per day by simply multiplying the wattage of the lighting by the amount of time it is in use.

It's important to realize that one day may not be the same as the next – particularly when talking about weekends versus weekdays.

Light Intensity

Light intensity levels are contained in the Canada Occupation Health and Safety Regulations [see additional resources], and require that lighting be at a certain **minimum** level for various activities. They also provide **recommended** levels, which are considered to be optimum for workplace health and safety. Lights can be both too dim and too bright.

When measuring lighting intensity levels using a light sensor, it is important to measure it at the right location. For example, in a classroom, this would be on the work surface.

Also keep in mind that lighting isn't uniform, and that some work surfaces may have higher light intensity than others. This might mean measuring light intensity at various points throughout a room.

Windows can also have a major impact on light intensity, and will obviously change throughout the day. This means that a light intensity measured at noon with all the lights on may not be the same as the light intensity measured at midnight with all the lights on. Again, keep in mind what you are measuring. In a classroom, we are most interested in light intensity between the hours of 8am and 4pm, but we have to be sure that they can still be used in the evenings or on overcast days.

Light also reflects off objects and surfaces, and the proximity of different surfaces, colours and finishes may have an influence on your results.

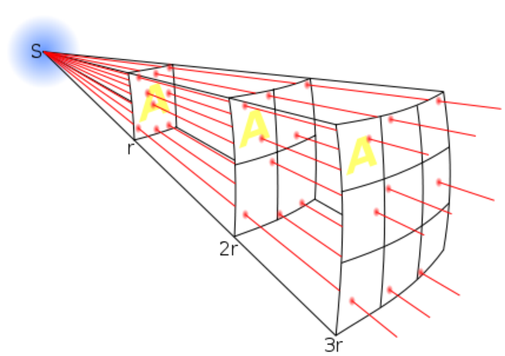
Calculating

Light spreads out from a point in a sphere. So if we have a fixed amount of lighting power, we can imagine that all that power is equally distributed over the surface of that sphere.

The surface area of a sphere can be calculated by:

$$A = 4\pi r^2$$

So that means, every time we double the radius (or distance from the light source), we have a sphere with four times the surface area ($2^2 = 4$). So if we double the distance from the light to a surface, we will only have ¼ of the light intensity on that surface. This is known as the **inverse square law** and is illustrated in Figure 1—note that tripling the distance results in nine times the surface area ($3^2 = 9$) each receiving



1/9 of the light.

Figure 1: Inverse Square Law

If we double the power of the light source, we will double the light intensity on all surfaces.

We measure light intensity in Lumens / m^2 or Lux.

$$1 \text{ Lm} / m^2 = 1 \text{ Lux}$$

Additional Resources

Canada Occupation Health and Safety Regulations

http://laws.justice.gc.ca/eng/SOR-86-304/page-3.html?noCookie#anchorbo-ga:l_VI

Inverse Square Law

http://en.wikipedia.org/wiki/Inverse-square_law

Light Intensity / Illuminance

http://en.wikipedia.org/wiki/Illuminance

Glossary

Energy

Rate of power use. Measured in Joules (J), Watt-hours (Wh) or more commonly, kiloWatt-hours (kWh).

Inverse Square Law

Light spreads out from a point in a sphere. Thie area of this sphere at any distance away from the light source (r) can be calculated as $A = 4\pi r^2$. The amount of light emitted by the light is spread over this area. If we double the distance from the light source, the area of the circle quadruples, meaning the light intensity at any point will be 1/4 of the original value.

Kilowatt Hour

Measure of energy consumption by electrical utilities. Equal to 1 kW of power use for a period of 1 hour.

Light intensity

A measure of the perceived power of light hitting a given area. It is measured in lux, defined as lumens per square metre, and can also be called illuminance.

Power

Rate at which energy is converted to do work. Measured in watts (Joules per second).

Useful Values

Energy

1kWh = 3,600,000 Joules

1 Wh = 3,600 Joules

Power

1 hp = 746 Watts

Energy Audit: Lighting

Table 2: Adding Time of Use to Lighting Inventory

Room	Light Type	Wattage per Bulb (W)	Number of Bulbs	Total Wattage (W)	Hours per Day (hours)	Energy Used per Day (Wh)	Energy Used per Day (kWh)
Classroom 1	Overhead Fluorescent	32	80	2,560	8	20,480	20.48
	Desktop In-candescent	60	3	180	3	540	0.54
Classroom 2	Overhead Fluorescent	32	40	1,280	12	15,360	15.36
	Desktop In-candescent	60	1	60	1	60	0.06
Gym	Metal Halide	400	40	16,000	14	224,000	224
Total				20,080		260,440	260.44