the gaia project
realistic environmentalism

Energy Audit: Plug-In Loads

Project Guide

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Energy Audit: Plug-In Loads

A guide to conducting a plug-in load 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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Plug-In Loads

Plug-in loads represent all of our devices that plug in to standard wall outlets. Many of them seem small and insignificant, but this is the fastest growing area of energy use in our schools and homes as we add more technology.

Discuss

Look around the classroom and notice how many and what types of devices are plugged in. Do you know how much power typical devices in the classroom like a SMARTboard or laptop might use?

What type of electrical devices are present in the classroom today that might not have been there 5 years ago? What types of electrical devices do you have at home that weren't there 5 years ago?

Plan

As a guide to start the process of auditing, this project guide includes **Worksheet 1: Plug-in Load Audit: Plan.** This worksheet begins by identifying what devices to focus on, and determine some of the basic action steps. **This worksheet should be completed first and passed in to the teacher**.

There is an important distinction to make here that needs to be very clear: the difference between power and energy. **Power** is measured in Watts (W), which is equivalent to a Joule per second, and is the rate at which electrical energy is converted to do work. **Energy** is measured in Watt-hours (Wh), or more familiarly, **kilowatt hours (kWh)**, and is the rate at which power is used. At the school and residentially, we are billed for the number of kWh used in the billing period.

As an analogy to driving a car:

- Power is similar to the speed of the car
- Energy is similar to the total distance travelled

A car travelling at a fast speed (i.e. a device using a large amount of power) will cover a large distance in a given amount of time (*will consume a large amount of energy in a given amount of time*).

Furthermore, a car travelling very fast for a short amount of time will cover the same distance as a car travelling slowly for a long period of time. Keep this comparison in mind when thinking about the energy use between a toaster and TV, for example.

Additional Resources (copy and paste into your browser)

Electrical Power

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

Kilowatt Hour

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

Power Requirements

Most electrical devices have a label on them that indicates the electrical specifications for the product. This will usually include a voltage, a current and a power rating. An example can be seen in Figure 1.

Figure 1: Electric label example

The problem is that these labels are usually written for the maximum operating condition, and often don't take account of power factor, so should generally not be used. Many devices have several modes. A computer, for example, will have three modes:

- On (in use)
- Off
- Standby (on, but not being used)

Each of these modes will likely have different power requirements. There are a few different ways to determine power requirements of these electrical devices. Remember that we do not need to analyze every single electrical load – *one SMARTboard is probably used in a similar way to another* (assuming they are the same model).

Appliance Meter

An easy way to determine the amount of power being used by an electrical device is to use an Appliance Meter. You can plug the device in question into the meter, and run the device through each of its modes (or wait for it to cycle through each of its modes), and take an approximate power reading in Watts from the LCD screen on the meter. The device has the ability to log data over long periods of time. Please see **Appliance Meter –Equipment Guide**, for full instructions on using the appliance meter.

Time of Use

Knowing the number of electrical devices and their operating power doesn't help much in assessing energy use associated with plug-in loads. The amount of energy used by a device depends on how much time it is used for.

Survey

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

An example of the survey process would be for the students to put sheets beside all the microwaves in the school, and ask people to put a checkmark on them for every time the microwaves were used, and for how long it was used. Students can help in the development of an appropriate survey for the type of device they are trying to measure.

Another option would be to interview the principal users of the devices, or to send out a survey to each of the users—such as teachers whose classes have SMART boards.

Students can develop a survey appropriate to the device they are examining. Consider the main disadvantage of surveys: 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 they turn off all the computers every time they leave the room.
- The individuals being surveyed often

aren't the only ones with control of the device. They may turn off all of the computers 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.

Energy Use

Students can now use their estimate of how long each device being examined is on for each mode to estimate how much energy the device consumes during a typical day. To scaffold this process, the Appendix of this document contains **Worksheet 3: Estimating Energy Use per Day**. **Hand this worksheet in to your teacher when complete.** Also, please see the sample calculations at the end of the appendix. The amount of energy (Wh, or kWh) used per day can be calculated by multiplying the power (W) of the device by the amount of time it is in use (h). This can be done for both school and non-school days, if the device is used differently on these occasions.

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

However, there is also value in making assumptions. Estimating the energy use for each SMARTboard in the school and taking an average is a good way to roughly estimate energy used by all of the SMARTboards in the school. It also opens the door to discussion of significant digits, or place value for numbers since this will be a gross estimate.

Analysis and Recommendations

Now that you have an estimate for energy used by devices, you will likely have some ideas as to what can be changed to save money spent on energy at the school. Some recommendations might be obvious such as turning out the lights when no one is in the room, or somewhat less obvious such as removing additional microwaves that are never used based on user surveys.

Think about who will implement any recommendations, and who will follow up on them. Turning the lights off in a classroom might seem easy for the first few days, but we also need to consider who will ensure that this continues into the longer term.

Economic Analysis

Considering the economics of possible energy savings gives a greater importance to items being identified.

This economic analysis of how much a particular device costs the school on school and non school days will give a good idea of where savings can be made most easily, and of the impact that they will have.

In calculating money spent on energy, please see **Worksheet 4: Estimating energy use per year** in the Appendix. **Hand this worksheet into your teacher when complete.** This worksheet begins by identifying the cost of electricity for schools - any savings made will be in the range for which schools are charged $0.0852/kWh.

Glossary

Energy

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

Kilowatt Hour

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

Power

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

Useful Values

Energy

1 kWh = 1,000 Wh

1 kWh = 3,600,000 Joules

1 Wh = 3,600 Joules

Power

1 hp (horsepower) = 746 Watts

Contents of Appendices

- Worksheet 1: Plug-in load audit: Plan
- Worksheet 3: Estimating energy use per day
- Worksheet 4: Estimating energy use per year
- Sample calculation: step-by-step process from power readings to estimating energy costs. Not meant to be supplied to students, but as a resource for teachers.

WORKSHEET 1

PLUG-IN LOAD AUDIT: PLAN

(Hand in when complete)

Devices we plan to look at (you don't have to fill in every line):

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For each device, think about the following:

Are there different modes for this device?
Example: Computer: ON, OFF, STANDBY

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How often do you think the device is used?

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How could you figure out how often the device is used?

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How many of these devices are there at the school?

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Is this device plugged in all year round? Or just on school days?

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If it is plugged in all year round, what are some opportunities for energy savings?

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WORKSHEET 3

ESTIMATING ENERGY USE PER DAY

(Hand in when complete)

Using the data you gathered from your Watts Up? meter, fill in this table. You don't need to fill in every row – just do as many as the number of devices your team examined, and the number of modes that device has.

Type of Device	Mode	Power (Watts)	Time (hours)/day	Energy (Watt-hours) = Power (W) x Time (h)
Example: Mr. B's Computer (typical school day)	On – in use	105 W	5 h	525 Wh
	On – standby	75 W	3 h	225 Wh
	Off	0 W	16 h	0 Wh
	Total time (always 24 hours):		24 h	
	Total energy (add up all of your energy estimates from the day):			750 Wh /day
	Total time (always 24 hours):			
	Total energy (add up all of your energy estimates from the day):			
	Total time (always 24 hours):			
	Total energy (add up all of your energy estimates from the day):			

WORKSHEET 4
ESTIMATING ENERGY USE PER YEAR

(Hand in when complete)

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Device	Energy/day for all devices (Wh)	Energy/day (kWh) = Wh/1000	Energy/year (kWh) = Energy/day (kWh) x days/year	Cost/year ($/year) = Energy/year (kWh) x $0.0852/kWh	Number of Devices in the school	Cost/year of all devices = Cost/year ($/year) x Number of devices
Example: Mr. B's Computer	750 Wh	0.75 kWh	0.75 x 185 = 138.75 kWh	138.75 kWh x $0.0852/kWh = $12/year	30	$350

Some important information: There are 185 school days. There are 365 days in a year. That means that there are 180 non-school days.

Sample Calculation

This sample calculation will examine power consumption of teacher's laptops at the school. Let's assume that there are 30 laptops in this particular school, and that they all possess three modes: on, standby, and off.

Table 1: Data Collection

Mode (example: On, off, clock)	Power Reading: Watts	Estimate time it's on for (hours)	Energy: Wh
On - Running	105	5	525
On – Standby	75	3	225
Off	0	16	0

In the case of table 1, there is only the fourth column for which we need to complete some calculations. We know that the units of Energy are Watt-hours, that the units of Power are Watts, and time, hours. In order to obtain our energy, we do the following:

$$Energy\ (Wh) = Power\ (W) * Time\ (h)$$

For the mode on-running, we would perform the following calculation:

$$Energy\ (Wh) = 105\ Watts * 5\ hours = 525\ Wh$$

Following this format for calculations allow us to fill in the fourth column of Table 1.

Once we have these numbers, we can move on to Table 2.

Table 2: Energy use for the Day

<table>
<tr><th>Device</th><th>Mode</th><th>Power (Watts)</th><th>Time (hours)/ day</th><th>Energy (Watt-hours) = Power (W) x Time (h)</th></tr>
<tr><td rowspan="5">Example:
Mr. B's Comput-er (typical school day)</td><td>On – in use</td><td>105 W</td><td>5 h</td><td>525</td></tr>
<tr><td>On – standby</td><td>75 W</td><td>3 h</td><td>225</td></tr>
<tr><td>Off</td><td>0 W</td><td>16 h</td><td>0</td></tr>
<tr><td colspan="2">Total time (always 24 hours):</td><td>24 h</td><td>-</td></tr>
<tr><td colspan="3">Total energy (add up all of your energy estimates from the day):</td><td>750 Wh /day</td></tr>
</table>

This table is extremely similar to the one that we just completed, with the exception that we will be calcu-lating the total energy used during the day. We can fill in the information that we already have, and in order to fill in the last remaining square, we simply do the following:

$$Total\ Energy = Energy\ Mode\ 1 + Energy\ Mode\ 2 + Energy\ Mode\ 3 + \cdots$$

In our case, this calculation looks like:

$$Total\ Energy = 525\ Wh + 225\ Wh + 0\ Wh = 750\ \frac{Wh}{day}$$

Now that we have calculated the total energy for a day, we can consider the total costs to the school of running the devices during the school year.

Table 3: Calculating Costs

Energy/day (Wh)	**Energy/day (kWh)** = Wh/1000	**Energy/year (kWh)** = Energy/day (kWh) * days/year	**Cost/year =** Energy/year (kWh) * $0.10/kWh	**Number of Devices in the school**	**Cost/year of all devices =** Cost/year ($/year)* Number of devices
750	0.75	0.75 x 185 = 138.75 kWh	138.75 kWh x $0.0852/ kWh = $12/ year	30	$350

We already have the values for the energy used each day per device. We now need to figure out what this number is in kWh, as that is the basis used for billing.

$$\frac{Energy}{day}\ (kWh) = \frac{Energy}{day}\ (Wh) * \frac{1\ kWh}{1000Wh}$$

This scenario, we obtain the following:

$$\frac{Energy}{Day}\ (kWh) = \frac{750Wh}{day} * \frac{1\ kWh}{1000\ Wh} = 0.75\ kWh$$

We now need to figure out how much energy we are using per year. There are 195 school days in a year. This allows us to calculate the following:

$$\frac{Energy}{year}\ (kWh) = \frac{Energy}{day}\ (kWh) * \frac{Days}{year}$$

$$\frac{Energy}{year}\ (kWh) = 0.75\ \frac{kWh}{day} * 185\ \frac{days}{year} = 138.75\ \frac{kWh}{year}$$

Once we known how much energy is used per year, we can calculate the cost of one device per year. This is done as such, using $0.10 as the cost of one kWh of energy.

$$\frac{Cost}{year}\ (\$) = \frac{Energy}{year}\ (kWh) * \frac{\$0.10}{kWh}$$

$$\frac{cost}{year}(\$) = 138.75\ \frac{kWh}{year} * \frac{0.0852\$}{kWh} = 11.82\ \frac{\$}{year}$$

Once this is figured out, the next step is to figure out how much all of the devices of this type cost the school over the course of the year. In order to do this:

$$\frac{Total\ Cost}{year}(\$) = \frac{Cost\ for\ one\ device}{year}\ (\$) * number\ of\ devices\ at\ school$$

For the example above, since we have 30 laptops in the whole school, we obtain:

$$\frac{total\ cost}{year}(\$) = \frac{12\$}{year} * 30\ laptops = \frac{\$350}{year}$$