the gaia project
realistic environmentalism

Project Guide: Energy Audit: Plug-In Loads

The Gaia Project
53 Shore Street
Fredericton, NB
E3B 1R3

1 (877) 442-4136
www.thegaiaproject.ca
contact@thegaiaproject.ca

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

The Gaia Project
53 Shore Street
Fredericton, NB
E3B 1R3
Canada
1 (877) 442-4136
contact@thegaiaproject.ca

This project guide has been produced with the support of:

- New Brunswick Department of Environment
- The McCain Foundation
- Irving Oil
- The R. Howard Webster Foundation
- Dillon Consulting
- Airfire Telephone and Data
- Stantec
- TD Waterhouse

Front Cover Credits

Plug-In Loads

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

Discussing with your class

Ask students to look around the classroom and notice how many devices are plugged in. Ask them if they 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?

Load Inventory

Establishing a load inventory is an important first step in assessing energy use. The inventory simply accounts for all the plug-in loads, location and average power usage.

There's an important distinction to make here—the difference between power and energy. **Power** is measured in Watts (Joule per second) and is the rate at which electrical energy is converted to do work. **Energy** is measured in watt hours, or more familiarly, **kilowatt hours** and is the rate at which power is used. We are billed for the kilowatt hours we use at home..

Taking an inventory is as straightforward as counting each plug-in load in a building. We won't need to analyze every load individually – for example there may be several computers that are identical in a room. An example of this inventory is shown in Table 1.

Table 1: Plug In Load Inventory

Room	Device	Number
Room 1	Computer (HP1234)	4
	Computer (HP5678)	3
	SMARTboard	1

Essential Resources

Sustainability Plan: The Gaia Project
http://www.thegaiaproject.ca/projects/sustainability-planning

Energy Audit: The Gaia Project
http://www.thegaiaproject.ca/projects/sustainability-planning/energy

Additional Resources

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

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

Determining 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: Electrical 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 photocopier for example will have:

- Warm-up
- Scanning
- Printing
- Standby
- Sleep

A refrigerator will have two main modes:

- Compressor on
- Compressor off

Each of these modes will 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 the same as another (assuming they are the same model).

Watts Up? Meter

The most effective way to determine the amount of power being used by an electrical device is to use the Watts Up? Meter. You can plug the device in question into the Watts Up? Meter, and run (or wait for) the device through each of its modes, and take an approximate power reading (in Watts) from the LCD screen on the Watts Up Meter or by uploading and viewing the data on a computer.

We can then amend Table 1, to include the additional information seen in Table 2 [see end of document].

It might be difficult to analyze each of the different modes, and sometimes it might not even be necessary to. For example, loads that run 24 hours a day on a pretty steady schedule may have different modes, but since these modes are not user-dependent, we don't really need to know the details. Instead, we could just find the average power.

For example, a vending machine or a refrigerator could be plugged into the Watts Up? Meter and left to run for a week. The data can then be analyzed and an average power consumption can be obtained. This can be seen in Table 3 [see end of document].

AC/DC Clamp Meter

Not all plug-in loads can be found using the Watts Up? Meter. Several large devices run off 220V power supplies, and have a different plug. These devices often have their own breaker in the circuit breaker panel, and it may be possible (not recommended for students) to determine the current flowing to the device.

Alternatively, use a 220V extension cord, strip the insulation off the outside of the wire to expose the inside wires (still individually isolated), and clamp the meter over a single conductor.

Power Factor

Many electrical devices contain **reactive loads** that react to current flowing through them. In contrast, purely **resistive loads** (such as heating and lighting) don't react to current flowing through them.

Reactive loads contain capacitors and inductors, such as in a motor where there are interfering magnetic and electric fields. In reactive loads, energy gets temporarily stored in the magnetic and electric fields inside the device before being returned to the grid. This energy is in addition to the energy consumed in the load.

Because a reactive load actually draws more current than it uses, it appears to use more power than it actually does. We call this amount of power **apparent power**.

Real power is used to define the actual amount of power a device uses.

Apparent power can be calculated by measuring the amount of current that flows to a device by the voltage driving that current.

Apparent Power (W) = Voltage (Volts) x Current (Amps)

Real power is always less than or equal to apparent power, and that difference is attributable to something called the **power factor**.

Real Power (Watts) = Voltage (Volts) x Current (Amps) x Power Factor (%)

The Power Factor is a number that relates the real power used to the apparent power used.

$$\text{Power Factor} = \frac{\text{Real Power (W)}}{\text{Apparent Power (W)}}$$

A couple of points to remember:

- Real power is what utilities charge for in terms of in terms of energy use.
- Devices such as lighting typically have a power factor of close to one, while motors tend to have a lower power factor.
- Higher power factors (closer to 1) are considered better by your utility.
- Some utilities actually charge customers who have a low power factor a premium for disturbing their system.

The Watts Up? Meter is capable of measuring power factor as one the variables which can be selected when setting up the meter.

It's important to realize that the current measured by the AC/DC Clamp Meter will only allow you to calculate apparent power. To calculate real power, we need to include the power factor. We can find approximate power factors for various devices by searching online, or looking in user manuals for the device.

Time of Use

Just 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 obviously depends on how much time it is used for.

Monitoring

The most effective way to determine the amount of time that a device is used for is to monitor it. This could be by 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, you have datalogging power meters available (Watts Up? Pro). Leaving one of these running with a plug-in load for an extended period of time will collect data on the power used by a device. It should be possible from analyzing that data later to tell when the device was in use and what mode it was in.

It may be necessary to verify some readings before leaving the Watts Up? Meter in place. For example, with a computer, find out approximate power used when the computer is:

- being used
- left idle with the screen on
- left idle with the screen off
- put into standby mode
- turned off

By answering questions like these beforehand, it becomes easier to tell which mode the computer is in, and for how long it was in that mode.

Remember that we don't need to analyze every single load. In a computer lab, it's very likely that every computer has a pretty similar time of use profile.

Survey

A quick way to determine time of use for device is to survey the user. In a classroom for example, it would 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.

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 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.

For this reason, surveys should be used with caution. While it may be impractical to monitor every device, it might be worthwhile monitoring a few devices 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 4 [see end of document]. We can now calculate the amount of energy use per day by simply multiplying the wattage (power) of the device 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.

Glossary

Apparent Power

Reactive loads draw more current than they actually use (some it is sent back to the grid) meaning that appear to draw more power than use.

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 kW 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).

Power Factor

Real power is always less than or equal to apparent power. The power factor describes this relationship and is calculated by dividing the real power by the apparent power.

Reactive Loads

The opposition to a change in current; this energy is stored inside the electric and magnetic fields before returning to the grid. This is in addition to the power already consumed and gives what we call apparent power.

Real Power

The actual amount of power an electrical device uses.

Useful Values

Energy

1kWh = 3,600,000 Joules

1 Wh = 3,600 Joules

Power

1 hp = 746 Watts

Table 2: Adding average power data for different modes

Room	Device	Number	Mode	Average Power (Watts)
Classroom 1	Computer (HP1234)	4	Working	150
			Idle	80
			Standby	40
			Off	2
	Computer (HP5678)	3	Working	130
			Idle	50
			Standby	10
			Off	1
	Smartboard	1	On	300
			Standby	50
			Off	2

Table 3: Adding average power data where different modes are irrelevant

Room	Device	Number	Mode	Average Power (Watts)
Cafeteria	Vending Machine 1	1	Average	400
	Vending Machine 2	2	Average	350

Table 4: Adding Time of Use to calculate Energy Use

Room	Device	Number	Mode	Average Power (Watts)	Time Used per Day (hours)	Energy Used per Day (Wh)	Energy Used per Day (kWh)
Classroom 1	Computer (HP1234)	4	Working	150	3	1,800	1.80
			Idle	80	4	1,280	1.28
			Standby	40	17	2,720	2.72
			Off	2	0	0	0.00
	Computer (HP5678)	3	Working	130	3	1,170	1.17
			Idle	50	4	600	0.60
			Standby	10	4	120	0.12
			Off	1	13	39	0.04
	Smartboard	1	On	300	4	1,200	1.20
			Standby	50	20	1,000	1.00
			Off	2	0	0	0.00
Cafeteria	Vending Machine 1	1	Average	400	24	9,600	9.60
	Vending Machine 2	2	Average	350	24	16,800	16.80
Total						36,329	36.33