



Project Guide: Energy Audit: Degree Days

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Energy Audit: Degree Days

A guide to using the concept of degree days in your energy auditing and conservation project

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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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Degree Days

Degree Days are a unit of measurement that allows us to compare the amount of heating or cooling required in a given period.

A **degree day** is equivalent to having to heat or cool a room / building by 1°C for an entire day.

For convenience, degree days are usually designated as **Heating Degree Days** (HDDs) where heating is required, and **Cooling Degree Days** (CDDs) where cooling is required.

Discussing with your class

Ask students whether we can compare energy used at the school on a day in September to a day in January (if the school is electrically heated). When is peak power use? How can we compare energy use at the school on a day in January to a day in April?

In Canadian schools, where most of the activity is in the winter months, and schools rarely have the need (or the ability) to cool the building, this guide will focus on Heating Degree Days. The process for Cooling Degree Days is identical (just in reverse).

Using Degree Days

Now that you know what Degree Days are, what exactly are they used for?

Degree Days allow us to effectively manage building energy usage. It would be nice to compare month to month how well a building is performing if you are trying to reduce its energy consumption.

Of course, it is pretty difficult to compare the month of February to the month of June. In

virtually all circumstances in Canada, substantially more energy will be used in February than in June due to heating.

Fortunately, most buildings lose energy in a proportional manner to the outdoor temperature. Double the difference in temperature between the indoors and outdoors, and we pretty much double the rate of heat loss.

So if you start to track energy use and degree days over an extended period of time, you can actually start to isolate the portion of your energy bill that is related to heat.

You can then eliminate the effects of changing temperature, and compare buildings on a like for like basis:

- How much energy is used **per Heating Degree Day** for heating?
- How much energy is used for everything else?

This process is discussed in detail in our Energy Audit: Heating package.

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>

Energy Audit: Heating: The Gaia Project

<http://www.thegaiaproject.ca/sites/default/files/teacher-resources/project-guides/heating-audit.pdf>

Calculating

Here is the process for calculating heating degree days using an example:

1. **If the outdoor temperature is a constant 10°C for one day and the indoor temperature needs to be 20°C, how many HDDs are there in the one day period?**

$$\text{HDDs} = (20^{\circ}\text{C} - 10^{\circ}\text{C}) \times 1\text{day}$$

$$\text{HDDs} = 10^{\circ}\text{C} \times 1\text{ day} = 10\text{ HDDs}$$

2. **How about in a twelve hour period?**

When working in hours, we simply need to divide by the number of hours in a day at the end of the formula.

$$\text{HDDs} = (20^{\circ}\text{C} - 10^{\circ}\text{C}) \times 12\text{hours} \times \frac{\text{day}}{24\text{hours}}$$

$$\text{HDDs} = 10^{\circ}\text{C} \times \frac{12}{24}\text{days} = 5\text{HDDs}$$

Of course, we are rarely going to experience a constant temperature for an extended period of time. So we could break it down to be more accurate.

3. **Suppose in a day the outdoor temperature is 5 °C for 12 hours, 6 °C for 6 hours, and 7 °C for 6 hours. The indoor temperature still needs to be kept at 20°C. How many HDDs are there in the 24 hour period?**

We have two options here. Firstly, we just perform the same calculation as in step 2. for each time period and add them together.

$$\begin{aligned} \text{HDDs} &= \left[(20^{\circ}\text{C} - 5^{\circ}\text{C}) \times \frac{12}{24}\text{hours} \right] \\ &+ \left[(20^{\circ}\text{C} - 6^{\circ}\text{C}) \times \frac{6}{24}\text{hours} \right] \\ &+ \left[(20^{\circ}\text{C} - 7^{\circ}\text{C}) \times \frac{6}{24}\text{hours} \right] \\ &= 14.25\text{HDDs} \end{aligned}$$

Or we could calculate the average temperature over the course of the 24-hour period, and then use that temperature for the whole day. This involves a weighted average calculation.

$$\text{Avg.} = \frac{(5^{\circ}\text{C} \times 12\text{hours}) + (6^{\circ}\text{C} \times 6\text{hours}) + (7^{\circ}\text{C} \times 6\text{hours})}{24\text{ hours}}$$

$$\text{Average Temperature} = 5.75^{\circ}\text{C}$$

$$\text{HDDs} = (20^{\circ}\text{C} - 5.75^{\circ}\text{C}) \times 1\text{day} = 14.25\text{HDDs}$$

As you can see, the results are the same.

If we already had access to the average daily temperature, then the second method would be a lot simpler, especially when you consider the fact that the temperature changes constantly throughout the day and is not just split into three distinct periods as in the example.

Fortunately, average daily temperature are readily available from at least one source.

Average Daily Temperatures

You may have site specific average daily temperatures available to you from a weather station.

If not, Environment Canada has weather stations located across Canada, and there is a good chance there is one fairly near you. While the data may not be exact for your location, it is probably going to be pretty close, and good enough for your application.

The climate data on the Environment Canada website can be a little tricky to navigate, so here are step by step instructions to find your data.

1. Go to the Environment Canada Climate Data Online website [see Essential Resources at end of section]
2. Click on **Customized Search**
3. Under **Search by Province**
 - a. Select Province of interest
 - b. Enter the appropriate range of years
 - c. Click **Search**
4. Choose the nearest weather station to your site
5. Set **Data Interval** to Daily
6. Select **Month** and **Year** of interest
7. Click **Go**
8. Weather data for specified station, month and year will be displayed
9. Scroll to the bottom of the page to download the data for the month, or the entire year in CSV or XML format (both can be opened in Excel)

Essential Resources

Environment Canada Climate Data Online
http://www.climate.weatheroffice.gc.ca/climateData/canada_e.html

Balance Temperature

Instead of using the indoor temperature as the reference point for calculating HDDs, we need to use something called the **Balance Temperature**. People and equipment emit heat, and sunlight provides some more, so it isn't necessary to actually heat a building all the way up to the desired temperature. We actually only need to heat it up to the balance temperature, and let the equipment and people inside the building will do the rest.

Of course, the balance temperature varies from building to building. A warehouse, with little electrical equipment and few people per square foot won't gain as much heat as a church or a school will when fully occupied.

You might have noticed this when you first walk into a building that has been empty all night (such as a school), and it feels colder than it does later in the day.

Typically, we can assume the balance temperature is 3.5°C below the indoor temperature. So if the desired indoor temperature is 20 °C, we use 16.5 °C when calculating HDDs.

Calculating from Environment Canada Data

The downloaded Environment Canada data already has Heating and Cooling Degree Days calculated and inserted into the table.

Environment Canada uses a balance temperature of 18°C for calculating their degree days; however, this may not be appropriate and we may need to recalculate.

The raw data downloaded should look something like Table 1 [see end of document]

Adjusting the Balance Temperature

The Heating and Cooling Degree Days, are just based on the difference between the Mean Temperature Column and the balance temperature of 18°C. So if we need to change the balance temperature, we can just reform the data into Table 2.

Table 2: Adjusted Balance Temperature

Date	Mean Temp (°C)	Balance Temperature (°C)	Heat Degree Days (°C)
01/01/2009	-11.5	20	31.5
02/01/2009	-9.3	20	29.3
03/01/2009	-9.8	20	29.8
04/01/2009	-5	20	25
05/01/2009	-5.3	20	25.3
06/01/2009	-6.5	20	26.5
07/01/2009	-6.5	20	26.5

We have to be a little bit careful here, and not just copy the formula all the way down blindly.

If we have a day where the average temperature is 10°C and the balance temperature is 20°C then the number of Heating Degree Days is clearly:

$$\text{HDDs} = (20^{\circ}\text{C} - 10^{\circ}\text{C}) \times 1\text{day}$$

$$\text{HDDs} = 10^{\circ}\text{C} \times 1\text{ day} = 10\text{ HDDs}$$

However, using the same formula when the outdoor average temperature is 21°C, yields:

$$\text{HDDs} = (20^{\circ}\text{C} - 21^{\circ}\text{C}) \times 1\text{day}$$

$$\text{HDDs} = -1\text{C} \times 1\text{ day} = -1\text{ HDDs}$$

This negative Heating Degree Day means heat needs to be removed from the building, and is actually a Cooling Degree Day, more correctly calculated as:

$$\text{CDDs} = (21^{\circ}\text{C} - 20^{\circ}\text{C}) \times 1\text{day}$$

$$\text{CDDs} = 1\text{C} \times 1\text{ day} = 1\text{ CDDs}$$

It might seem ok to leave Cooling Degree Days at negative Heating Degree Days, but the problem occurs when we try to look at the number of Heating Degree Days in a period, say over the course of two days.

If we simply sum them as we initially calculated:

$$\text{Total HDDs} = 10 + -1 = 9\text{ HDDs}$$

which is not correct, as it implies we had to heat the building less than we did. Just because the following day was warm, does not mean we didn't need to heat the building up as much the previous day. The correct calculation would be:

$$\text{Total HDDs} = 10 + 0 = 10\text{ HDDs}$$

$$\text{Total CDDs} = 0 + 1 = 1\text{ CDDs}$$

Variable Daily Balance Temperature

Depending on how a building is occupied, or

managed, the balance temperature may be different on different days. For example, a school on a weekend may not have all the computers running or people in the building. For this reason, the balance temperature may only be 2°C below the actual indoor temperature. The school may also be allowed to cool down since there is no occupancy.

This could be reflected in our heating degree days calculation as seen in Table 3 [see end of document].

Variable Hourly Balance Temperature

It may also be the case that your building is allowed to cool down at night. In this case, we can calculate a weight average daily balance temperature.

So on a day where between 7am and 7pm, the balance temperature is 20°C, while between 7pm and 7am, the balance temperature is 17 °:

$$\text{Avg. Bal. Temp.} = \frac{(\text{Bal. Temp. 1} \times \text{hours1}) + (\text{Bal. Temp. 2} \times \text{hours2})}{\text{hours1} + \text{hours2}}$$

$$\text{Avg. Bal. Temp.} = \frac{(20^\circ\text{C} \times 12) + (17^\circ\text{C} \times 12)}{24} = 18.5^\circ\text{C}$$

This would then be reflected in your calculations as in Table 4 [see end of document].

Glossary

Balance Temperature

People and equipment emit heat, and sunlight provides some more, so it isn't necessary to actually heat a building all the way up to the

desired temperature. We only need to heat it up to the balance temperature, and let the equipment and people inside the building will do the rest. For an average building, this is usually about 3.5°C below the desired temperature.

Cooling Degree Day

Maintaining a room / building 1°C cooler than the outside temperature for an entire day.

Degree Day

Measure of heating or cooling required in a building.

Heating Degree Day

Maintaining a room / building 1°C warmer than the outside temperature for an entire day.

Table 1: Raw Environment Canada Climate Data

Date/Time	Year	Month	Day	Data Quality	Max Temp (°C)	Max Temp Flag	Min Temp (°C)	Min Temp Flag	Mean Temp (°C)	Mean Temp Flag	Heat Deg Days (°C)	Heat Deg Days Flag
01/01/2009	2009	1	1		-10.5		-12.5		-11.5		29.5	
02/01/2009	2009	1	2		-5.5		-13		-9.3		27.3	
03/01/2009	2009	1	3		-5.5		-14		-9.8		27.8	
04/01/2009	2009	1	4		0.5		-10.5		-5		23	
05/01/2009	2009	1	5		-2		-8.5		-5.3		23.3	
06/01/2009	2009	1	6		-4.5		-8.5		-6.5		24.5	
07/01/2009	2009	1	7		-0.5		-12.5		-6.5		24.5	

Table 3: Different Balance Temperatures for Different Days

Date/Time	Mean Temp (°C)	Indoor Temperature (°C)	Balance Temperature (°C)	Heating Degree Days (°C)
01/01/2009	-11.5	23.5	20	31.5
02/01/2009	-9.3	23.5	20	29.3
03/01/2009	-9.8	19	17	26.8
04/01/2009	-5	19	17	22
05/01/2009	-5.3	23.5	20	25.3
06/01/2009	-6.5	23.5	20	26.5
07/01/2009	-6.5	23.5	20	26.5

Table 4: Allowing for variations in balance temperature throughout the day

Date/Time	Mean Temp (°C)	Indoor Temperature	Hours per Day @ T1	Indoor Temperature 2	Hours per Day @ T2	Balance Temperature	Heating Degree Days (°C)
01/01/2009	-11.5	20	12	17	12	18.5	30
02/01/2009	-9.3	20	12	17	12	18.5	27.8
03/01/2009	-9.8	20	0	17	24	17	26.8
04/01/2009	-5	20	0	17	24	17	22
05/01/2009	-5.3	20	12	17	12	18.5	23.8
06/01/2009	-6.5	20	12	17	12	18.5	25
07/01/2009	-6.5	20	12	17	12	18.5	25