Green Building Series

REGIONAL DISTRICT OF NANAIMO

Renewable Energy
INTRODUCTORY GUIDEBOOK

DEVELOPED FOR HOMEOWNERS in the REGIONAL DISTRICT OF NANAIMO
British Columbia, Canada

Introduction of Residential Renewable Energy Systems

MESSAGE FROM THE CHAIR

REGIONAL DISTRICT OF NANAIMO

On behalf of the Regional District of Nanaimo Board of Directors, I'm pleased to present the RDN's second Green Building Best Practices Guidebook. This volume focuses on Residential Scale Renewable Energy Systems.

Whether residents are passionate about addressing climate change, or motivated by personal responsibility, independence and self-sufficiency, this Guidebook aims to provide useful information on the different types of renewable energy systems suitable for the Regional District of Nanaimo.

Transitioning toward renewable energy systems and putting the power to generate energy into the hands of local residents combines taking responsibility for our own needs with economic development opportunities and environmental benefits. Our hope with this work is to help that transition along, ensuring that the RDN remains a great place to live for generations to come.

Joe Stanhope, Chair, Regional District of Nanaimo Board of Directors

ALSO IN THE GREEN BUILDING SERIES

Rainwater Harvesting Best Practices Guidebook:

Residential Rainwater Harvesting Design and Installation. (2012)

Disclaimer:
The RDN assumes no responsibility for the performance of any renewable energy system designed or installed, whether in reliance on this handbook or otherwise, and makes no warranty or representation regarding the quality, safety or performance of any renewable energy system.

"We are on the verge of a profound shift in the way we produce and use energy.

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David Suzuki Foundation, Energy Overview

ACKNOWLEDGEMENTS

The Residential Renewable Energy Systems Guidebook is part of the Regional District of Nanaimo's (RDN) Green Building Action Plan and supports the strategic priorities, goals and objectives of the RDN Board of Directors.

"If we work now to influence more conservative behaviour, increase our knowledge and understanding and build efficient infrastructure, we will reduce potential impacts and adapt successfully to new conditions... ensuring that the region remains an exceptional place to live, adapting and thriving to continuous and inevitable change."

-Regional District of Nanaimo's Board of Directors
Board Strategic Plan, 2013-2015

This Renewable Energy Best Practices Guidebook has been produced by the Regional District of Nanaimo (British Columbia, Canada), in partnership with:

TERRATEK ENERGY SOLUTIONS INC.
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Terratek's System Schematics provided by David Peacock of Lloma Design.

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1.) INTRODUCTION

This guidebook has been produced by the Regional District of Nanaimo (RDN) to encourage the use of renewable energy systems in existing residential homes and new construction. It has been designed as an educational tool to support homeowners and builders to make decisions about appropriate renewable energy systems, and considerations to ensure high quality installations.

The information in this publication represents industry knowledge at the time of publishing, and provides the best local information available to assist homeowners and builders interested in exploring renewable energy options in this region. Some of the information here will become out of date as the renewable energy industry continues to evolve. Readers are encouraged to use this Guidebook as a starting point and consult qualified professionals in the field to obtain the most up-to-date technical and pricing information.

Homeowners and builders who are interested in installing renewable energy systems should also consult local governments to ensure the proposed projects are in compliance with relevant regulations. Solutions to addressing legitimate concerns such as view access, noise level, height restrictions, setbacks, and development and building permits should be considered and discussed as early in the process as possible.

The Regional District of Nanaimo and its member municipalities have voluntarily embraced developing climate change and energy plans for their respective operations and the region-wide community.

1.1) Chapter Summaries

- **Chapter 1:** Introduction
  Outlines the advantages of renewable energy systems, defines energy units, describes the benefits of energy monitoring and offers insight into finding the right professionals for the job.

Section I: Thermal Heating Systems covers common systems that generate heat rather than electricity.

- **Chapter 2:** Solar Hot Water
  Solar systems that use sunlight to heat water for domestic uses.
- **Chapter 3:** Geoexchange
  Heat exchange systems that use the constant temperature of the earth to provide heating and cooling.
- **Chapter 4:** Biomass
  Combustion systems that use organic matter as fuel to provide heating.

Section II: Electric Power Systems covers common systems that generate electricity directly for household use.

- **Chapter 5:** Power Systems Overview
  Explains grid-tie, battery back-up, and off-grid systems.
- **Chapter 6:** Solar Electric
  Photovoltaic systems that convert sunlight directly into electricity.
- **Chapter 7:** Wind Electric
  Systems that use a wind turbine to convert the movement of the wind directly into electricity.
- **Chapter 8:** Micro-Hydro
  Systems that use the power of rushing water to spin a turbine generator for electricity production.

1.2) Why Renewable Energy?

Renewable energy is generated from the sun, wind, earth, vegetation and water. These energy sources are replenished naturally and reduce dependence on non-renewable energy sources such as fossil fuels, natural gas and oil. Renewable energy systems can help homeowners reduce emissions, while increasing cost savings and energy efficiency.

These are long-term investments, with multiple factors to consider to fully understand the real return on investment. Over the 2010-2013 period, electricity rates increased by over 20% (6.11% in 2010; 8.00% in 2011; 3.91% in 2012 and 1.44% in 2013), and further increases are planned for coming years (28% from 2014 to 2018). Investing in renewable energy systems can decrease reliance on utilities in favour of freely available renewable energy. With the promise of energy independence in the face of increasing uncertainty, renewable energy systems can provide security and peace of mind now and for future generations.

The amount of energy consumed can depend on many factors. Climate, fuel prices, household size, and dwelling size can all influence the quantity of energy used by a household.

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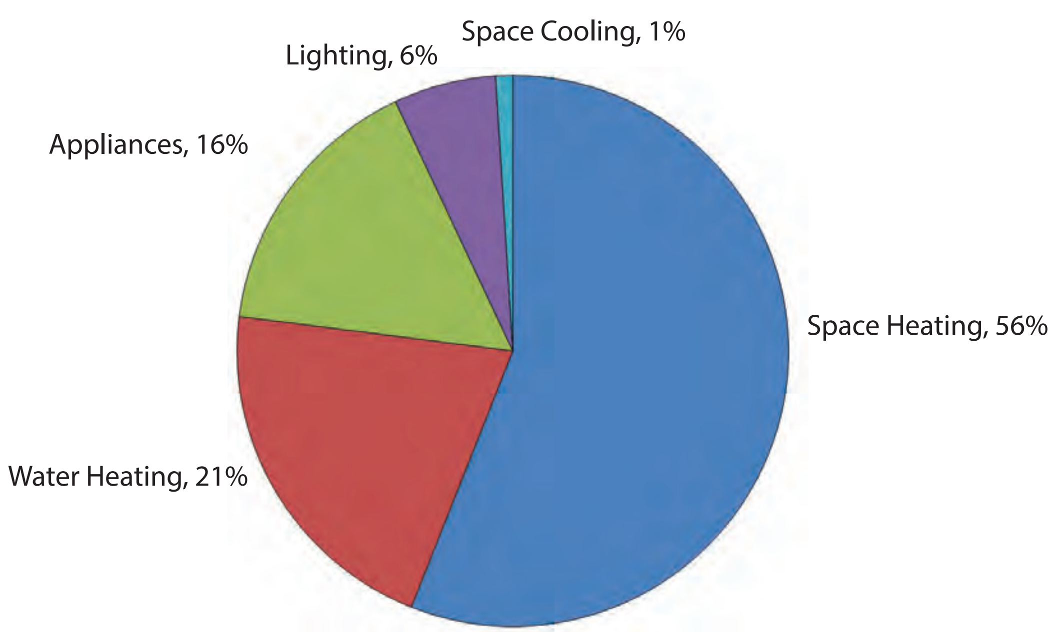
Statistics Canada Website

1.3) Average Household Energy Consumption

Every household is different. Household energy use varies according to home size and age, number and age of occupants and personal habits, as well as geographic location and local climate. Nevertheless, there are consistent patterns for energy consumption in homes in the RDN and across Canada. Canadian homes use energy for a number of household needs, from lighting and heating (including water), to running refrigerators and air conditioners. While space heating and water heating account for a significant amount of energy consumed, appliances and other devices, such as TVs and computers, also contribute to total household energy use.

The first step to lower energy consumption is to eliminate waste energy and reduce energy loss. This can be achieved primarily through improving the performance of the building envelope such as adding insulation, replacing old windows or weatherproofing doors and other openings. . Home energy efficiency can be further improved through energy efficiency upgrades. For example, replacing an old refrigerator with an Energy Star appliance, or replacing incandescent light bulbs with LED lighting. The final step to achieving energy independence or net-zero energy capacity is through the installation of renewable energy systems.



Average Household Energy Use in Canada
Source: Natural Resources Canada

1.4) Considering Peak Loads

For the purpose of this discussion, 'load' refers to the sum of all energy consumption by all consumers in a given network. Peak load is the moment when this sum of all consumption reaches its highest point in a given interval of time, usually a day. Peak load is important because it is the time when the highest level of stress is placed on an energy network. It also represents the highest level of demand for energy across a network, therefore peak load determines the scale of the infrastructure that must be built, including generating capacity, transmission lines, and so on.

Meeting homeowners' future demand for electricity during peak loads requires utilities to consider what new electricity transmission and generation resources will be needed down the road. Average growth rate in domestic electricity demand, primarily through growth in population and economic activity, will be taken into account when peak load costs are addressed in BC.

Although not currently in place in BC, in some jurisdictions prices increase during periods of peak load, usually between 7am - 11am and 5pm - 7pm. This approach to pricing is known as time-of-use billing, and uses price signals to shift household behaviour. For example, running the dishwasher at 10pm at night, or during the afternoon, will optimize time-of-use rates resulting in lower energy costs. The graphic below illustrates how time-of-use billing works in Ontario.

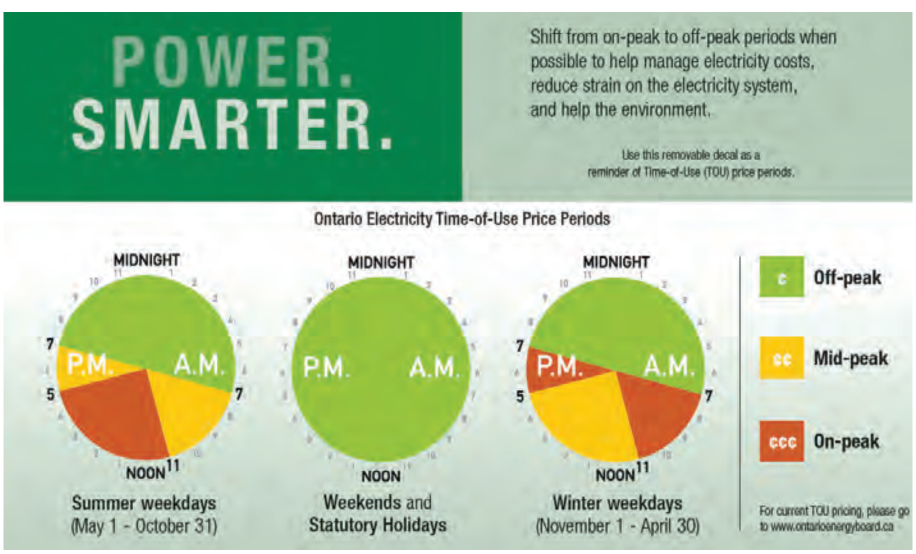


Image Courtesy of Ontario Energy Board
www.ontarioenergyboard.ca

Renewable energy systems can play two important roles in limiting the effects of peak load:

- By providing power from a source of energy that is separate from the grid, renewable energy systems can reduce the overall demand distributed along conventional utility networks thereby reducing peak load. This is generally only the case when renewable energy systems are producing energy or have a means to store energy, with battery banks, for use during peak periods.

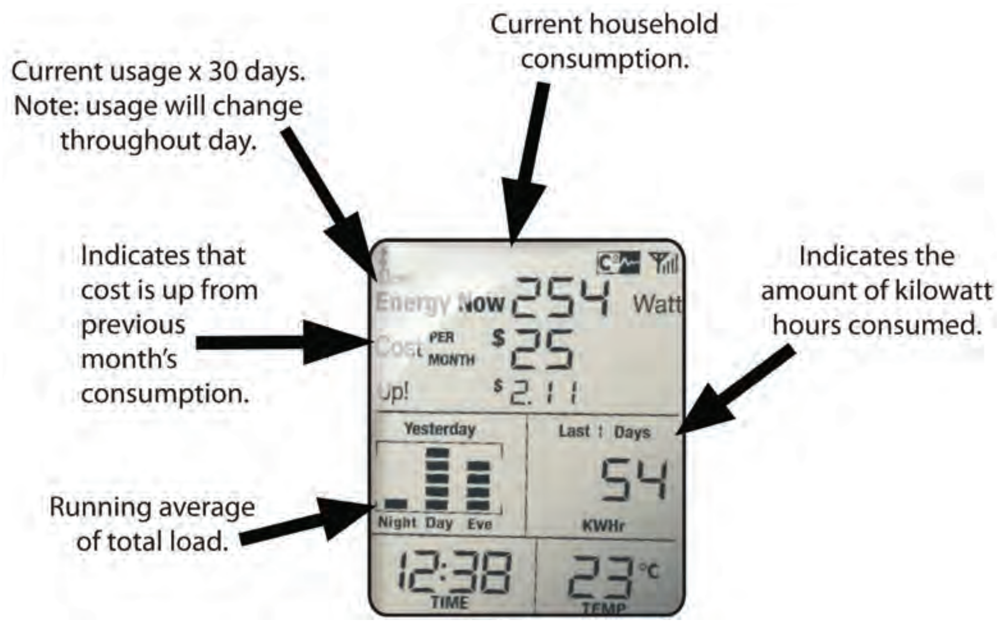
- With time-of-use billing in place, renewable energy producers are encouraged to sell electricity for a premium price during peak periods, limiting the need to increase centralized generating capacity to meet peak loads.

1.5) Energy Monitoring

Energy monitoring is simply a matter of keeping track of household energy use. When homeowners compare energy consumption month to month by looking at utility bills, they have taken the first step toward energy monitoring. Unfortunately, monthly billing does not provide very useful information for homeowners interested in details about home energy use. For this, more sophisticated monitoring tools are needed.

Nowadays anyone can purchase and install an energy monitoring device that measures household energy use minute-by-minute in real time. These devices can even be connected to individual appliances, revealing the load in watts, consumption in kilowatt hours, or cost of energy used by a fridge, stove, water heater, or any other plug-load in the home.

By providing this level of instantaneous information, energy monitors can help homeowners take control of their energy use. This can encourage conservation and translate into reduced energy consumption. For example, energy monitors maximize efficiency and productivity by pinpointing inefficient appliances like an energy guzzling fridge. Identifying these issues can help when making upgrade decisions in the home.



Basic home energy monitor screen capture.

Energy monitors are an indispensable tool for understanding energy use and identifying opportunities for further conservation in the home. This is extremely beneficial knowlege for a homeowner operating a renewable energy system.

Energy monitors for renewable energy systems are also available to measure the performance of renewable energy systems and can alert to problems needing attention, thereby ensuring the system performs to its highest potential. This can be an important part of protecting your investment in renewable energy technology.

For people considering investing in a renewable energy system for their home, installing an energy monitoring device that shows real time energy use on an appliance by appliance basis should be an immediate first step.

1.6) A Note on Common Terms

There are specific units of energy used when discussing renewable energy systems. In **Section I: Thermal Heating Systems**, energy production for solar hot water, geoexchange and biomass systems centres around **Coefficient of Performance**, or COP. This is the ratio between the heating or cooling produced by a system and the energy required to operate that system. A COP of 1 means the same amount of energy is produced and consumed by a system. Other common terms used when describing a thermal heating system's energy output are Gigajoules and British Thermal Units.

Gigajoule (GJ): A GJ is equal to one billion joules (10^9), which is a unit of energy, work, or amount of heat. The GJ is the common unit of measure for natural gas consumption that customers will find on gas bills in BC.

» One GJ can keep a 60-watt light bulb continuously lit for six months.

British Thermal Unit (BTU): BTU is a standard unit of measurement to state the amount of energy in a fuel, as well as the amount of output of a heating device. One BTU is equal to about 1,055 joules.

» Eight BTUs will raise a US gallon of water one degree F. For an average home in BC, roughly 30,000,000 BTUs are used per year for household space and water heating.

In **Section II: Electric Power Systems** The unit commonly used to describe the energy output of solar electric, micro-hydro and wind systems is kilowatt-hour, or kWh.

Kilowatt-hour (kWh): A kWh is a unit of energy equivalent to one kilowatt, or 1000 watts (10^3), of power expended for one hour of time.

» A device using one kilowatt of energy consumes one kWh of energy in exactly one hour. An average BC home, according to BC Hydro, uses 11,000 kWhs a year.

An online tool to convert energy units is: **www.onlineconversion.com**.

1.7) Finding the Right Professionals

Due diligence is critical when looking for qualified renewable energy installation companies. Below are key considerations to ensure service excellence and workmanship, and maximize system performance.

Key Questions:

- Are they a licensed contractor?
- Do they have industry training from associations like the Canadian Solar Association, CanSIA, or Canadian Wind Energy Association, CanWEA?
- What is their education in renewable energy? What is their history of experience and number of installs?
- What awards or industry recognitions does the company have?
- Are testimonials available from previous customers?

Section I: Thermal Heating Systems

Thermal heating systems are systems that provide heat, primarily for domestic hot water and space heating. These technologies include solar hot water, or solar thermal, geoexchange and biomass.

Solar domestic hot water system.

“I’d put my money on the sun and solar energy, what a source of power! I hope we don’t have to wait until oil and coal run out, before we tackle that.”

***

Thomas Edison

2.) SOLAR HOT WATER

2.1) An Introduction to Solar Hot Water

In Canada, hot water is the second highest energy demand in an average household, representing about 25%-35% of total energy consumption in BC homes, according to Environment Canada. Installing a solar hot water system offers one of the most cost-effective renewable energy solutions to reducing your electric or gas bill by alleviating reliance on utility-produced energy sources. When properly sized and installed, a solar hot water system can provide up to 60% of your annual hot water needs.

Solar hot water systems convert sunlight into heat through solar collectors usually mounted on the roof. The solar collector, or collectors, are positioned to face south for best performance. As the sunlight passes through the collector's glazing, it strikes a material that converts the sunlight into heat while the glazing prevents the heat from escaping. Water, or a water and antifreeze solution, carries heat from the collectors through a heat exchanger to a solar storage tank, which holds domestic hot water for subsequent use. A solar storage tank typically works in conjunction with a traditional hot water tank or on-demand heater, since weather affects solar hot water production. The traditional tank, or on-demand heater, then becomes a back-up to the solar tank, bringing the solar pre-heated water up to the desirable temperature when needed.


© Terratek
Two flat plate solar hot water collectors on a residential home in Comox Valley.


© Terratek
Four collector residential solar hot water system.


© Terratek
Flush-mount roof racking system for solar collectors.

© Terratek
Solar hot water tank (r) with a pump station and external heat exchanger attached.

Quick Self-Assessment: is Solar Hot Water Right for You?

There are some simple ways to find out if your home is suitable for solar hot water:

- You have a high demand for hot water, due to a large household, or a need for large volumes of washing, for example.
- Your home has at least six square metres of south-facing roof space.
- There is limited shade from 10am - 4pm on the south-facing roof space.
- You have room for a solar storage tank next to your existing hot water tank.

2.2) Viability of Solar Hot Water

A common misconception is that BC is not feasible for solar technologies because of the weather. Our province actually gets quite a lot of sunshine, with most people in BC enjoying an average of 2,000 hours of sunshine per year[1].

In Southern regions, such as Victoria and Vancouver, sunshine provides roughly 2,100 hours per year. In Nanaimo the average sunshine hours per year is 1,905, based on The Weather Network's average over 30 years.

If you consider this in terms of 10 hours of daylight per day, it equates to almost five and a half months of sunshine, which is plenty to make solar heating an effective renewable energy source. In contrast, Germany which is one of the leading countries to use solar technology, receives 1,625 sunshine hours a year in Berlin, with the highest sunshine hours of 1,740, received in Southern Germany's Freiburg[2].

The supply of solar energy comes from light generated by the sun, rather than from direct sunlight, so even on cloudy days solar energy can be used to provide a percentage of domestic hot water needs.

2.2.1) Bylaw Requirements and Permits

All bylaw requirements or building permits needed for the job are usually handled by the installation company you choose to hire. For the installation of a solar hot water system your contractor will need to get a plumbing permit, and a building permit may be required. These additional fees should be part of their quotation.

1 Source: Environment Canada Climate Weather Office.
2 Source: www.currentresults.com.

2.3) Different Types of Systems

A variety of solar hot water designs are available for consumers. There are different types of collectors and components, as well as methods of freeze and overheating protection. For the purpose of this guidebook the focus is on systems with water or an antifreeze mix; typically propylene glycol, which are known as closed-loop systems. Many solar hot water systems in BC are closed-looped, proving to be popular in our climate because of their efficiency in freezing temperatures. Closed-loop systems make use of a heat exchanger and a heat-safe, gylcol-based heat transfer fluid that gives the system a means of freeze protection. They are also easy to install for both new construction and retrofit projects. Other system types are: open systems, drain back systems and thermosyphon systems. These systems can be difficult to install due to unique, individual requirements such as sloping the supply and return piping at an angle large enough to drain or needing to install the collectors below the solar storage tank.

For more on open and closed loop systems, a brief summary can be found on the Solar Contact website listed in 2.8) Resources.

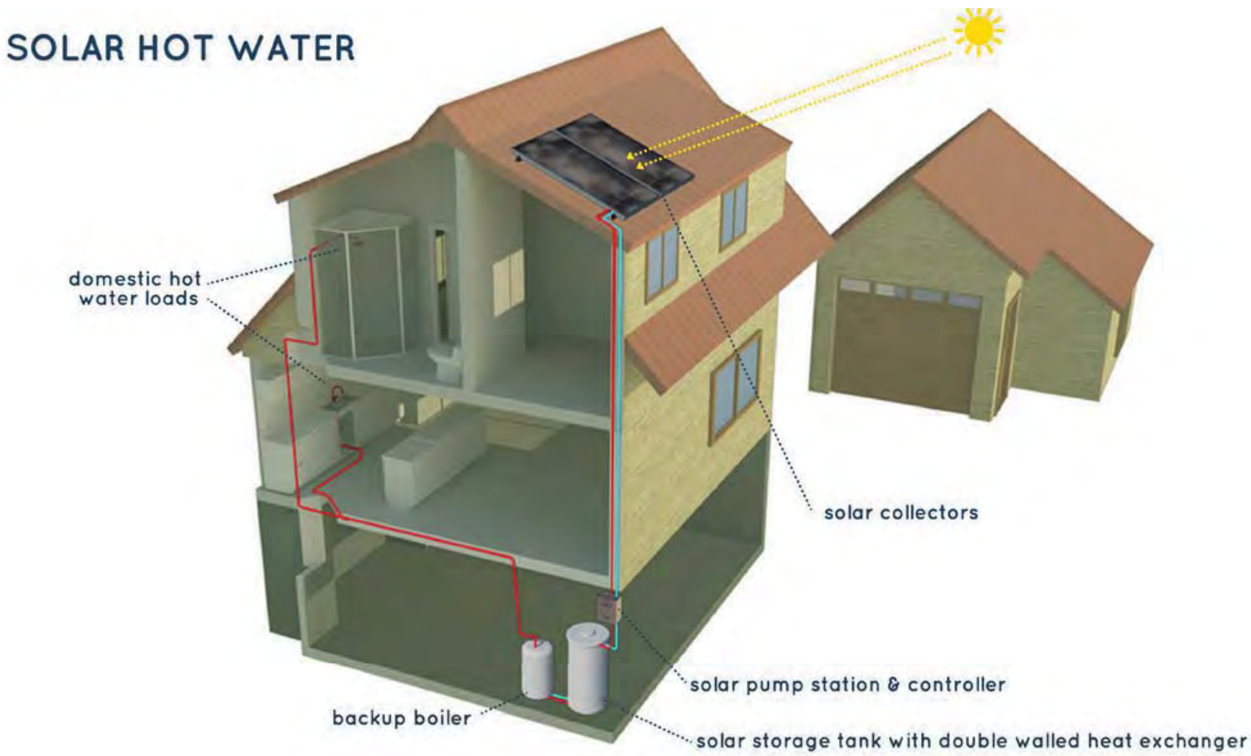
There are two main types of collectors for closed-looped systems:

- **Flat Plate** collectors consist of a dark flat-plate absorber, heat-transfer fluid to remove heat from the absorber, insulation and a heat reflecting back sheet. Sunlight hits the absorber plate, heating it up and changing solar energy into heat energy. Heat is then transferred to liquid passing through pipes attached to the absorber plate, and pumped into an insulated water tank.
- **Evacuated tube** collectors are composed of multiple evacuated glass tubes each containing an absorber plate fused to a heat pipe. Heat from the header or top hot end of the heat pipes is transferred to the transfer fluid and pumped into an insulated water tank.

Single flat plate collector.

Two evacuated tube collectors.

2.3.1) System Schematics



2.3.2) Basic Components

The basic components of a solar hot water system are:

- Solar collector(s) and metal racking equipment, typically for a roof.
- Solar pump station, usually located next to the solar storage tank. The solar pump station is used to circulate the glycol and to control the temperature of the hot water storage. The controller, also known as a differential controller, measures the temperature of the collector and the temperature of the storage tank.
- Double walled heat exchanger with visible leak detection for glycol-based systems. The double-wall design means that any leakage passing through the heat exchanger shows up on the outside of the heat exchanger, which can safely be taken out of operation for service.
- Solar storage tank, the size of which depends on the number of collectors. For example, a single collector would require a 40 gallon tank, two collectors would need a 60 gallon tank.
- Back-up boiler is the home's traditional hot water tank.

2.3.3) Sizes of Systems and Price Averages

In homes of three people or less, a one-collector solar hot water system should be adequate. In households with three to six people, two collectors will usually be needed. Today, single collector systems typically start at $6,800. Two collector systems usually begin at $8,800. This price has not changed dramatically over the last five years because there is less demand for the technology in comparison to the increased global application of solar electric, where prices have dropped considerably in the last five years. While almost everyone uses electricity, not everyone uses a significant amount of domestic hot water.

For a quick energy savings calculation on a solar hot water system, refer to Natural Resources Canada's "Solar Water Heating Systems, A Buyer's Guide".

Case Study: Solar Hot Water, Duncan, BC

Friends and neighbours had a lot of questions when one homeowner in Cowichan Bay, BC, was building a solar hot water system into his new home. While most of the queries revolved around the technology and cost benefits one neighbour in particular wasn't too sure about the system's performance potential. "But he was eventually won over when I told him about the difference in my hydro bills," says the homeowner.

Compared to the house he and his wife lived in previously, a similar sized single-family home in the area, the hydro bills have been significantly lower. "I get a real kick out of looking at the temperature on the hot water tank," he adds. "Especially on a sunny day."

The couple decided to incorporate solar hot water into their new build in part because they knew they'd be in the home well into retirement. They also learned after calling various installation companies in the area to determine a price, that it was cheaper to build the system into the new home construction.

The total cost of installation was $6,500 before taxes, saving the homeowner approximately $400 if he were to retrofit the installation. While there was the option of building "solar ready" to make it easier to retrofit a system down the road, the couple was prepared to pay the initial cost upfront in order to begin recouping those savings right away.

For more on building solar ready, refer to "Guide to the Province of BC Solar Hot Water Ready Regulation" listed in 2.8) Resources.

In terms of the build itself, incorporating the system proved to be both straightforward and tidy. "It was an easy thing to do," he says. "In my case it was quite simple, I had my hot water tank planned in a closet in the laundry room so I made the closet a bit bigger to accommodate the solar hot water tank."

Now that they're living with the system, he says his favourite aspect is that it's completely unobtrusive, as well as the knowledge that when the pump turns on they know they're relying on the sun, rather than a utility company.

Source: Terratek Energy Solutions

Single collector solar hot water system on new home in Duncan, BC.

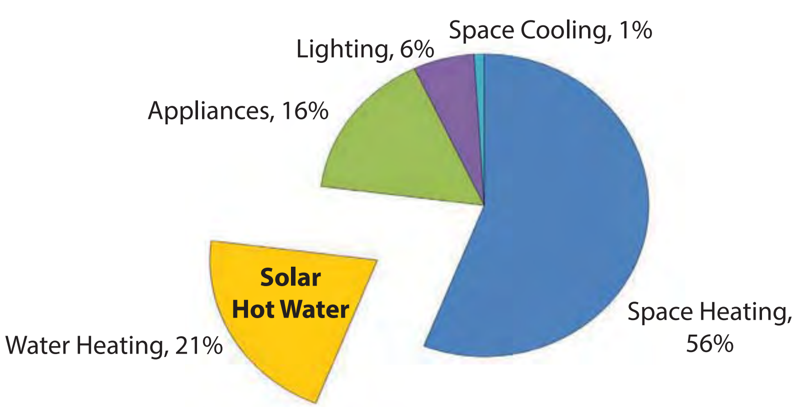
2.4) Energy Management

As discussed in the Introduction, the first step homeowners should take before committing to a renewable energy system is to take conservation measures. In the case of installing a solar hot water system, they include:

- » Installing low-flow shower heads.
- » Adding an insulating jacket to the original hot water tank in the home, if it is not a high efficiency tank.
- » Insulating hot water pipes.
- » Changing washers in leaky faucets.

To determine how efficient a solar hot water system works, a measure called **Coefficient of Performance**, or COP is often used. This is the ratio of energy gained from sunlight over the energy used to run the system. While the drawback of a solar hot water system might be that it only provides energy savings towards the water heating piece of the home energy consumption pie, solar hot water has the benefit of providing the highest COP compared to other renewable energy systems. This is because it does not convert energy, it simply collects heat to use as heat, thus avoiding the loss of energy during conversion. The average COP is 80, or 8000% efficiency, with one unit of energy consumed to run the system producing 80 units of energy output. In comparison, an electric water heater has a 100% efficiency, with natural gas or oil heaters having an efficiency of 50%-98%.

A solar hot water system can meet an average of 40%-60% of a home's hot water demand throughout the year. During the winter months when there is sufficient ambient light, the system will meet 20% to 30% of the hot water demand, and up to 90% in the summer months.



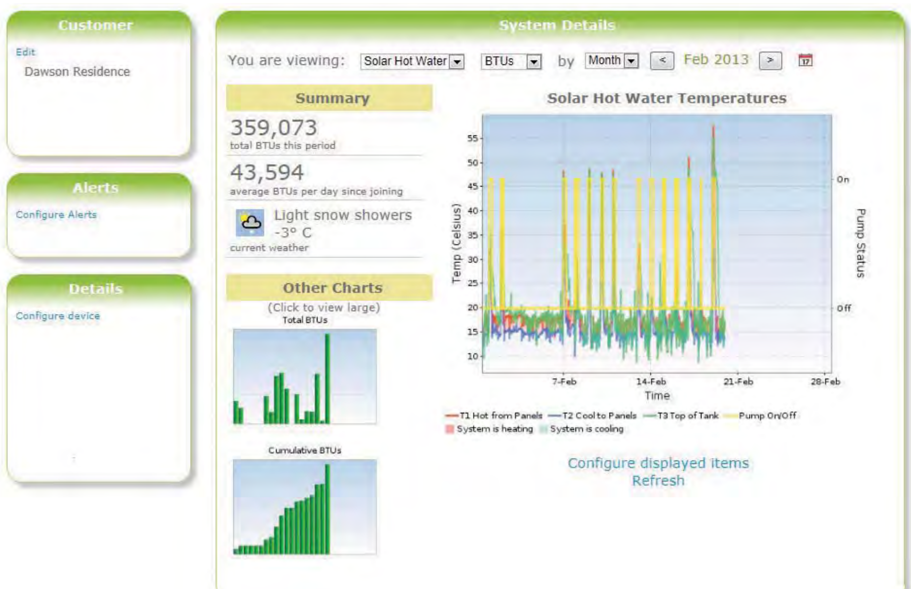
This diagram shows that a solar hot water system can assist with a home's water heating energy savings. Average annual household energy consumption data by NRCan.

2.4.1) Monitoring Solar Hot Water Systems

A renewable energy monitor is a great way to measure your system's performance as it provides daily, weekly and monthly energy use statistics. Monitors can notify the user to any problems needing attention and ensure the system continually performs at its maximum potential.

The screen capture below shows a renewable energy monitor report for a residential solar hot water system in Kingcome Inlet, BC. The system produces on average 43,594 BTUs per day. Since 8 BTUs will raise a gallon of water one degree F, and therefore 320 BTUs are required to raise the temperature of a 40 gallon tank by one degree F, this system is capable of increasing a standard 40 gallon tank of water by 136 degrees F, or 58 degrees C, on a daily average.

This screen capture was taken in February 2013, and indicates both the total BTUs for the month as well as the average daily BTUs of the system since installation. Note that the average will increase during the summer months. Based on the annual average-sized home consuming roughly 7,350,000 BTUs in water heating, this system is capable of producing about half that amount.



Screenshot Courtesy of SunReports
www.sunreports.com

2.4.2) Changes of Habit

Solar hot water systems are unobtrusive to the home and daily routines, although many homeowners in BC who have made the switch say the presence of their solar hot water system creates a new perspective on their household hot water use. For example, using cooler water temperatures for laundry is one behavioural change that can be done to maximize the free hot water being provided by the sun.

"It took us a while to adjust to the system so that we were using our hot water to capitalize on the renewable energy," says one Nanaimo home-owner. She is referring to the fact that on sunny days the system will be generating the most energy from the sun, whereas on a day with heavy cloud cover, and no ambient light, the water usage will generally be coming from the regular water tank, which acts as a back-up to the solar hot water tank.

"I am very in tune to it now," she says. "I use the dishwasher and run baths when the system is coming on so we're making the best use of it."

Source: Terratek Energy Solutions

Every year, the sun irradiates the land masses on earth with what would be equivalent to 19,000 billion tons of oil.

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Pembina Institute

2.5) Other Applications

Heating an outdoor pool in the summer months can account for as much as 60% of a home's summer energy bills, making it more expensive to heat a pool in the summer than the house in the winter, according to BC Hydro. Each degree you set your pool's temperature above 25.5 degrees C, the minimum recommended temperature, will cost 10-30% more in energy bills. A preferred pool temperature for relaxing and recreation can be up to 30 degrees C. **Solar pool heating** will instantly reduce those heating costs, while extending a pool's season by several weeks. Solar energy heating for outdoor pools generally uses unglazed collectors on a seasonal basis. These collectors will use heat from the sun to raise your pool's temperature, displacing anywhere between 50%-90% of the electricity or gas needed to heat the pool throughout the season. This allows for a payback period of as little as two to five years. For indoor pools, glazed collectors identical to those found in solar domestic hot water systems are more appropriate.

Solar hot water can also be used for **livestock barns and greenhouses**. A residential solar hot water system can also help supplement your home's radiant **in-floor heating** system.

2.6) Maintenance and Warranties

Solar hot water systems will last 25 years or more. Glycol should be replaced in closed-loop systems once in a while depending on the manufacture or usage. Also depending on the manufacturer, the pump may need to be replaced during the life of the system. These services can be provided by a contractor.

Homeowner responsibility is minimal as the controller, or computer software, operates the system. At most, collectors may require a wash if dirty, such as during heavy pollen seasons. This is up to the discretion of the homeowner. It is recommended collectors be washed on cooler or cloudy days to avoid shocking the surface.

2.7) Frequently Asked Questions

Q) How much savings can I expect over a year?
A) A properly sized system can provide 40%-60% of your annual hot water energy consumption.

Q) What is the Return on Investment, or ROI, with solar hot water?
A) A solar hot water system should be thought of as an up-front investment in free hot water over the long term. It is not a financial investment, and will not necessarily yield a simple five year payback. Because of this, money should not be the sole measure of value in terms of the ROI. It is important to look at several non-monetary factors to understand the real value of the investment, such as freedom from energy price volatility, zero emissions, increased value and peace of mind. According to the BC Utility Commission, natural gas prices have increased an average of 12% per year since 1998, solar hot water will help protect against those rising energy costs with its reliance on free renewable energy. Also consider that an owner can recoup the capital investment of a solar hot water system at resale by emphasizing reduced energy costs and sustainability as a selling feature.

Q) What size system should I get and what are the costs?
A) System size depends mainly on how many people live in the house. For a one to three person household a system with one 4' x 8' collector plus a 40 - 60 gallon solar storage tank is recommended. This tank supplies preheated water to your existing domestic hot water system, which can be a tank or tankless "on-demand" water heater. BC does not have the solar resource necessary to have solar hot water configured as a one tank system. Today, single collector solar hot water systems start at around $6,800 fully installed, before tax. For four to six people, a two-collector system would be more appropriate costing around $8,800 installed before tax. These are cost estimates and it is recommended that a homeowner call at least three different installation companies to compare install costs.

Q) I am building a new home. Can I add one of these systems later?
A) Yes, but consider making your house "solar ready." To do so, have some conduit or appropriately sized copper pipe and sensor wire installed from the attic space to the area where your hot water tank will sit. That way, should you choose to install solar at a later date, the installation will be easier, cleaner looking and less expensive.

2.8) Resources

SolarBC: Canada's most successful solar pilot program ran in BC from 2009-2011. The incentivized program focused mostly on residential solar hot water, and although it is no longer active the website remains an excellent resource.
www.solarbc.ca

BC Sustainable Energy Association, or BCSEA: A non-profit society that empowers BC residents to build a clean, renewable energy future. Their Sustainable Energy Directory provides links to solar installers and suppliers in the province.
www.bcsea.org

EnergyBC: An online resource on energy sources, uses and issues in BC.
www.energybc.ca

Canadian Solar Industry Association, or CanSIA: A national trade association that represents approximately 650 solar energy companies throughout Canada.
www.cansia.ca

Natural Resources Canada, or NRCan: A Solar Hot Water Buyers Guide, is available on their website. See "renewables" for solar thermal reading materials including the guide.
www.canmetenergy.nrcan.gc.ca/publications/3047

Solar Contact: An online resource on solar energy. A brief summary on the open and closed loop systems can be found on the website.
www.solarcontact.com/solar-water/hot-water-systems/open-closed-loop

Guide to the Province of BC Solar Hot Water Ready Regulation:
www.housing.gov.bc.ca/pub/codepdf/SRGuide.pdf

Solar Water Heating:
by Bob Ramlow and Benjamin Nusz (2010)

Solar Home Heating Basics:
by Dan Chiras (2012)

2.9) Homeowner Checklist

- ☐ Do you use a significant amount of hot water?
- ☐ Is your roof in good condition?
- ☐ Do you have ample south facing roof space?
- ☐ Is the south facing roof minimally shaded?
- ☐ Do you have room for a secondary storage tank next to your existing hot water system?
- ☐ Have you called at least three installation companies in your area and received information on their company, their products, the costs for installation, permitting requirements and any incentives that may be available to you?
- ☐ Have you determined which system and size is best suited to your needs?
- ☐ Have you developed a budget?
- ☐ Have you determined the feasibility of additional applications such as pool heating?
- ☐ Have you requested a site analysis for a cost breakdown and installation plan from the installation company of your choice?

"We do not inherit the earth from our ancestors, we borrow it from our children."

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Native American Proverb

3.) GEOEXCHANGE

3.1) An Introduction to Geoexchange

Geoexchange systems are one of the most efficient ways to heat and cool a home, as well as having the ability to provide pre-heating for domestic hot water. These systems utilize the naturally constant temperature of the earth or a body of water in combination with a ground source heat pump.

Using earth energy systems as an example, to understand geoexchange systems, the earth should be thought of as a solar battery, collecting and storing the energy from the sun to maintain a relatively constant year-round temperature underground, even as daily air temperatures fluctuate dramatically over the seasons. A resulting effect of these conditions is that three to 10 metres below the surface the mean earth temperature is relatively constant at approximately 10 degrees C. This property makes the earth an ideal natural source to provide heat in winter and absorb heat from a house in summer. Similarly, large bodies of water also maintain relatively constant year round temperatures when compared to the air, and can serve the same purpose as the earth in a geoexchange system.

When leveraged with a mechanical heat pump, this low-grade heat becomes a very useful and efficient source for heating and cooling. Using the same mechanical process as a refrigerator, the geoexchange heat pump draws heat from one source and deposits it to another. The idea is to take advantage of the heat storage capabilities of the earth and influence that using the heat pump to create ultra-efficient heating and cooling.

The grey box in the corner is the heat pump, the heart of a geoexchange system. Red hoses for infloor heating. Domestic hot water back-up tank (r), buffer tank and desuperheater for domestic hot water pre-heating (l).

While geothermal and geoexchange are sometimes both used to describe these systems, the two terms are technically different. Geoexchange involves the transfer of heat from the soil, by the sun, at shallow depths no more than 500 ft. This heat is usually used for residential, commercial and institutional buildings. Geothermal energy involves extracting heat in the form of hot water or steam deep from within the earth's core, over one km or more. This heat is used to generate electricity on a large scale, such as geothermal power plants.

Horizontal loops coil.

Quick Self-Assessment: is Geoexchange Right for You?

There are some simple ways to find out if your home is suitable for geoexchange:

- You have a large open area, such as a field, or access to a large body of water such as a pond or ocean.
- You have a forced air or in-floor heating system.
- There is space in the mechanical room for the geoexchange heat pump.
- You are prepared to have a heat load calculation carried out to determine the size of system necessary for your home. This should be done by a professional designer or engineer, and will cost approximately $250 or more, depending on the complexity of the home.

3.2) Viability of Geoexchange

Geoexchange uses two methods of extracting heat, either from the water or ground. An ocean or fresh water geoexchange system is one of the most effective system setups. With the close proximity of the Strait of Georgia as well as many other small lakes and bodies of water in the area, many homes in the region may be well suited to water-based geoexchange. For a ground-based geoexchange system to offer the greatest benefit to a residential home, it is important to have a large field, ideally at least two acres, to accommodate the loop coil in the ground. Drilled applications are rare due to the high capital costs associated with drilling a vertical borehole. Because of the land requirement, geoexchange systems are often installed in more rural areas.

3.2.1) Bylaw Requirements and Permits

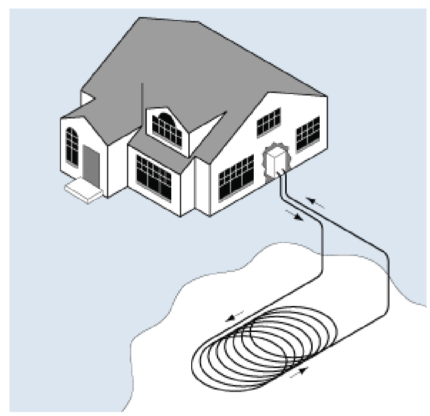
All permits, approvals and reports for geoexchange systems are the responsibility of the installer. Among those that may be required for a geoexchange system is an Approval from the Ministry of Forest, Lands and Natural Resource Operations. This is a written authorization for changes in a water course, like a stream or ocean. Within the RDN and depending on the area, geoexchange systems may require a development permit for environmental protection. Additional information may be required as part of the permit application. Commonly required reports include riparian area assessments and geotechnical reports for fish habitat protection and hazard land. It is recommended that you contact your local government to determine what permits apply to your property.

3.3) Different Types of Systems

Most installed systems have two loops on the ground side: the primary refrigerant loop is contained in the appliance cabinet where it exchanges heat with a secondary water loop that is buried underground. After leaving the internal heat exchanger, water flows through the secondary loop outside the building to exchange heat with the ground before returning.

There are two main loop configurations with geoexchange systems. In **closed loop systems** the secondary loop is placed below the frost line where the temperature is more stable, or submerged in a body of water if available.

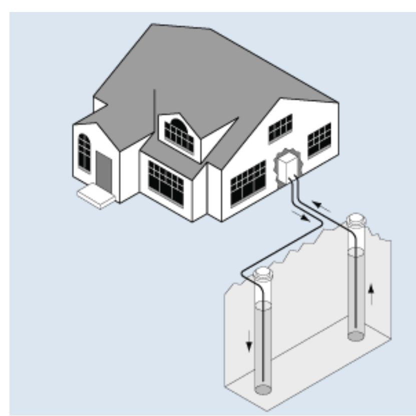
This option involves the installation of horizontal loops or runs involving a trenching machine or excavator with a narrow bucket. The size of field depends on the combined heating and cooling loads within the home. Depending on the system configuration a horizontal field can have a length of up to 130 metres. There is a second option for closed ground loops but it involves drilling, which on most small residential lots proves too costly. Other options include closed ocean or pond loop.



Closed pond/ground loop system.

In **open loop systems**, the secondary loop pumps natural water from a well or body of water into a heat exchanger inside the heat pump. Heat is either extracted or added by the primary refrigerant loop, and the water is returned to a separate injection well, irrigation trench, tile field or body of water.

The benefits of this type of system are that the unit operating efficiency can be much higher and installation cost can be much lower, compared to the closed loop option. Water quality is important as the heat pump can lose performance with contaminants. This can usually be mitigated with an intermediate heat exchanger between ground loop and heat pump. The key item in this scenario is the amount of water available in the heating season. A simple draw down test can be conducted to test flows. While required water flow will increase with house size, 57 - 76 litres per minute is the average recommended for a 2,000 sq/ft home[1].



Open loop system.

Image Courtesy of www.top-alternative-energy-sources.com

1 Source: www.nordicghp.com

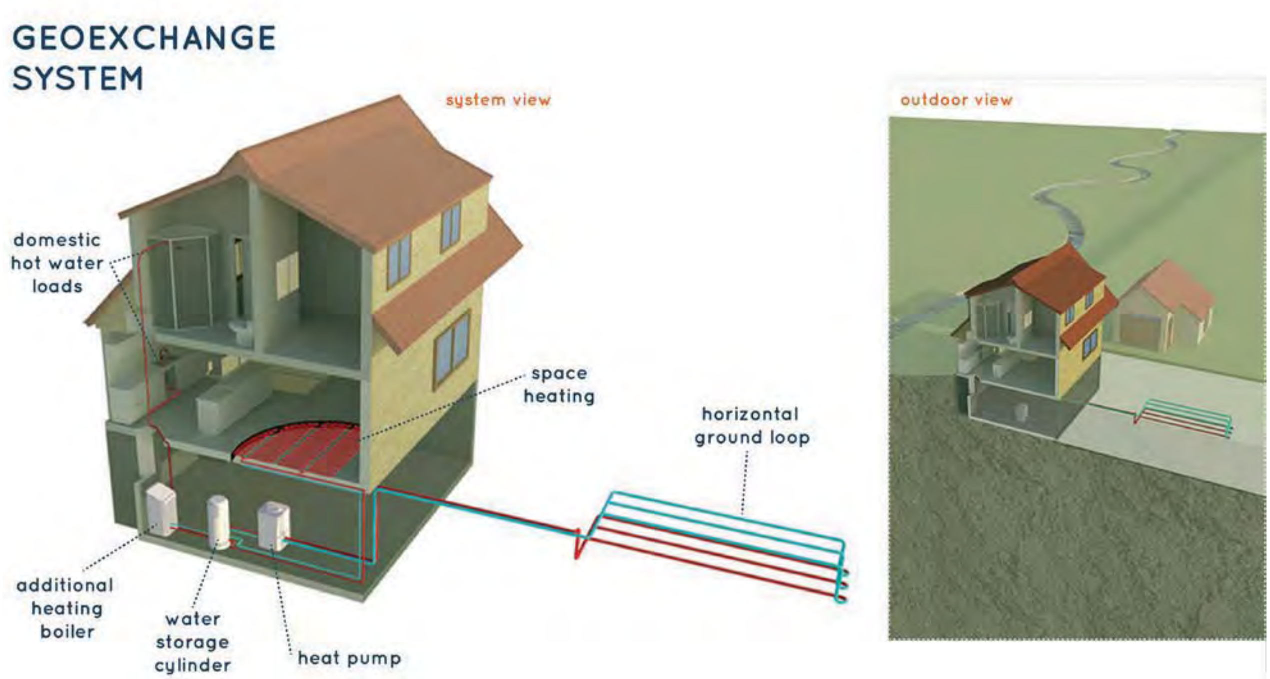
There are several methods to draw heat from the ground or body of water with a geoexchange system, which are:

- **Horizontal Trench:** if there is land available, horizontal trenches can be dug and loops of high-density polyethylene pipe can be laid and buried. This length of pipe is sized to accommodate the heating and cooling needs of the building.
- **Ocean/Lake Loop:** similar to a horizontal trench, if there is a large body of water available loops can be anchored down into the water.
- **Vertical Borehole:** if space is a problem, a vertical borehole can be drilled and a pipe run vertically into the ground.
- **Vertical Well:** if there is abundant ground water source available a pump and dump system may be possible, which means pumping water from one source through a heat exchanger and then returning it back to the ground.

Horizontal trench manifold.

Pond loop being sunk. Length of pipe is sized to accommodate the home's heating and cooling requirements.

3.3.1) System Schematics



3.3.2) Basic Components

The basic components of a geoexchange system are:

- Loop: either underground or under water. Made of high-density polyethylene pipe.
- Heat pump and controller.: the heat pump is the machine that extracts heat from the ground or water and pumps it indoors. The controller allows for sophisticated control over heating and cooling algorithms designed for the specific home installation.
- Delivery system: standard duct system for delivery of hot or cold air, or in-floor radiant slab heating with chill beam for cooling.
- Back-up heating source: similar to other renewable energy systems, generally an electric system acts as a back-up for the geoexchange compressor in the heat pump.

3.3.3) Sizes of Systems and Price Averages

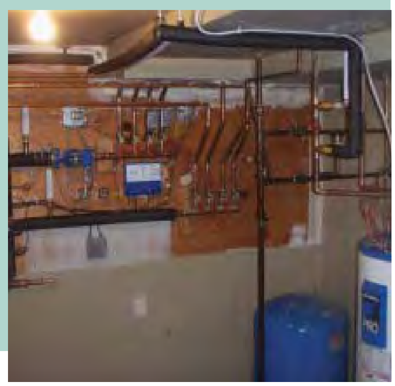
As with all renewable energy system installations there are any number of site-specific variables that can add or subtract from a general estimate. On average, cost begins at $25,000, as of February 2013. Despite this upfront investment, geoexchange systems cost significantly less than traditional heating systems on an annual basis, with an average cost of $750 a year for a single family home, compared to $1185 for natural gas and $1930 - $2135 for an electric baseboard or furnace[1]. Taking into account future energy rates, this gap will likely continue to widen.

Geoexchange systems work in tons, and the heat pump will need to be sized according to the size of the home. To determine this, a professional designer or engineer is required to carry out a heat load calculation.

1 Source: Fortis BC.

Case Study: Geoexchange, Powell River, BC

This four-person, 2,300 sq/ft home on the Sunshine Coast, was burning fuel oil in a low efficiency boiler for space heating and domestic hot water. Thermal efficiencies on aging boilers of this type can be as little as 50%-60%, meaning half the energy in the fuel oil is not effectively converted to useable heat. This oil burning system was replaced with a modern, high efficiency, geoexchange system, which included five 130 feet long trenches at three feet wide. All of the heat and domestic hot water now utilizes electricity at a system COP of 3.5 or efficiency of 350%. Due to the fact that this geoexchange system is replacing an expensive fuel oil at $1.25/l, with a cost effective horizontal loop, combined with incentives available at the time of installation this system was an affordable option for the homeowners and one that presented a short term return on investment.



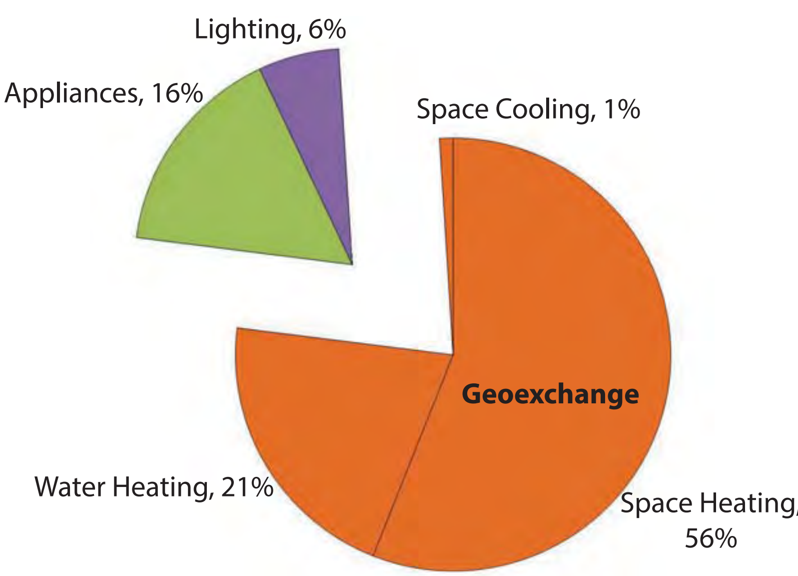
A two-pipe per trench horizontal ground loop provides superb performance, minimal pumping power requirements and minimum pipe in the ground. It did, however, require more digging and more land, but provided excellent long-term performance. An outdoor reset control strategy provides more evenly distributed heat to the spaces, reducing energy consumption. This system costs approximately $25,000 including installation.

Source: Stage 3 Renewables

3.4) Energy Management

Coefficient of Performance, or COP, is a term that is commonly used to refer to the performance of geoexchange systems. The COP is the ratio of energy gained over the energy used to run the system.

Each unit of electricity used to operate a geoexchange system draws three to five units of free, renewable energy from the ground. This gives it a COP of 3 to 5, or an efficiency of 300% to 500%. Over the course of the year the highest COP will be at the start of the heating season, eventually dropping as the field or water source cools down. Despite a dip in performance during the winter months, a geoexchange system remains very efficient over the course of the year. To optimize efficiency, a geoexchange system must be properly designed by a professional engineer or person certified by the Canadian Geoexchange Coalition.



This diagram shows the areas within a home where a geoexchange system can assist with energy savings: space heating, cooling, and water heating. Average annual household energy consumption data by NRCan.

The best way to make the most of your geoexchange system is to manage heat loss and implement conservation measures. For example, add insulation, draftproof the entire house, and upgrade to high-performance windows and doors.

3.4.1) Monitoring Geoexchange Systems

With the help of a geoexchange energy monitor you can measure energy consumption based on the system's heat pump efficiency. Systems are on average 48% more efficient than the most efficient gas furnaces, and more than 75% more efficient than oil furnaces, according to the Canadian Geoexchange Coalition. With a monitor you can keep an eye on efficiency, money saved, and any issues that may arise in system functionality.

Geoexchange monitoring can also:

- Measure, quantify and illustrate the amount of renewable thermal energy drawn from and returned to the ground, or water source.
- Provide graphs of system data that includes the entering and leaving loop fluid temperatures, heat pump run times and BTUs per hour.
- Illustrate the amount of other fuels that would be needed to produce an equivalent amount of thermal energy.

Screenshot Courtesy of Ground Energy Support, ©Copyright 2011-2013 www.groundenergysupport.com

3.4.2) Changes of Habit

For homeowners used to electric or gas heating systems, the biggest change is the fact that geoexchange is slower to respond, requiring extra time for a home to reach a set temperature. However, it offers a more comfortable mode of heating or cooling. The air temperature produced by a geoexchange system is generally around 35 degrees C. The air produced by electric or fossil fuel furnaces is often heated to 50 - 60 degrees C, much warmer than room temperature, creating hot spots and temperature differences between three to four degrees C.

Geoexchange systems are able to maintain very even temperatures throughout the home. They match the heating and cooling loads of your home year round. In spring and fall, when you do not need full system capacity, the compressor and fan will operate at low speed to provide heating and air conditioning as needed. During colder days and in the winter, or hot summer days, the system operates at high speed.

An additional feature of geoexchange systems is the ability to pre-heat domestic hot water by way of an auxiliary heat-recovery system, called a desuperheater. During the geoexchange system's cooling mode, hot water is produced free as a byproduct of the thermal process, using heat removed from the house, while in the heating mode, the desuperheater heats a portion of your hot water.

People living in homes with a geoexchange system often say, "This home is the most comfortable we've ever lived in."

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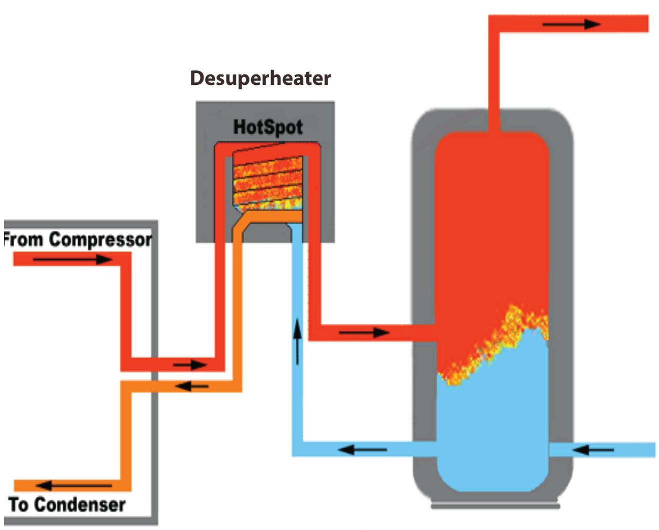
Canadian GeoExchange Coalition



Example of how a desuperheater works.
Graphic Courtesy of Hotspot Energy LLC, www.hotspotenergy.com

3.5) Other Applications

Pool heating, solar hot water and geoexchange systems complement one another. For pre-heating domestic hot water, a solar hot water system can be used during the summer months and work in conjuction with a geoexchange system to provide pre-heating in the winter time, meeting the home's heating needs.

For homeowners using geoexchange systems for cooling, solar hot water might not be the best option in hot summer months, as geoexchange can produce all the necessary hot water during the cooling stage, using the heat removed from the house.

3.6) Maintenance and Warranties

A consumer should request a copy of both the manufacturer's warranty and the contractor's warranty, in writing. Most heat pumps come with a one-year general warranty and a five to ten year warranty on the majority of parts.

Optimal forced-air system performance is achieved when air filters are clean. A homeowner should change/clean filters, except electrostatic units, at least once a month. All other maintenance, such as system purging or refreshing of antifreeze should be performed by a qualified contractor. For closed loop systems this should take place every 15 years and once a year with open loop systems. The heat pump will likely need to be replaced once every 15-20 years.

3.7) Frequently Asked Questions

Q) How efficient are geoexchange heating systems?
A) For every one unit of electrical energy used to run the heat pump, three to five units of heat energy is produced, or an efficiency of 300% to 500%. An electric water heater has an efficiency of 100%. In comparison, natural gas or oil fired heaters have an efficiency of 50% to 98%.

Q) What are the main functions of geoexchange?
A) The main function of a geoexchange system is to provide space heating.

Cooling: Although cooling is usually not necessary due to the mild climate in this region, it can be incorporated. There are a number of ways of doing it. If this is a desirable function, ask your contractors to provide more information on what options are suitable for your home.

Domestic Hot Water: Water pre-heating capability can be added to your heat pump simply by including a heat exchanger into the refrigerant circuit inside the heat pump. Most heat pump manufacturers offer units with a desuperheater. Whenever the heat pump compressor is running to heat or cool your home, water from a domestic pre-heat water tank is circulated through the desuperheater and heated by the hot refrigerant. Depending on hot water use, a desuperheater can provide 30%-60% of the hot water needed in the average home, according to the Canadian Geoexchange Coalition.

3.8) Resources

Geoexchange BC: Dedicated to the education, promotion and responsible design and installation of low-temperature ground source geoexchange energy systems.
www.geoexchangebc.com/

BC Sustainable Energy Association, or BCSEA: The BC Sustainable Energy Association concerns itself with the sustainable use and production of energy in British Columbia. Their Sustainable Energy Directory provides links to geoexchange installers in BC.
http://www.bcsea.org

Ontario Ministry of Agriculture, Food and Rural Affairs: Provides information about geothermal and other renewable energy technologies for farmers, or those with rural properties.
www.omafra.gov.on.ca

Canadian Geoexchange Coalition: The coalition is guided by a vision to transform the heating, ventilation and air conditioning market in Canada.
www.geo-exchange.ca

Earth Energy Society of Canada: The society represents the domestic earth energy of ground-source/geothermal heat pump industry, with a mission to promote quality installations and earth energy technology as a viable economic and environmental option in Canada's energy scenario.
www.earthenergy.ca

Residential Earth Energy Systems: A Buyer's Guide
Published by Natural Resources Canada (2002)
http://www.awil.ca/downloads/pdf/EARTH-BuyersGuide-ResidentialE-arthEnergySystems.pdf

The Smart Guide to Geothermal: How to Harvest Earth's Free Energy for Heating and Cooling
Donal Blaise Lloyd, Michael Hunt (2011)

Residential Geothermal Systems: Heating and Cooling Using the Ground Below
John Stojanowski (2010)

3.9) Homeowner Checklist

- [ ] Have you developed a budget for a geoexchange system?
- [ ] Do you have proper space outside?
- [ ] Do you have the electrical capacity for the upgrade?
- [ ] Is there space in the mechanical room for the heat pump and necessary components?
- [ ] Is open or closed-loop best for your property?
- [ ] Have you chosen to pre-heat domestic hot water with your geoexchange system or combine the system with solar?
- [ ] Have you found a qualified installer, certified by the Canadian Geoexchange Coalition, or professional engineer on staff?
- [ ] Have they provided system information, cost and permits required?
- [ ] Have you requested a site analysis for a heat load calculation, cost breakdown and installation plan from the installation company of your choice?

"Energy is liberated matter, matter is energy waiting to happen."

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Bill Bryson, A Short History of Nearly Everything

4.) BIOMASS

4.1) An Introduction to Biomass

Biomass is organic matter such as wood, straw, energy crops, sewage sludge, organic waste materials, and animal litter. It can be viewed as a form of stored solar energy which is captured by the organic matter as it grows. [1]A biomass heating system is any heating system that primarily uses biomass as a fuel. For residential biomass systems this fuel source is typically logs, woodchips or wood pellets. These systems can be used for space heating, domestic hot water production, or both.

There are three main types of biomass heating systems:

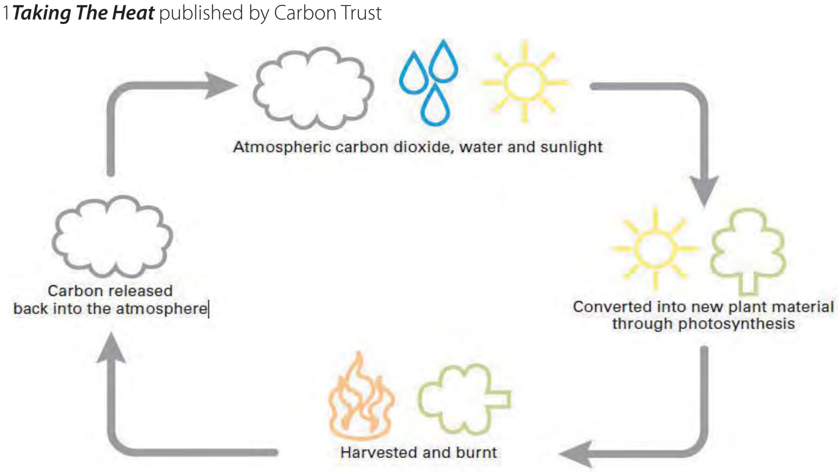
» Biomass furnaces, which uses wood pellets or logs, provides space heating with warm air to a home.

» Hydronic biomass boilers, which uses wood pellets, chips or logs, provides heating with warm water.

» Biomass stoves or wood stoves, which use wood pellets or logs, provides space heating and are the low-tech solution that is simple to operate but typically more labour intensive.

As biomass stoves are relatively common and simple to operate, this chapter will focus on the first two types of biomass heating systems.

1 ***Taking The Heat*** published by Carbon Trust



Source: Carbon Trust, Biomass Heating

4.2) Viability of Biomass

In BC, with wood waste being a significant available resource, there are economical benefits to installing biomass heating systems. The valuable biomass resources in this province also have the potential to provide opportunities for employment, and economic diversification, as fuels typically used tend to have diverse and localized supply chains.

It is important to access local biomass sources when determining the right type of biomass boiler for a home. Sources include local wood heating specialty stores, community forests, wood lots, wildfire abatement programs, municipal landscaping operations, local wood processing facilities such as sawmills and value added plants.

There are no permits required to own and operate a residential biomass boiler in the RDN. It is recommended that you hire a qualified installer or inspector, such as those who received certification from Wood Energy Technical Training (WETT) program in BC.

Quick Self-Assessment: is Biomass Right for You?

There are some simple ways to find out if your home is suitable for a biomass boiler:

- Do you have existing water or air distribution systems? Biomass boilers are best combined with hydronic or air distribution systems. Electric baseboards can be a difficult retrofit situation.
- Do you have access to a regular fuel source such as wood, pellets or chips?
- You will need a dry area for a boiler system, roughly the size of a small freezer, and fuel storage space.
- Pellet or chip systems will need space near the system for storage, while wood can be stacked in a separate area.
- Are you prepared for the maintenance and labour required to own and operate a biomass heating system?

4.3) Different Types of Systems

Systems can vary from manually fed stoves with few controls, through to fully automatically-fed boilers with automatic ignition, full remote monitoring, control systems and automatic ash removal. There are two processes for feeding biomass heating sytems: a batch process or continuous flow process. With the batch, a load of fuel burns through and then must be manually restocked. This requires frequent labour, but can be less expensive. With chip systems, and some pellet systems, they can be automated to feed continuously, in a continuous flow process, and will only require refueling anywhere from every three weeks to once a heating season. These type of systems tend to be higher in cost.

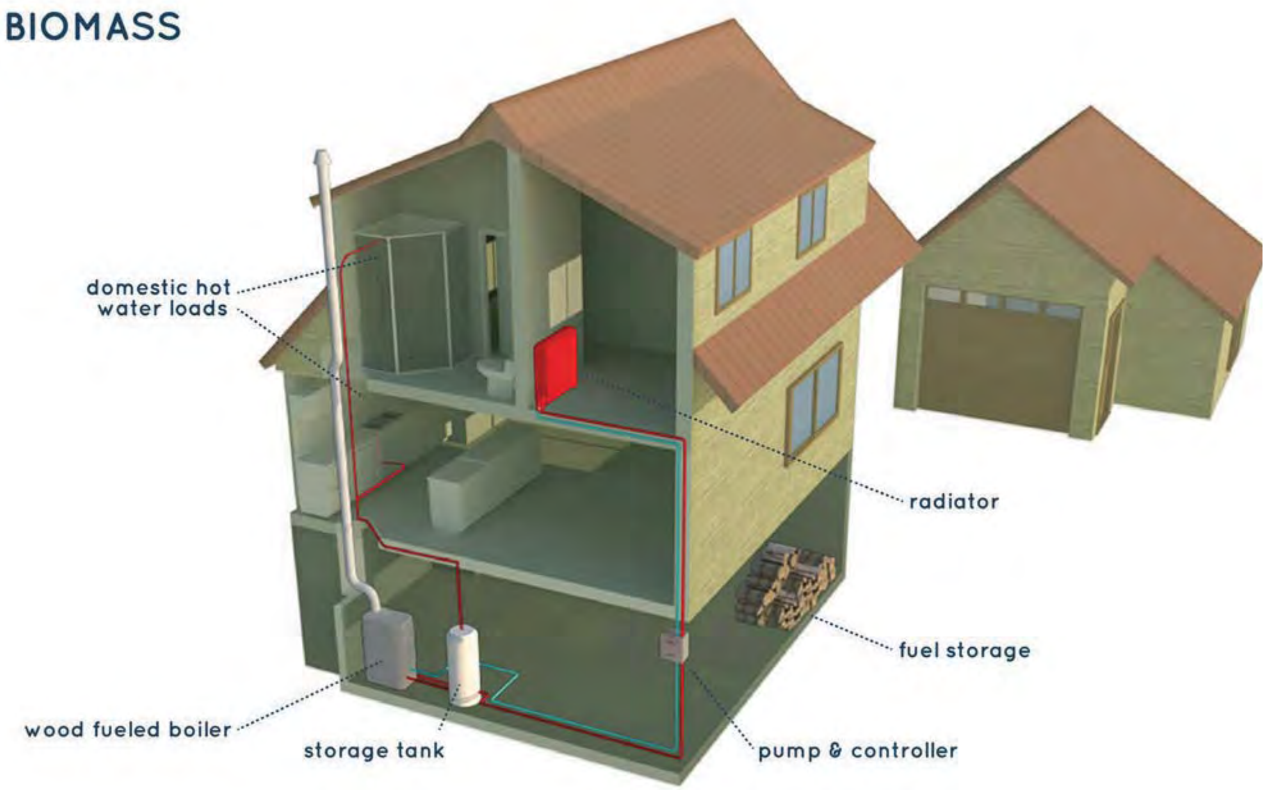
Choosing the right fuel source depends on your heating needs and the availability of fuel stock in your area. Logs are a popular fuel source due to their availability and low cost. Chips are produced as a by-product in milling operations, and while relatively inexpensive compared to more processed forms of biomass, the quality can vary. Poor quality can lead to more fouling, or the loss of heat transfer efficiency, and more maintenance. As well, the more moisture you have within the chips the more time it takes to dry them off.

Wood pellets are a wood product processed to reduce the water content and increase density, for a fuel stock that is easier to handle, store and transport compared to firewood and wood chips. This uniformity allows pellet systems to burn more efficiently.

A standard log-fuelled boiler.

A standard wood chip furnace.

4.3.1) System Schematics



4.3.2) Basic Components

The basic components of a hydronic boiler/furnace system are:

- Biomass fired boiler/furnace.
- Pump and controller, provides distribution network for air/hot water.
- Storage tank, preheats domestic hot water
- Fuel storage, where the biomass fuel, in this case logs, will be kept.

4.3.3) Sizes of Systems and Price Averages

The size of system needed for a household depends on the type of biomass heating system you choose, and the amount of BTUs necessary to heat the home. It is important the system be designed to the right size, as oversizing can cause inefficiencies and higher maintenance costs.

To make a general estimate, homeowners can expect to replace an existing gas or oil heating system with a biomass system half of that size in terms of heating capacity measured in BTUs[1]. For example, with a 100,000 BTUs natural gas furnace, you will likely only need 30-50,000 BTUs of wood heat, if integrated properly, to generate up to 80-90% of the home's heating demand.

The different types of biomass heating systems, assistance with systems sizing and associated costs can be found at a local hearth store.

1 Source: Wood Waste 2 Rural Heat Project.

A standard pellet stove.

4.4) Energy Management

Compared to traditional fossil fuels, the average cost per heat unit of wood fuel is significantly lower in most areas in North America. So while the investment cost of a biomass system may be higher than a conventional heating system in most cases, the fuel cost savings per unit of heat can offset that investment in a fairly short time frame.

Biomass is one of least expensive form of Energy in BC

Comparative Energy Prices in BC[1]

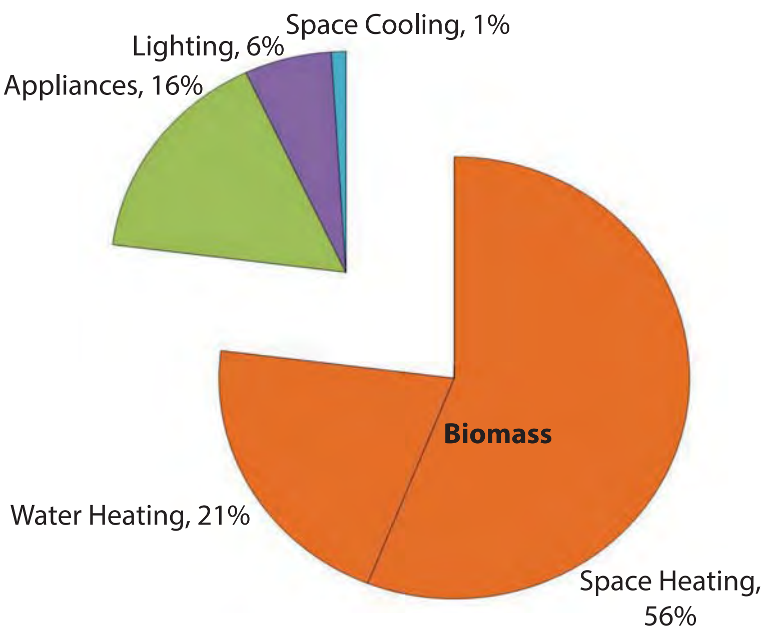
Fuel Type	Unit Sale size	Energy Content of Unit	Retail Price	Typical cost in BC[2]	Typical cost in BC[2]
Natural Gas	GJ	1 GJ/GJ	$11-14/GJ	$11-14/GJ	$40-60/MWh
Propane	Litres	0.0253 GJ/l	$0.48-0.63/l	$19-25/GJ	$70-90/MWh
Electricity	kWh	0.0036 GJ/kWh	¢6.8-8.3/kWh	$19-23/GJ	$70-80/MWh
Heating Oil	Litres	0.0387 GJ/l	$0.74-0.97/l	$19-25/GJ	$70-90/MWh
Ponderosa Pine [3]	Cord	17.9 GJ/cord	$200-250/cord	$11-14/GJ	$40-60/MWh
Wood Chips	Green Tonne	11.2 GJ/tonne	$35-55/Tonne	$3-5/GJ	$10-20/MWh
Pellets (Retail)	Tonne	19.2 GJ/tonne	$175-210/tonne	$9-11/GJ	$30-40/MWh

1) Energy Values are reference values only
2) Based on GHI observations and assessments
3) Approximate values for wood based on a cord of firewood equal to 85 cubic feet and 20 % Moisture wet basis and $200-250/cord

WOOD WASTE 2 RURAL HEAT

Source: Wood Waste 2 Rural Heat, as of Feburary, 2013.

Biomass systems are typically 90-95% efficient, based on a review of various equipment suppliers in BC.[1]



This diagram shows the areas within a home where a biomass system can assist with energy savings: space heating and water heating.

4.5) Other Applications

The higher cost of heating a greenhouse using natural gas or oil has resulted in many growers switching to alternate fuels.[2] There are many biomass fuels available to heat a greenhouse including wood-based fuels or farm waste such as plant materials, seeds or food processing waste.

1 Source: Wood Waste 2 Rural Heat Project.
2 Source: Ontario Ministry of Agriculture and Food.

4.6) Changes of Habit

The biggest change of habit to be expected will be maintaining the fuel storage. Homeowners will need to ensure regular fuel supply, whether wood, pellets or chips and it will be important to base the install on available options and comfortability with those options. For example, log fed biomass boilers will require more time spent on cutting and storing wood, feeding boilers with fuel and cleaning out the ash.

4.7) Maintenance and Warranties

Warranties will depend on the manufacturer and will differ with system design. Typical warranties range between 5-10 years.

Biomass boilers are clean and easy to use, with automatic ignition and a thermostatic control. They generally hold enough fuel for one to three days operation. The ash pan needs to be emptied about once a month. Long-term maintenance may include a chimney cleaning, as well as cleaning of biomass system components. A list of maintenance requirements will be provided with the system.

4.8) Resources

Alliance for Green Heat: The Alliance for Green Heat promotes high-efficiency wood combustion as a low-carbon, sustainable, local and affordable heating solution.
www.forgreenheat.org

Wood Waste 2 Rural Heat Project: The project is built upon the foundation of the Community Futures North Cariboo Green Heat initiative, or GHI. The project works to address issues such as the high cost of energy, carbon emission reductions and energy usage diversification.
www.canadianbiomassmagazine.ca

Biomass Thermal Energy Council: The Biomass Thermal Energy Council is a non-profit association dedicated to advancing the use of biomass for heat and other thermal energy applications.
www.biomassthermal.org

Canadian Biomass Innovation Network, or CBIN: The Network's goal is to continually ensure the availability of knowledge, technology and enabling policy to support the development of a sustainable Canadian bioeconomy.
www.nrcan.gc.ca/energy/renewable/1580

Biomass Innovation Centre: Established by Nipissing University's School of Business, in Ontario, in the spring of 2009 as a centre for knowledge and support in the development of an expanding clean technology industry.
www.biomassinnovation.ca

Canadian Biomass Magazine: Canada's premiere trade magazine, providing comprehensive coverage of the emerging Canadian biomass, bioenergy and bio-products markets.
www.canadianbiomassmagazine.ca

Warm Up to Biomass Heating and Improve Your Bottom Line
Published by Natural Resources Canada (2001)

Forest-Based Biomass Energy: Concepts and Applications
Frank Spellman(2011)

4.9) Homeowner Checklist

- [ ] Do you have proper indoor space for the boiler or furnace, and sufficient space for fuel storage?
- [ ] Does a biomass heating system fall within your budget?
- [ ] Have you found a qualified installer?
- [ ] Have they discussed with you the best type of system for your household?
- [ ] Have they conducted a site visit and heat load analysis to determine proper system size?
- [ ] Do you have an adequate fuel source?
- [ ] Is there a power supply available?
- [ ] Is there adequate ducting for incoming air?
- [ ] Is there adequate exhaust, such as a typical chimney?

Section II: Electric Power Systems

This section will focus on renewable energy systems that produce electricity. These technologies include solar photovoltaic or PV, wind and micro-hydro. These systems can supplement a home's traditional utility provider, like BC Hydro, with electricity that is produced onsite using energy sources available naturally on earth. There are three types of power systems: grid-tie, grid-tie with battery back-up and off-grid.

5.) POWER SYSTEMS OVERVIEW

5.1) Introduction

The most common system is **grid-tie**, which connects to the utility grid. This is the most straightforward of all three systems. As you generate energy, it feeds into a regular household electrical panel. If you produce more power than needed you will receive credits on excess energy and will always have power. These systems also avoid the financial costs associated with battery back-up.

For those in more rural or remote areas, a **grid-tie with battery back-up** is also tied to the grid but can provide limited back-up power, with a battery bank, to deal with emergencies. This application tends to be most applicable where the electric utility grid is unreliable.

Off-grid systems operate independently from the grid to provide some or all of a household's electricity. These systems are typically used when access to the electric utility grid is not available, or when full energy independence is desired. There are several different types of applications for off-grid systems, depending on a pre-determined load size. Common scenarios include:

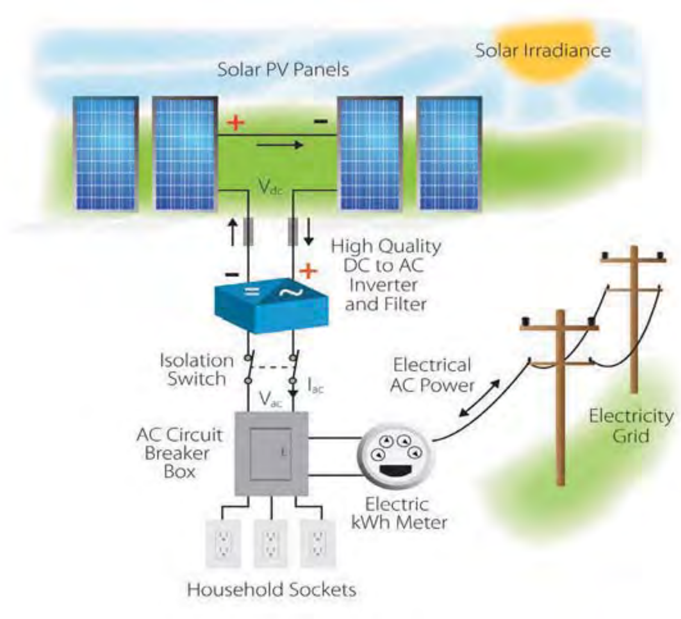
- Basic systems to provide lighting only, such as a seasonal remote cabin.
- Lighting and occasional charge up of electronic equipment for a simple off-grid vacation cottage.
- Lighting and appliances for year round residence. For homeowners seeking to remain fully off-grid year round, a generator, or hybrid system, may be required.

For fully off-grid homeowners, a load analysis calculates average daily energy consumed in the home. This value is used to design a battery bank large enough to store that energy each day. As discussed in the thermal heating chapters, the first step you can take to minimize the load size of the home is to take conservation measures. To put it simply, the less electricity you have to use, the smaller and less expensive the system will be.

5.1.1) Grid-Tie

With grid-tie systems, the direct current (or DC), electricity that is generated by the system passes through to an inverter. The inverter converts the DC electricity to alternating current (or AC), electricity which is compatible with the wiring and appliances in the home. The AC electricity from the inverter passes to the main electrical panel where it can meet the electrical demand of the home. Any excess energy that is generated by the system is passed back through the electricity meter and to the electrical grid. In most cases, you will get credited for this excess electricity on your electric bill. When you are not generating electricity from sun, wind or water sources, you will use electricity from the utility grid as if you did not have a system installed. Grid-tie systems can be sized to meet all or part of your electricity needs. Systems that meet all of your needs will produce enough electricity to fully offset your annual consumption from the grid.

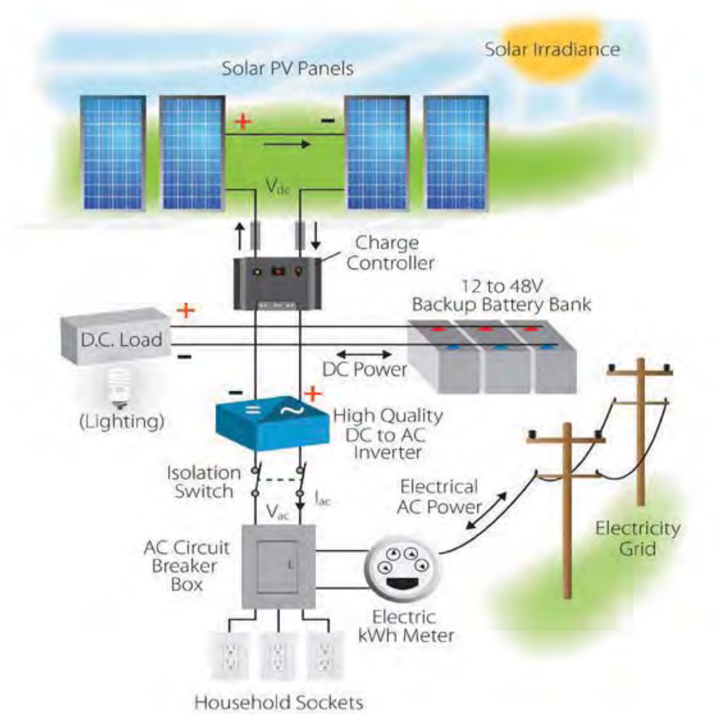
The following diagrams shows the basic functions of a solar PV grid-tie system. The same schematic can be applied to wind and micro-hydro systems.



5.1.2) Grid-Tie With Battery Back-Up

For this type of system, DC power travels to a charge controller which monitors the charge level of the batteries. If the batteries are low, electricity passes to them. If they are full, the electricity passes to an inverter and into the electrical wiring of the house. When the sun, wind or water source is unavailable, the utility grid provides power to the house like a grid-tie system. When there is no power from the utility grid, power is provided by the batteries. The backup system is sized to provide power for a limited amount of time to a limited number of appliances, which often includes lighting, pumps, fridges, freezers, computers or TVs and a kitchen plug. A typical backup battery bank for an average residential home tends to be 10 kWhs.

These systems are more complicated than a grid-tie system, and tend to be more expensive, as battery banks add cost and maintenance requirements. The following diagram shows the basic functions of a solar PV grid-tie with battery backup system. The same schematic applies to wind and micro-hydro.

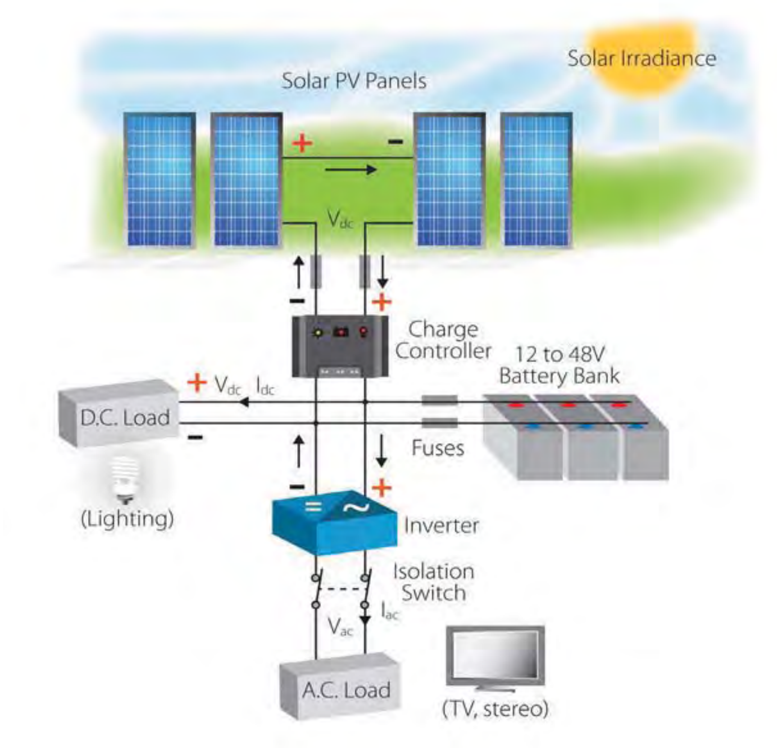


5.1.3) Off-Grid

For these systems, DC power is sent to a controller which charges the batteries and prevents overcharging. DC power from the PV panels and batteries is sent to either DC circuits in the house or to an inverter which converts the DC electricity to AC electricity, which is sent to AC circuits in the house. Batteries are the heart of this type of system. The battery bank needs to be large enough to provide power during periods without sun or wind, but should not be so large that the system is not capable of charging them properly. Most off-grid systems also need a generator for backup. This system can be the most complicated to own and operate and will require the most maintenance of the three system types, as it is essentially like operating your own electrical plant[1].

The following diagram shows the basic functions of a solar PV off-grid system. The same schematic applies to wind and micro-hydro.

1 Source: www.solarwindworks.com



5.2) Energy Management

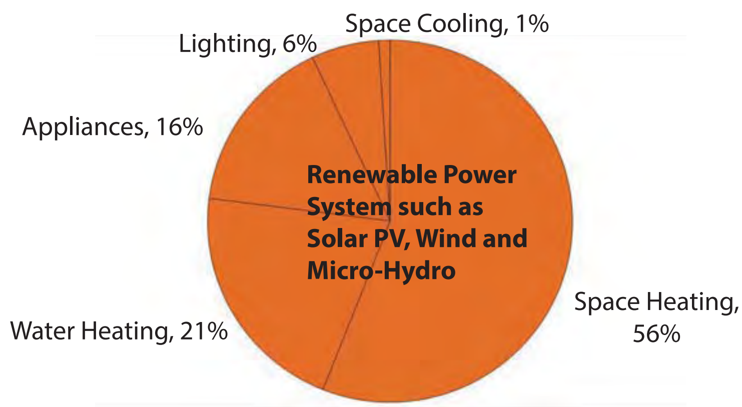
Homeowners can determine what size of system they need in order to meet their energy savings goals by checking the average annual kWhs on their utility bills, or requesting an analysis by an installation company.

Within the boundary of the Regional District of Nanaimo, many houses are relying on wood, propane or oil and some use natural gas for space and/or water heating, instead of electricity. This dramatically reduces the amount of electricty that a renewable power system is targeting to offset, compared to an all-electric home. As a result, a smaller renewable energy system will suffice.

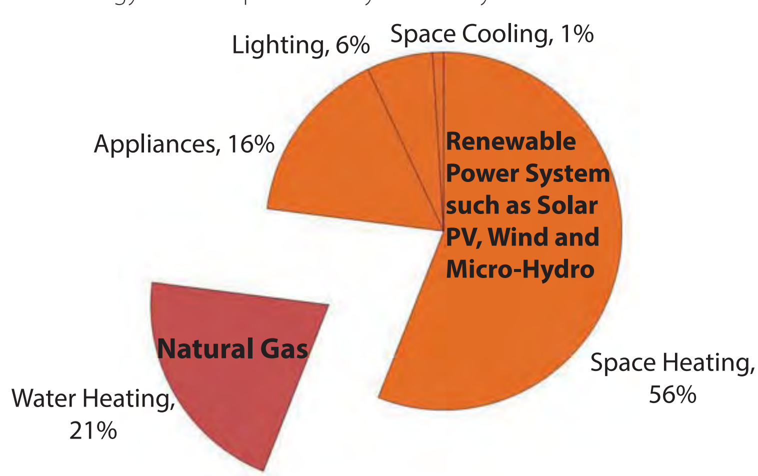
These diagrams show the areas within a home where a renewable power system such as solar PV, wind and micro-hydro can assist with energy savings, depending on the available sources of energy.

Below are three scenarios of household energy sources.

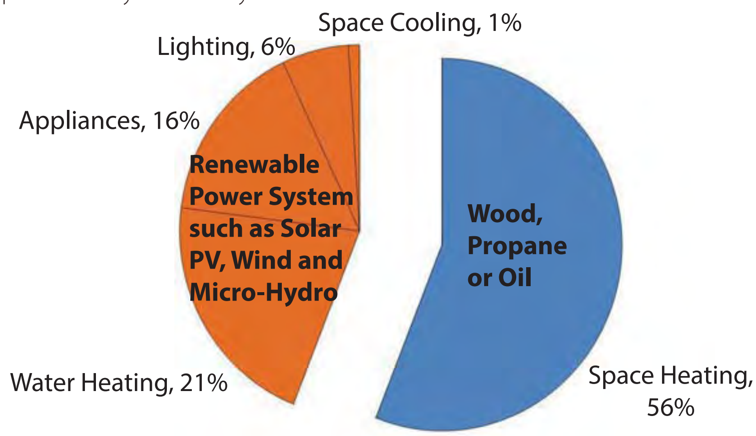
1. All energy uses are provided by electricity.



2. Water heating is provided by natural gas while the rest of household energy uses are provided by electricity.



3. Primary space heating is provided by wood, propane, or oil. Supplementary space heating and other household energy uses are provided by electricity.



The more efficient a home, and the fewer kWhs you use a day, the further a renewable power system is going to offset your electric usage. Homeowners can improve energy efficiency through the following upgrades:

» draft proof a house

» add insulation to exterior walls, roofs, and basement walls and floors

» install ENERGY STAR or other high performance windows and doors

» install heat pumps to provide space and/or water heating

» use compact fluorescent light bulbs, or LED lights

» use ENERGY STAR appliances

"PV systems have a typical life of at least 25 years, so a panel will generate many times more energy than is needed to produce it."

***

Greenpeace

© Terratek

6.) SOLAR PHOTOVOLTAIC

6.1) An Introduction to Solar Photovoltaic

Solar photovoltaic systems, also known as solar PV, convert sunlight into electricity. PV cells are made from layers of semi-conducting material, usually silicon. When light shines on the cell it creates an electric field across the layers. The stronger the sunshine, the more electricity is produced. Groups of cells are mounted together in modules, also known as panels, that can be mounted on your roof.

Solar PV performance is measured in kilowatt hours, or kWhs. This refers to the amount of energy produced by the panel and is represented as kW per square metre of panel surface.

Energy produced from solar modules in **grid-tie** and grid-tie with battery back-up system, first satisfies electrical loads within the house. The excess electricity produced can then be fed directly into the grid using BC Hydro's net-metering program. In **grid-tie with battery back-up systems** energy is also stored in battery banks, for emergency situations. When systems operate apart from the utility grid they are considered **off-grid** systems. This chapter will focus on grid-tie system. To read more on the differences between the three see **Section II: Electric Power Systems** on page 49.

Check the BC Hydro website for up-to-date information on the BC Net Metering Program: www.bchydro.com

Three kilowatt solar photovoltaic system, with battery back-up, installed in Fanny Bay, BC.

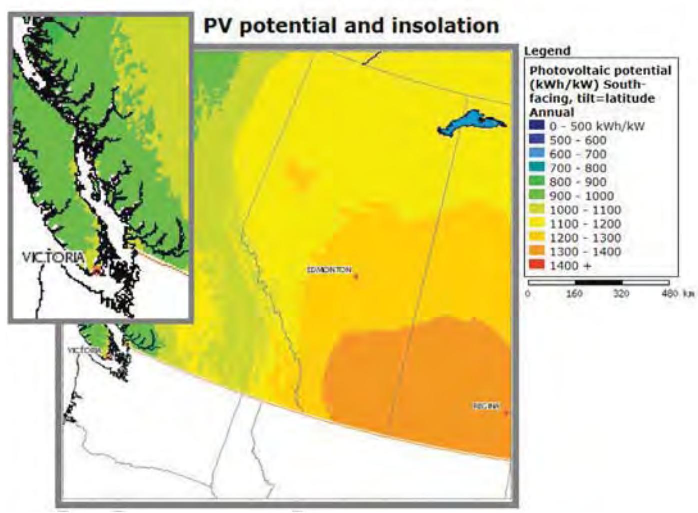
Quick Self-Assessment: is Solar Photovoltaic Right for You?

There are some simple ways to find out if your home is suitable for solar PV:

- Your roof is in good condition and faces south. Panels mounted on a roof facing south, south west or south east will perform the best.
- Your roof has a clear space of up to 24 sq/m. The area should be free from shading from trees, chimneys or other buildings for most of the day.
- If the roof is not an option, you have sufficient and adequate space on the ground for ground or pole mount installations.
- You have space inside the home, usually the mechanical room, for a string-inverter. Micro-inverters may be an alternative should interior space be limited.

6.2) Viability of Solar Photovoltaic

The higher the solar potential for a region, the easier and more affordable it is to meet energy production goals. There is a common misconception that BC doesn't get enough sun for solar systems but in the Nanaimo area, one kilowatt of solar energy provides up to 1076 kWhs a year[1]. This is just under the solar potential for the Okanagan. In Berlin, Germany, the leading country in solar installations, the average annual sunshine potential is less than 900 kWhs. While solar panels have a higher production capacity on sunny days, our cooler west coast summer temperatures actually make solar PV more efficient, since heat decreases efficiency. Solar modules can absorb ambient light on cloudy days to produce electricity.



Source: Natural Resources Canada

Ultimately, when setting goals for a grid-tie solar PV system, it is a good idea to first determine how much of your electric bill you want to offset, how much roof space is available and what size system fits within your budget.

6.2.1) Bylaw Requirements and Permits

All permitting will be done by the installation company. An electrical permit will be required, from BC Safety Authority. A building permit may be required for a roof-mounted system depending on the size. This permit is not required for pole or ground mounted systems.

1 Source: Natural Resources Canada.

6.3) Different Types of Systems

Photovoltaic modules are the solar electric system's main component, where sunlight is absorbed to generate electricity.

Solar modules are available in many sizes, voltages and formats. These include monocrystalline or polycrystalline modules which are rigid and mounted to frames. These are typically used in residential applications because of their availability and affordability. There are other higher cost options that include thin film panels, which use lightweight layers of photovoltaic material; building integrated photovoltaics, or BIPV, which look like real roofing tile; or laminated modules, which are flexible solar panels bonded directly to the roof. Solar PV modules are virtually maintenance free and very long lasting with a lifespan of 25 years or more.

While there are many types of installations for solar photovoltaic, which include awnings, carports and other covered areas, there are three main methods of module installations on residential properties:

» **Roof top:** solar modules can be mounted flush to an angled roof or angled for maximum south-facing efficiency on a flat roof.

» **Ground Mount:** When south-facing roof space isn't an option modules can be mounted on the ground where there is maximum south facing access and limited shading.

» **Pole Mount:** If more height is required to access sunlight and eliminate shading challenges, pole mounts are an option. These tend to be more expensive but slope angles can be manually adjusted to follow the sun in winter and summer for maximum efficiency.


© Terratek

Six kilowatt ground-mount installation, Nanaimo, BC.


© Terratek

22 kilowatt solar photovoltaic roof installation, Comox, BC.


© Terratek

One kilowatt solar photovoltaic pole mount, Fanny Bay, BC.

Inverters convert direct current (DC) to alternating current(AC) electricity. There are two types of inverters to choose from:

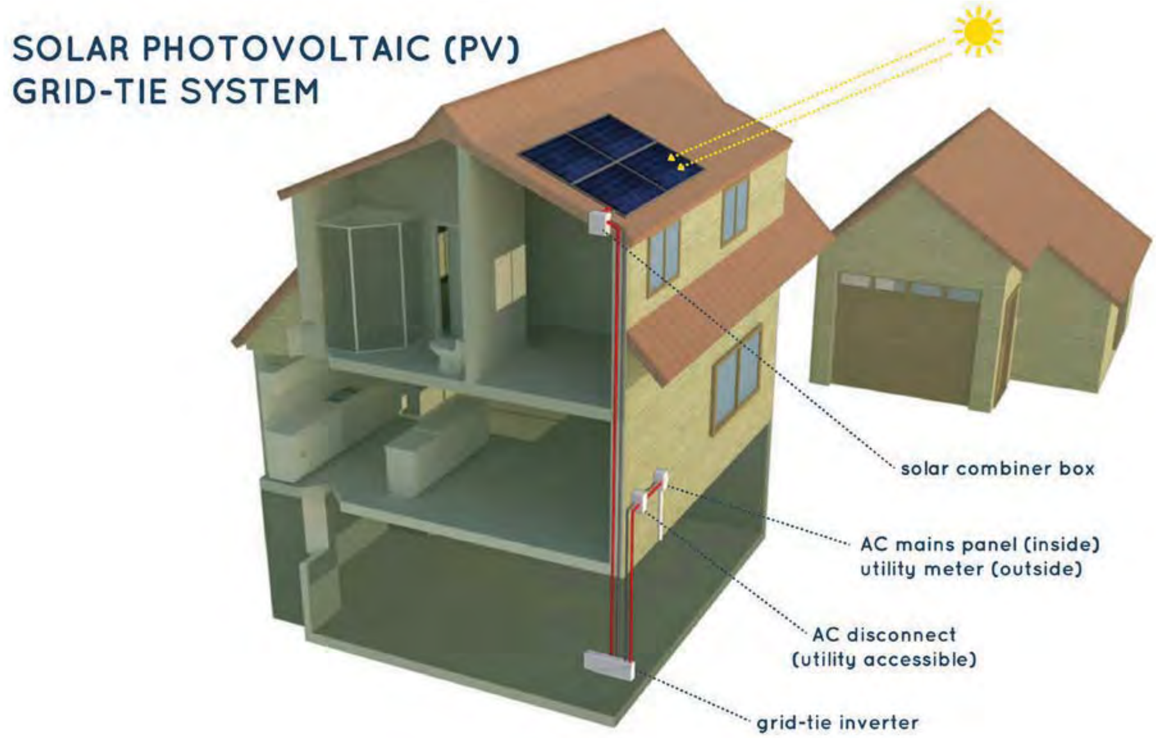
» **String Inverter**: Wiring is run from the solar modules to the inverter. An inverter hung on the wall near an electrical service panel works best. This inverter is most optimized when there is no shade on the solar panels, as the main shortcoming of the this inverter is that all modules are strung together and do not work independently. For example, output can drop dramatically if one panel is shaded, as it will affect the output of the string as a whole. This traditional inverter is the least expensive option, but if an expanded system is planned for the future a larger capacity inverter will be required.

» **Micro-Inverter:** These inverters are the newest technology and are installed behind each module directly on the roof, eliminating the need for wall space in the electrical room. They also work better than string-inverters if a roof has partial shading because one panel will not affect the performance of the other modules. While they can be more efficient than string inverters they are also higher in cost. Micro-inverterbased systems are easily expanded and would be a good option, for those on a limited budget with the goal of developing a larger system over time.

String Inverter.

Enphase Micro-inverter.

6.3.1) System Schematics



6.3.2) Basic Components

The basic components of a solar PV system with a string-inverter are:

- Solar array, which includes modules and racking equipment.
- Solar combiner box. Combines the inputs from multiple strings of solar panels into one output circuit.
- AC mains panel and utility meter. The mains panel is the general purpose AC electric power supply. The utility meter measures the flow of electricity between the home and the utility company.
- AC disconnect. A safety device to isolate electrical equipment on the AC (the "house" or grid) side, from the DC (the solar panels) side.
- Grid-tie string inverter. Converts PV power from DC to AC electricity. These units either use the utility grid as power storage in grid-tie systems, or use batteries, in grid-tie with battery back-up systems.
- If a battery back-up is requested, additional switchgear, or assembly of switching and interrupting devices, along with control, metering, protecting and regulating equipment would be required.

6.3.3) Sizes of Systems and Price Averages

With solar PV systems, the price varies depending on how much energy the homeowner would like to generate. Today in BC the current installed system price per watt for a direct grid-tie system, is just under $4, having dropped from $12 per watt five years ago, due to the increased demand for solar PV worldwide.

A typical residential install in Southwest BC is three kilowatts, or 3,000 watts. The installation cost of a system that size ranges from $11,500 - $14,000. It will offset about 25 - 35% of a home's electricity usage.

By estimating annual kWh consumption, systems can be sized accordingly following the formula that one kW of solar energy yields 1,076 kwh in electricity in the Nanaimo region.

For example, if a homeowner wants to generate at least half their energy with solar and they use 10,500 kWhs a year, a five kW system will be needed as 1,076 kWhs X 5 = 5,380 kWhs.

$$\frac{\textbf{Energy Production Goal (kWh)}}{\textbf{1,076 kWhs}} = \textbf{Size of System}$$

4.5 kW grid-tie solar array with battery back-up, for a home in the Comox Valley. Total cost is about $28,000 (installed Oct, 2012). Without battery back-up cost would be closer to $20,000. This should provide roughly 50%-60% of the couple's home energy usage.

Case Study: PV Grid-Tie With Battery Back-Up, Duncan, BC

The journey to carbon zero has been a productive one for a Duncan couple that began investing in a more sustainable home a few years ago. As they settled in, they began looking at a variety of renewable energy options before deciding on solar PV.

"Wind wasn't feasible for our location, and we don't use a lot of hot water so solar thermal wouldn't have been economical," they explained. "PV allowed for flexibility and resilience, and on sunny days we think, 'Wow! This is great.'"

The couple installed a 1.75 kW solar array, and 6 kWh battery bank for well pump, septic system, refrigerator and freezer, after upgrading the insulation in their home. For those considering a renewable energy system installation, the couple says energy efficient upgrades in the home can be an important first step.

"Insulation upgrades are particularly applicable for people with electric heat," they say. "Poor insulation is a huge gobbler of electricity."

The system has raised their awareness of their electrical consumption, including phantom loads, and what appliances draw the most energy. In terms of energy costs they are happy to report that they're seeing a decrease in their bills, with additional credits back from BC Hydro's net metering program.

They have also installed a ductless heat pump for further home energy efficiency, and just finished installing a biogas digester, where their organic waste is converted into methane that they're able to use for cooking on their outdoor burner.

"People have been quite excited and fascinated," they say, of friends and neighbours who stop by. "We're just trying to do our bit to educate others in the valley."

Below is a cost breakdown at the date of install, as well as an overview of the couple's subsequent savings. It should be noted that the total cost, as of 2013, would be closer to $18,000.

PV Solar

1.75 kilowatt Solar Grid Tie System with 6 kw-hr Battery Bank

10 SunTech 175 watt Solar Modules	*$720 X 10*
Pro Solar Flush Mount Racking System	*$810*
Tilt Kit on Upper Row of Solar Array	*$470*
Powerboard with Xantrex XW4024 Grid Tie Inverter, Charge Controller & Battery Monitor	*$7,100*
2 East Penn 257 Amp Hour Sealed AGM Batteries	*$640 X 2*
Connection Hardware	*$2,580*
Installation	*$2,880*
BC Hydro Net Metering Requirements	*$210*
BC Safety Authority Electrical Permits	*$695*
Total	***$25,945***

PV Solar Production (Installed mid May 2010)

Production in 6 months	*1210 kwH*
Average daily production in July	*10 kwH*
Average daily production in Nov.	*1.5 kwH*
Aug 2009 hydro bill - $48	*Aug 2012 hydro bill - $16*
Oct 2009 hydro bill - $65	*Oct 2010 hydro bill - $33*

10 kWh battery bank for residential solar grid-tie with battery back-up.

6.4) Energy Management

For information on how to best manage household energy with renewable power systems, see **5.2) Energy Management**.

6.4.1) Monitoring Solar Photovoltaic Systems

Monitors for PV systems can help homeowners visibly track the energy that their solar PV system is producing. Monitors also track inverter performance and most provide alerts to owners and installers of any deviation in performance. Other variables to monitor include irradiance, temperature, wind and grid parameters like voltage and frequency. If monitoring the system itself is not enough to satisfy a homeowner's curiosity, there are a few manufacturers that allow monitoring of household site loads as well, down to the level of individual appliances and equipment.

Module level monitoring by microinverters can also give the homeowner a view into the heart of their system, isolating the performance of individual strings or modules.

The screen shot of a PV monitoring system below shows peak power production, energy produced, trees saved and carbon offsets.

Week	Peak Power	Energy Produced
02/01/2013 - 02/07/2013	4.42 kW	39.4 kWh
02/08/2013 - 02/14/2013	4.34 kW	56.2 kWh
02/15/2013 - 02/21/2013	4.85 kW	89.3 kWh
02/22/2013 - 02/28/2013	4.59 kW	53.1 kWh
	February 2013 Total:	**238 kWh**
	Previous Month Total:	**199 kWh**
	Year to Date:	**437 kWh**

For more details on these production results, please visit your Enphase® system.

Your **Carbon Offset** for this month: 363 lbs

You have offset the equivalent of: **4 Trees**

Source: Enphase Energy, Enlighten

Germany set a solar world record in 2012, producing 22 gigawatts for a cloudless stretch beginning at around noon on Friday, May 25. The International Economic Platform for Renewable Energies pointed out that was the equivalent of about 20 nuclear power plants.

6.4.2) Changes of Habit

There is very little lifestyle change with a grid-tie system, although homeowners can maximize their system's performance by adjusting habits and behaviour around energy consumption.

Using appliances with a high energy demand, such as washing machines, dishwashers, irons and vacuum cleaners, while you are generating electricity during the day, can be a good way of utilizing the sun's free energy. Another habit to consider would be charging devices such as laptops and mobile phones at the same time, when the system is performing, rather than at night, when you would be relying on the utility grid. Another way to take advantage of the daytime energy production from a solar PV system is to purchase electrical appliances with a timer that will enable them to start working if you are going to be out of the house.
For those choosing a grid-tie with battery back-up system, a certain amount of maintenace will be required for the batteries. It will be important to know the state of charge, or SOC. Homeowners will be required to keep close watch on the SOC of the batteries. By not allowing batteries to discharge below a certain point, performance can be maximized and their life can be extended. Monitoring the voltage and current readings in your system will tell you how full your batteries are and how fast they are charging or discharging. This can be monitored via the inverter with one or more energy metres.

For more on off-grid PV system, refer to "Solar Power Your Home for Dummies", 2nd Edition listed in 6.8) Resources.

For fully off-grid systems, homeowners can expect a complete lifestyle change where daily routine is driven by the availability of energy. When the system is producing energy, the homeowners will be doing the high energy tasks, like running a washing machine. When the system is not producing, the homeowners will draw a limited amount of power from the battery bank. The reorientation of one's lifestyle around energy production is a very real challenge, making 100% off-grid system appealing to only the most motivated and dedicated homeowners.

6.5) Other Applications

Solar photovoltaic systems can help offset energy costs for farms, orchards and wineries, including solar awnings and shade structures that give the ability to create shade spaces while generating electricity.

Solar pumps are also currently being used by a number of orchards in BC. These pumps are solar PV powered and independent of any infrastructure, energy grid, or other power sources.

Solar photovoltaic systems can help offset power generation at farms, orchards or wineries.

6.6) Maintenance and Warranties

Most residential solar photovoltaic modules have a 25 year limited warranty. Inverter warranties range from 10-25 years, and in most cases extended warranties are also available. Modules will degrade over time, and typically output can be expected to diminish no more than 1% per year.

Homeowner responsibility is minimal. At most the modules may require a wash on a cloudy day so that the water does not shock the modules during heavy pollen or dusty seasons. This is up to the discretion of the homeowner. Usually one wash per year will be sufficient.

6.7) Frequently Asked Questions

Q) How does a PV grid-tie system work and what is the average cost?
A) Solar photovoltaic, or solar electric systems for residential grid-tie customers are done through the BC Hydro Net Metering program. The program allows customers to be able to produce a portion of their own power. If a customer produces an excess amount of electricity, above and beyond what they consume, they will be credited from BC Hydro. The current installed cost is just under $4 a watt.

Q) How big of a system do I need?
A) Typically, when dealing with grid-tie systems, you must look at three different variables. How much of your electric bill do you want to offset? How much south facing roof space is available? Do you have a budget in mind? As these variables are different for everyone, and because different clients use different amounts of electricity, all grid-tie systems should be custom designed to meet your needs.

Q) What is an inverter?
A) There are two kinds of electricity, Direct Current or DC and Alternating Current or AC. Homes that are connected to utility power use AC electricity. Flashlights, small radios and automobiles use DC electricity. In order for you to be able to use solar to operate the appliances in your home, an inverter will convert PV power from DC to AC. Inverters can be further classified as units that use batteries, in grid-tie with battery back-up scenarios, and those that use the utility grid as power storage, in grid-tie scenarios. For off-grid systems, an inverter is optional if you use DC loads exclusively.

Q) What is the approximate return on investment with solar PV?
A) As with any renewable energy system, this is a longer term investment. Given the current pricing information, the amortized capital cost of a solar photovoltaic system equates to 11plus cents per kilowatt hour over a 30 year lifespan. If the price of solar PV continues to fall and utility rates increase in the future, the system will look even more economically favorable.

6.8) Resources

BC Sustainable Energy Association, or BCSEA: A non-profit society that empowers BC residents to build a clean, renewable energy future. Their Sustainable Energy Directory provides links to solar installers and suppliers in the province.
www.bcsea.org

EnergyBC: An online resource on energy sources, uses and issues in BC.
www.energybc.ca

Canadian Solar Industry Association, or CanSIA: A national trade association that represents approximately 650 solar energy companies throughout Canada.
www.cansia.ca

Canadian Mortgage and Housing Corporation, or CMHC: Canada's national housing agency provides a detailed fact sheet on solar PV as part of their About Your House General Series.
www.cmhc-schl.gc.ca/en/co/maho/enefcosa/enefcosa_003.cfm

Solar Power Your Home for Dummies, 2nd Edition: A brief summary of off-grid solar PV systems can be found here.
www.dummies.com/how-to/content/what-you-need-to-go-off-the-grid.html

Solar Electric Handbook: Photovoltaic Fundamentals and Applications (2012) and **Photovoltaics:** Design and Installation Manual (2004)
Published by Solar Energy International

Physics of Solar Energy (2011)
C. Julian Chen

Solar Electricity Basics (2010) and **Power From the Sun** (2009)
Dan Chiras

6.9) Homeowner Checklist

- ☐ Do you have an understanding of your electricity use throughout the year, from either tracking consumption with a home energy monitor or calculating your total annual electricity consumption based on utility bills?
- ☐ Do you know how much energy you would like to produce with a solar PV system, and have you developed a budget?
- ☐ Do you have minimally shaded south-facing roof or property space?
- ☐ Is the roof in good condition?
- ☐ If your roof will not be adequate, do you have unshaded south-facing property for a ground installation?
- ☐ Have you found a qualified installer?
- ☐ Has the installer conducted a site visit and provided system information including analysis of module and inverter options for your requirements, cost estimate and permits required?
- ☐ Has the installer walked you through the application process for the BC Hydro net-metering program, if applicable?
- ☐ Have you discussed with the installer any special safety precautions, such as hydrogen venting of batteries?

7.) WIND ELECTRIC

7.1) An Introduction to Wind Electric

Wind energy is the form of energy conversion in which wind turbines convert the kinetic energy of wind into electrical energy that can be used for power. All wind systems consist of a turbine and a tower. Small wind turbines, for residential use, protect themselves from high winds with a tilting rotor, or by changing the pitch of the blades. Electricity is transmitted down the tower on wires as "wild" alternating current, or AC. It's called "wild" because the voltage and frequency vary with the rotational speed of the wind turbine. It is regulated to direct current, or DC voltage, which then passes through an inverter converting to AC electricty for home use. Excess electricity generated by a **grid-tie** wind system or a grid-tie with battery back-up system, can be fed back to the BC utility grid and homeowners can receive credits from BC Hydro through the net metering program. When power is stored in a battery bank for later use, such as when the power goes out, this is called **grid-tie with battery back-up**. Systems that generate power separate from the utility grid are called **off-grid** systems. In this chapter grid-tie systems will be discussed. See **Section II: Electric Power Systems**, page 49, to review the differences in system types.

To produce real power, sustained winds, or winds that blow over a significant period of time, need to be 25-40 kilometres per hour, or km/h. Tower height plays an important role in accessing reliable wind speeds and increasing performance in a wind generator. Because of some height restrictions due to bylaws, or trees and other obstructions, wind systems are very site specific. Assessing site feasibility is the first step in considering a wind system.

Below are some useful terms related to wind electric systems:

- **Start-Up/Cut-In Speed:** The wind speed at which a wind turbine will actually start to produce power. Wind speeds are often measured in metres per second, or m/s, and a good quality turbine should have a cut-in speed of around 3 m/s, or 3.6 kilometres an hour.

visit www.onlineconversion.com for speed conversion calculator.

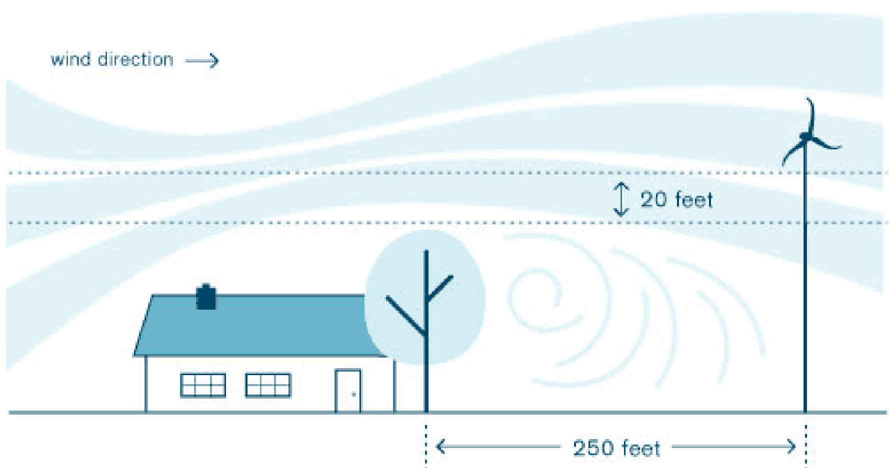
- **Rated Speed:** Wind speed at which a wind turbine will produce its published amount of power. See "Average Power vs. Wind Speed" chart on following page. Most turbines have a rated wind speed of approximately 10 to 11 m/s, or 35 to 40 km/hr.

- **Cut-Out Speed:** The wind speed at which a wind turbine will start to protect itself from higher wind speeds. Some turbines furl out of the wind, where others have blades that flex or turn slightly to lessen the brunt of bigger winds. Many higher quality turbines do not need such protection.

- **Survival Speed:** Some turbine manufacturers will publish a maximum wind speed that the wind turbine can survive in. This is mostly a warranty clause.

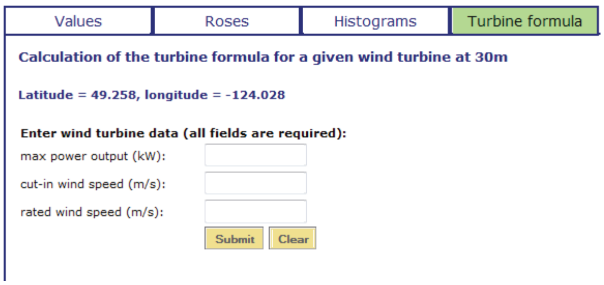
7.2) Viability of Wind Electric

There are certain geographical locations best suited for wind, and generally rural and remote areas are more suitable than urban environments. Systems are best suited for homes on a hill, or near the ocean, with unobstructed exposure to the strong winds of the southeast and northwest. A general rule is that the wind turbine should be at least 20 feet taller than obstacles located within 250 feet of the tower.



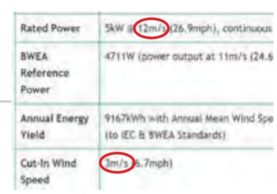
Courtesy of Southwest Windpower, www.windenergy.com.

A formula to determine potential wind production for the site can be found at **www.windatlas.ca**. In the "maps" section, select "mean wind speed" and "30m," which is the typical residential tower height, and click on the geographical tile to enter latitude and longitude or a specific postal code. This will generate a turbine formula. The example below is using the postal code for the airport postal code in Nanaimo:

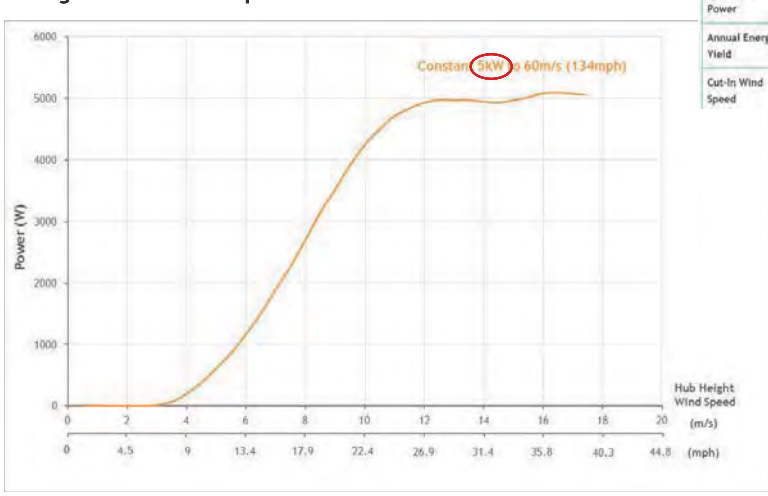


You will be prompted to enter the max power, cut-in speed and rated speed. You can find this information on manufacturer spreadsheets, usually available online. See below as an example. For a list of manufacturers, visit the Canadian Wind Energy Association website (**www.smallwindenergy.ca)**.

9,167kWh with an average annual wind speed of 5m/s
17,877kWh with an average annual wind speed of 7m/s



Average Power vs. Wind Speed



Courtesy of Evance Wind Turbines, www.evancewind.com

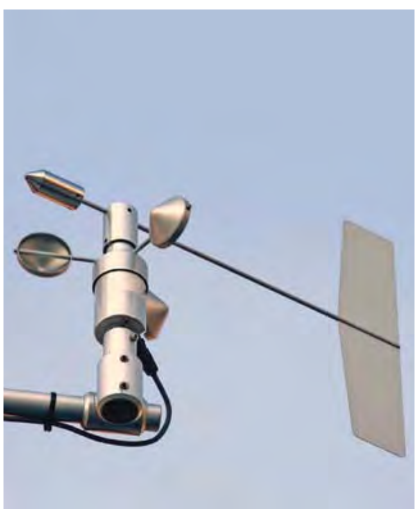
Once this data is entered into the turbine formula, a chart will be provided with the power output, energy output and use factor for a wind turbine, specific to the site, over the course of the year.

See 1.6) Note on Common Terms in the Introduction for a refresher on kWhs.

Below is a screen shot result illustrating that a 5 kW turbine would produce 12.01 megawatt hours a year. One megawatt hour is 1,000 kilowatts used or delivered in an hour, which means this turbine would provide 12,010 kWhs annually in ideal wind conditions. Note that the higher the "use factor" percentage, the more efficient the site.

Period	Power Output	Energy Output	Use factor
Annual	1.37 kW	12.01 MWh/year	27.40 %
Winter (DJF)	1.79 kW	3.92 MWh/period	35.77 %
Spring (MAM)	1.23 kW	2.71 MWh/period	24.70 %
Summer (JJA)	1.26 kW	2.76 MWh/period	25.21 %
Fall (SON)	1.33 kW	2.91 MWh/period	26.53 %

It should be noted that the estimates generated from this formula may be higher than in reality as it will not take into consideration the various obstacles that might be present around the location.



An anemometer, a common weather station instrument.

A wind installer will be able to provide a more accurate calculation, or a homeowner can install a monitoring device, called an anemometer, to accurately measure the amount of wind on site, over a period of time. Anemometers are common weather station instruments used to measure wind speeds and wind pressure. They can be purchased from any local hardware or marine store. To be truly representative of the wind available, they should be installed at roughly the same height as a turbine in an obstruction-free location.

7.2.1) Bylaw Requirements and Permits

An electrical permit from the BC Safety Authority will be required. The RDN also has a height restriction of about 10 metres, or 33 feet. Working within the restriction does not allow for enough height for a turbine to be effective, as there will simply be too much turbulence, so a height variance will need to be approved. Contractors will take care of both the permit and variance, if required.

7.3) Different Types of Systems

There are two different types of wind turbines: vertical and horizontal axis. **Horizontal axis** turbines consist of a rotor with blades driving a generator at the top of a tower. They must be pointed into the wind, with the help of a tail vane or fantail. These turbines are usually more efficient than vertical-axis units[1].

Vertical axis turbines have a rotor shaft set vertically and the main components are located at the base of the turbine, which makes these components easier to service and repair. However, the difference in efficiency occurs in the swept area, or the area of the circle created by the blades as they sweep through the air. A horizontal axis turbine's swept area always faces the wind. But with a vertical axis turbine, the swept area is a cylinder perpendicular to air flow., meaning that while part of the "swept area" is working, the other part is being blown around, not at an optimal angle to generate lift. This results in a less efficient rotor.

1 Source: Renewable Energy World.

Horizontal axis turbine.

Vertical axis turbine.

Quick Self-Assessment: is Wind Electric Right for You?

There are some simple ways to find out if your home is suitable for wind electric:

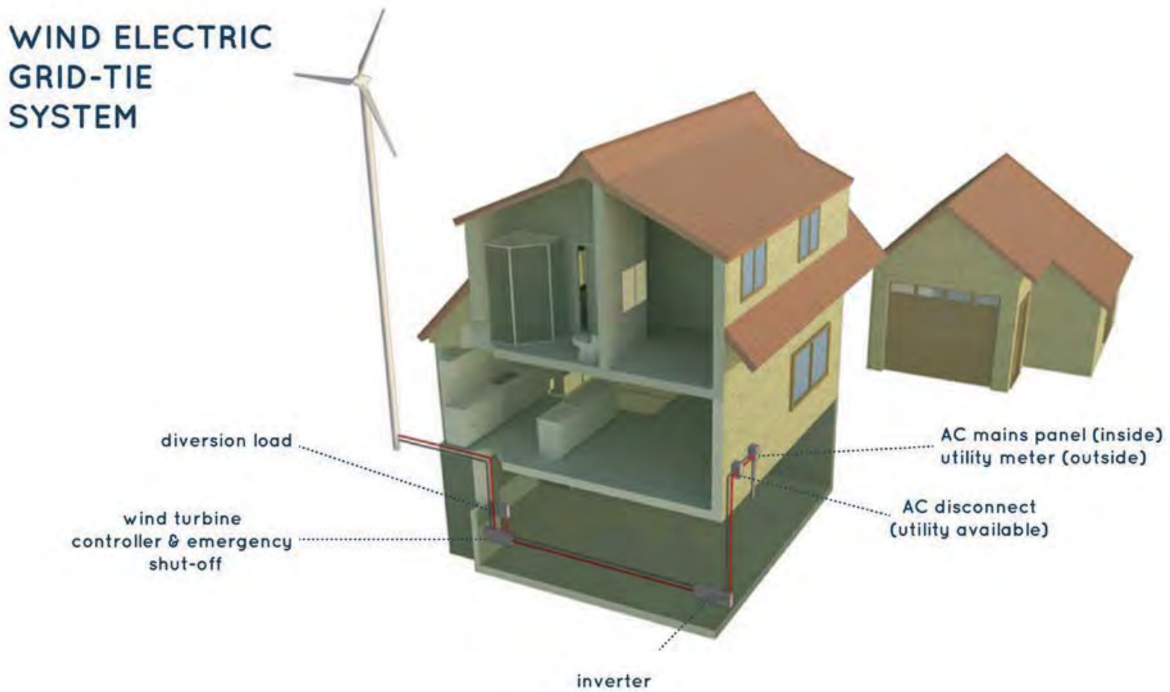
- Do you need to obtain a height variance?
- Do you have wind speeds of more than 10 km/h?
- Is your property free from obstructions?
- Do you have space in or near your electrical room for an inverter, disconnect and diversion load?

Towers are available in different configurations and heights. Some can be tilted up or down for easy maintenance and installation, while others are freestanding and need to be erected with a crane. All towers require significant concrete foundations.

The most cost effective tower for residential systems is a **guyed tower**. It has the ability to tilt and consists of sections of pipe, held in place by tension cables:

Guyed tower and monopole tower.
Courtesy of Southwest Windpower. www.windenergy.com

7.3.1) System Schematics



7.3.2) Basic Components

Basic components of a wind electric system are as follows:

- Wind turbine and tower. Turbine includes rotor and generator/alternator in horizontal axis turbines.
- AC Mains panel and AC disconnect. The mains panel, also known as the AC panel, is the point at which all of a home's electrical wiring meets with the provider of the electricity, whether that's the grid for grid-tie systems, or a wind-electric system for off-grid systems. The disconnect allows the inverter to be quickly disconnected from either the grid or batteries for service.
- Wind turbine controller and emergency shut-off switch. These controls determine at what wind speeds the turbine starts up and when it is shut-off.
- Diversion load. Also called a "dump load" is the device to which wind generator power flows when the system batteries are too full to accept more power. This is the electrical grid for grid-tie systems, or a battery bank for grid-tie with battery back-up systems.

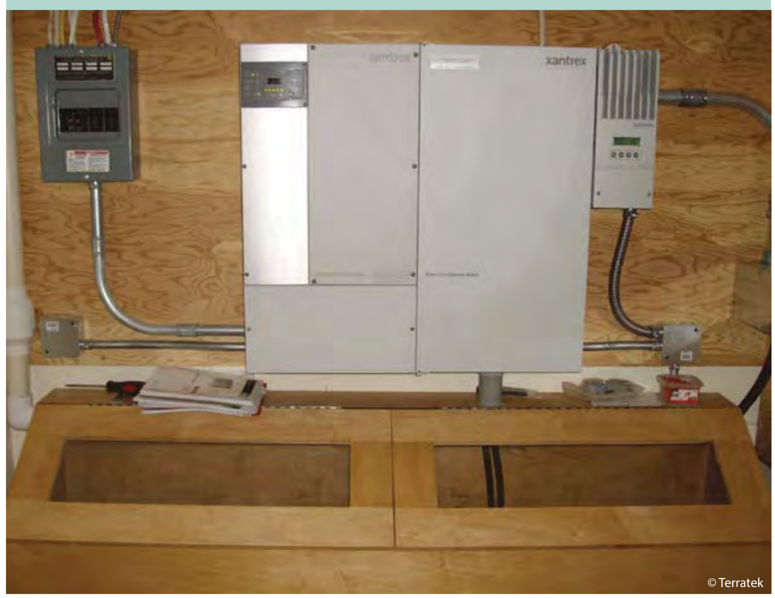
7.3.3) Sizes of Systems and Price Averages

Wind turbines are classified in terms of size, such as 1,000 watt turbine or 1 kW turbine. Manufacturers will have information on the estimated amount of power that turbines will produce at average wind speeds. Currently, the average cost for an entry level residential wind system starts at around $20,000.

Case Study: Wind Grid-Tie With Battery Back-Up, Courtenay, BC

Homeowners on a rural property in Courtenay began building their dream home in 2009 and one of their renewable energy goals was to install a wind electric system. Good access to prevailing southeast and northwest winds made for a feasible wind site, with no land permitting required for their hobby farm. An electrical permit and equipment certification were completed for this project.

A 2.5 kW wind turbine was installed on an 85 foot guyed tower. This model of turbine is designed for the coastal climate, robust enough to handle the winter storms and with a large enough swept area to produce power in light winds. Estimated production is 20% of the property's power requirements, and total cost of installation came to approximately $35,000.



The homeowners also chose to have a battery back-up as they were experiencing fairly frequent power outages in the winter. The battery bank is sized to 20 kWhs, and this was determined by undertaking a load analysis for the four person, 3000 sq/ft home. This back-up load includes kitchen lighting, kitchen plug, fan on woodstove, septic pump, water pump, fridge, freezer and computer.

All battery bank equipment is stored in the downstairs utility room, with batteries vented to the exterior. Homeowners are required to undertake monthly visual checks on battery cables, as corroding can occur with flooded batteries. These battery types are more maintenance heavy but less expensive than sealed batteries. Equalization and refill of distilled water is also done every six weeks to "reset" the batteries and replace exhausted fluids. The battery based grid-tie inverter monitors battery status and production.

© Terratek

See Section II: Electric Power Systems on pg. 49 to review the differences between grid-tie, grid-tie with battery back-up and off-grid systems.

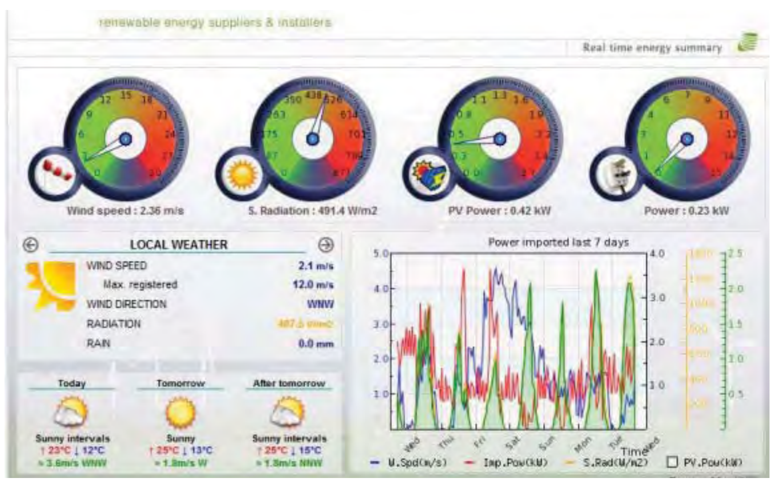
7.4) Energy Management

For information on how to best manage household energy with renewable power systems, see **5.2) Energy Management** on page 54.

7.4.1) Monitoring Wind Electric Systems

Because of the moving parts involved in a wind system, monitors should be installed. They can measure and display several different aspects of your system's performance and status, tracking how full a battery bank is, how much electricity your wind generator is producing or has produced, and how much electricity is in use. Monitors can also help identify errors in performance, which will help homeowners keep their system running at maximum efficiency.

Monitors can also offer a variety of management software options to supervise turbines and equipment including performance and blade monitoring, weather forecasts and analysis, wind speed and power forecasting.



Screenshot of monitoring display, Courtesy of Logic Energy www.logicenergy.com

7.4.2) Changes of Habit

A wind turbine can affect your view or that of your neighbours, and it might block or change an historic landscape. Objections are more likely to occur in areas that are more populated, and least likely in rural areas. However, in other cases, small wind turbines can actually become a tourist attraction. These are all factors to bear in mind when considering a wind system.

Most modern residential wind turbines produce a sound pressure leveo of 52 to 55 decibels, equivalent to the noise generated by an average refrigerator[1],. The sounds produced by a wind turbine are the swishing of rotating blades and the whirring of the generator. Within several meters, these sounds may be heard against background noise but the noise level depends on the turbine itself, as some turbines are noisier than others. Other potential noise factors to consider are wind patterns, such as turbulent winds, and site terrain. Sound will travel further in certain areas. A general rule to abide by is that the mean sound pressure level value should not exceed 6 decibels above background sound, as measured at the exterior of the closest neighbouring inhabited dwelling (for wind speeds >10 m/s). If the turbine is well sited, noise shouldn't be a problem. However, If neighbours are nearby it is important to consult with them before moving ahead with a wind system installation.

For grid-tie with battery back-up and off-grid systems, battery maintenance will be a significant part of operating the system. By not allowing your batteries to discharge below a certain point, called State of Charge, or SOC, performance can be maximized to extend their life. Monitoring the voltage and current readings in your system will tell you how full your batteries are and how fast they are charging/discharging. This will be monitored by the inverter or wind charge controller.

1 Source: Canadian Wind Energy Association.

7.5) Other Applications

Hybrid systems are typically renewable energy systems that use wind and solar as power sources. By taking advantage of both, this setup becomes a suitable option for most Vancouver Island areas due to our sunny summers and windy winters.

7.6) Maintenance and Warranties

Wind turbines will last over 20 years and come with a five year warranty. Most inverters have a five year warranty, at a minimum.

Visual inspections are recommended once a month on tower components, which can be done by the homeowners. Because it is a moving system, there will be wear and tear on the turbine. Typically, tilting the turbine down or climbing up once a year for servicing will be required by a wind installation company.

Every five years the turbine will need to be taken down to grease bearings and be re-built. This means taking it apart, cleaning parts and putting it back together. This should also be professionally done by the wind installation company.

7.7) Frequently Asked Questions

Q) I live in an urban environment. Can I install a tower?
A) Wind systems are site specific. Turbulence, neighbours, fall zones, etc., are major factors for urban wind systems. Applying for a height variance in the RDN Electoral Areas costs $400, and the process would likely take 2 months. While it may be feasible, often times wind is most suitable for rural areas.

Q) How tall of a tower do I need?
A) Because of the turbulence that is created by structures and trees it is recommended that the turbine, when installed, should be at least 20 feet taller than those obstacles located within 250 feet of the tower.

Q) Can I mount a turbine to my roof?
A) Generally, this is not recommended. Roof-mounted turbines will produce a vibration that will travel. If your home or business is a wood structure, the vibration will amplify. If your home or business is a concrete or steel structure, the vibration will not be noticeable.

Q) What is the lifespan of these systems?
A) Wind turbines contain many moving parts. If a turbine is regularly maintained, it should have a lifespan of 20 years or more.

Q) What energy savings can I expect on wind systems?
As with any renewable energy system, this is a longer term investment with a higher capital cost and demand on maintenance than solar photovoltaic as well as higher maintenance costs. The cost for wind systems typically begins at $20,000. But if you have a great wind site, it can be a lot more productive than solar.

Q) What sort of maintenance can be expected?
A) An annual checkup and inspection is recommended for the first five years of operation. This checkup will include checking connections and tightening bolts. On five year increments, the turbine needs to be taken down for maintenance such as greasing bearings. Service contracts can be set up with the installation company.

Dutch-style windmills were first used in the 12th Century, and by the 1700s, had become a major source of power in Europe, according to Natural Resources Canada.

For a simple payback evaluation of a wind electric system, refer to Natural Resources Canada's Stand-Alone Wind Energy Systems, A Buyer's Guide.

7.8) Resources

Small Wind Energy: An off-shoot site of Canadian Wind Energy Association, or CanWEA, website that provides information on small wind systems, case studies, and a list of small wind manufacturers in Canada.
www.smallwindenergy.ca

Canadian Wind Energy Association: CanWEA is a non-profit trade association that promotes the appropriate development and application of all aspects of wind energy in Canada. Case studies of residential applications of wind electric and wind and solar hybrid system can be found on their small wind energy website.
www.canwea.ca
www.canwea.ca/swe/

Canadian Wind Energy Atlas: Environment Canada's Wind Energy Atlas web site aims at developing new meteorological tools to be used by Canada's wind energy industry. It offers the possibility to browse through the results of the numerical simulations that were run on all of Canada in order to determine its wind energy potential.
www.windatlas.ca

Natural Resources Canada: This website provides a buyer's guide for stand-alone wind energy systems as well as links to other wind resources.
www.canmetenergy.nrcan.gc.ca/renewables/wind/publications/2997

Wind Energy Institute of Canada, or WEICan: This organization advances the development of wind energy across Canada through research, testing, training, and collaboration.
www.weican.ca

Wind Energy Explained: Theory, Design and Application (2010)
James F. Manwell, Jon G McGowan, Anthony L. Rogers

Small Wind Systems for Rural Energy Services (2003)
Smail Khennas, Simon Dunnett, Hugh Piggott

Wind Power Basics (2010)
Dan Chiras

7.9) Homeowner Checklist

- ☐ Have you determined the site feasibility for a wind system, including appropriate wind speeds, freedom from obstacles, restrictions, and neighbours?
- ☐ Have you gained permissions from nearby homes and/or the local authority for a height variance, if applicable?
- ☐ Have you developed a budget for such a system?
- ☐ Have you determined whether this system will be grid-tie, grid-tie with battery back-up or off-grid?
- ☐ Have you determined whether this will be a hybrid system, combined with a solar system, or if this will be a standalone system?
- ☐ Have you found a qualified installation company?
- ☐ Has the installation company conducted a site visit and provided information on system size and the differences between turbines, cost and any permits required?
- ☐ Has the installation company provided information on applying for the BC Hydro net metering program, if the system will be grid-tie or grid-tie with battery back-up?
- ☐ Have you discussed with the installation company any special safety precautions, such as if children have access to the system, or hydrogen venting of batteries, if applicable?

Two thousand years ago, the Greeks learned to harness the power of running water to turn the massive wheels that rotated the shafts of their wheat flour grinders.

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Clean Energy Resource Teams

8.) MICRO-HYDRO

8.1) An Introduction to Micro-Hydro

Hydroelectricity is derived from the energy contained in falling water; it is a renewable, comparatively non-polluting energy source. It is Canada's largest source of electric power generation.[1]

In Canada we understand hydropower as involving big dams and large-scale generating facilities. In BC, hydroelectric dams accounts for a significant amount of our electricity supply from the utility grid. Small-scale hydropower systems, however, can be an excellent renewable source of electrical power for homes with ideal site conditions.

Flowing and falling water offers a continuous form of kinetic energy. Hydropower comes from converting the energy in flowing water by means of a water wheel, also known as a turbine, into useful mechanical power. This mechanical power drives a generator that produces electricity for use within the home.

1 Source: www.pembina.org/re/sources/hydro-power

An example of a micro-hydro turbine.

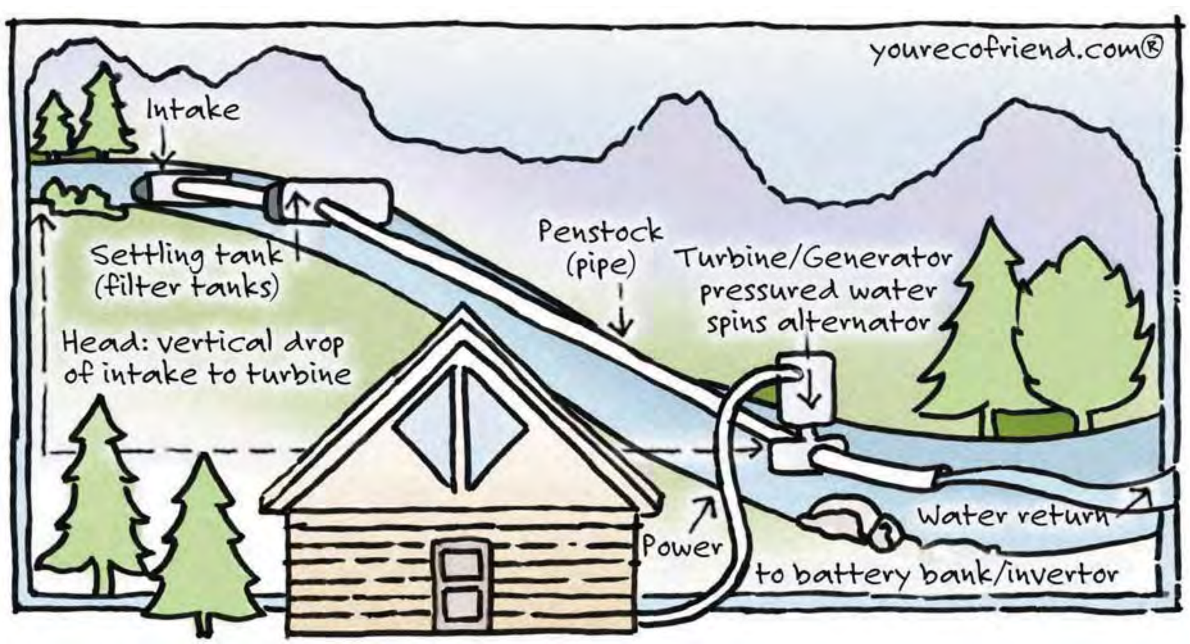
Photo Courtesy of Paul Cunningham, Energy Systems and Design www.microhydropower.com

An example of an intake.

The amount of energy within a water source is based on two factors: head and flow. Flow is the amount of moving water and head is the pressure of the moving water at an elevation drop. The more flow and head that is available, the more energy that can be produced. Because some amount of head is required, most systems will use a pipe, called a penstock, to carry the water down to a turbine, which is a micro-hydro system's main component. Water flowing through the micro-hydro turbine produces DC, or direct current electricity, which is then converted to AC, or alternating current electricity by an inverter, in order to provide household power. Water is then returned to its original source, also using a pipe, called a tailrace.

Visit the BC Hydro website for up-to-date information on the Net Metering Program: www.bcyhdro.com

Excess electricity generated by a **grid-tie** micro-hydro system can be fed back to the BC utility grid and homeowners can receive credits from BC Hydro through the net metering program. Batteries are typically incorporated into the system.



Micro Hydro Off-Grid Mountain Retreat, Courtesy of Terry Kruse, ©Copyright 2013 www.yourecofriend.com

This means batteries are charged first and excess electricity is fed back into the grid. Batteries act as a backup source in case of emergency. There are some instances where residential micro-hydro systems will not require battery back-up for direct grid-tie, but these are site specific, large head systems. Systems that generate power independent of the utility grid are called **off-grid** systems. In this chapter grid-tie/grid-tie with battery back-up systems will be discussed.

An example of off-grid living on a micro-hydro system can be found on Blue Living Ideas website, listed in 8.8) Resources.

8.2) Viability of Micro-Hydro

A great benefit of micro-hydro systems is the system's continuous duty cycle. Micro-hydro systems aren't affected by nightfall or weather. Even a small hydro resource can provide electricity 24 hours a day, and often 365 days a year, if the water source is year-round. Since the bottom line for all renewable energy systems is the amount of energy it can produce, a small residential micro-hydro system working all of the time can often produce a lot more energy than a more powerful source, such as a wind turbine, that only works intermittently.

It is also worth noting that in our west coast climate, our largest power consumption occurs in the winter months, and often this is when there is an abundance of running water. However, micro-hydro systems are very site specific because the available running water needs to be on, or near, the site of the electrical loads.

The important qualifiers for a viable micro-hydro site are access and water flow. A simple way to determine if your water source is viable is to assess the flow rate in litres per minute (LPM). This can be done by measuring the time it takes to fill an 18 litre bucket. Once the bucket fill seconds (BFS) are determined, take 60 (S) divided by the BFS, and multiplying that by 18, the bucket litres (BL).

Quick Self-Assessment: is Micro-Hydro Right for You?

There are some simple ways to find out if your home is suitable for micro-hydro:

- You have a significant amount of falling water. A drainage ditch in the yard won't be sufficient. You need water flowing at a minimum of 108 litres per minute and a drop of 15 feet or more.
- Ideally, the water source will be within 200 feet of the home and be non-fish bearing to avoid lengthy and costly permitting processes.
- Is the source reliable? If it is seasonal, planning and research will need to be done in advance to determine if energy requirements will be met.
- Do you have space outside the house, like a utility shed, for the turbine?

Basic Flow Rate Calculation:

$$\frac{\textbf{60 Seconds}}{\textbf{Bucket Fill Seconds}} \textbf{ X Bucket Litres = Flow Rate}$$

For example, if it takes 25 seconds to fill the bucket, calculate: 60 (S) / 25 (BFS) = 2.4 and then 2.4 x 18 (BL) = 43.2 litres per minute.

If it takes eight seconds to fill the bucket then: 60 (S) / 8 (BFS) = 7.5 and then 7.5 x 18 (BL) = 135 litres per minute.

A minimum flow rate of 108 LPM is typically required for an efficient system.

8.2.1) Bylaw Requirements and Permits

A water use permit will be required, which is issued by the Water Stewardship Division, or WSD, of the Ministry of Environment, and an electrical permit will also be necessary. A contractor should obtain these permits as part of the installation process.

8.3) Different Types of Systems

There are two types of micro-hydro turbines. DC turbines are set up to charge a battery bank. The power is taken from the battery bank and converted to household AC electricity by using an inverter. Electricity stored in a battery bank can also be used for backup when the power is out. DC turbines with battery banks are usually used for residential grid-tie systems, as well as off-grid systems, because of their cost-effectiveness for smaller site specifications. [1]

AC turbines are generally used in large-scale hydroelectric stations and typically not applicable to residential systems. These turbines are set up to drive a generator, which produces AC output and don't require battery banks.

1 Source: '*The Electric Side of Hydro Power*', article in Home Power Magazine, updated in 2012.

Pelton Wheel (DC) turbine for residential micro-hydro system.

8.3.1) System Schematics

8.3.2) Basic Components

Basic components of a DC turbine micro-hydro system are as follows:

» Penstock: the pipe that carries the water to the turbine.
» Tailrace: the pipe that returns the water to its original source.
» Turbine: generates electricity. Includes nozzles, runner, and generator.
» Wire run: for transferring the electrical energy into the house.
» Hydro charge controller: this will ensure that the batteries do not get overcharged. This will also control the diversion load.
» Diversion load: absorb excess energy in emergency situations where battery banks are full and the grid is down.
» Batteries: where excess energy is stored for back-up.
» Inverter, where DC electricity is converted to AC electricity.
» AC disconnect: allows inverter to be disconnected from batteries for service, and protects against electrical faults
» AC mains panel and meter: the general-purpose AC electric power supply and utility meter, which measures the flow of electricity between the home and the utility company.

8.3.3) Sizes of Systems and Price Averages

Since year-round micro-hydro systems do not rely on intermittent energy sources like wind and solar, a small sized, DC turbine system is adequate for residential use. While micro-hydro systems are very site specific, at an ideal site they can be more cost-effective than wind or solar. Currently, the price for such systems generally starts at $15,000.

With any electrical application, the further away the point of use is from the point of power production, the greater amount of power loss occurs over that distance. For homes with water sources further away than the ideal 200 feet, there are turbines available that produce higher voltages, which means loss is minimized over that greater distance. Generally these turbines cost a little more.

Systems can be divided into two groups "low head" and "high head":

» Low-head systems are the most common system for residential installations. These may have less than five feet of vertical drop, which means that a large volume of water in the stream will need to run through the turbine to maximize output. The runner, or the part of the turbine that receives the water and turns its energy into rotation in a shaft, typically has short penstock pipelines that allow the water to drop through the runner.

» High-head systems are generally used for sites with more than 10 feet of head. These systems may have hundreds of feet of penstock pipeline with the water delivered to the runner through multiple nozzles. These are generally suited for AC turbines that do not require a battery back-up.

For all systems, space will be required for an outbuilding, such as a separate power shed, on the property to house the turbine. This is because the system does make some noise, and therefore is generally not suitable for installing in or next to the home.

"The first hydroelectric power plant was built at Niagara Falls in 1879. In 1881, street lamps in the city of Niagara Falls were powered by hydropower."

***

National Geographic Website

8.4) Energy Management

For information on how to best manage household energy with renewable power systems, see **5.2) Energy Management** on page 54.

8.4.1) Monitoring Micro-Hydro Systems

See information about home energy monitors in the Introduction: 1.5) Energy Monitoring, on pgs 6-7.

The best way to monitor the energy savings of a micro-hydro system is to use a home energy monitor. By using a clamp-on device to the inverter that is linked to a wireless home display, information is provided on the electrical generation and kilowatt hour savings of the system.

A home energy monitor will also monitor individual loads to provide home-owners real time feedback on electricity use.

8.4.2) Changes of Habit

Micro-hydro systems require regular maintenance such as making sure the in-take is not clogged, clearing out silt, checking for leaks, greasing machinery, and tightening belts. The installation company will outline servicing require-ments, as well as what a homeowner can do themselves. Try to become prop-erly trained during the installation of the project. It will be better and more cost-effective in the long run for the homeowner to practice preventive maintenance, to avoid any potentially large issues with the system. The manufacturer will also provide detailed information on maintenance procedures and when they should be carried out.

Battery maintenance will also be required for battery-based micro-hydro sys-tems. A battery's lifespan is affected by how much it is discharged before getting charged back up, and how long it stays in that discharged state. A battery's state of charge, or SOC, is the amount of remaining battery energy. Maintaining this will require regular monitoring of system performance.

There is some noise involved because of the rotation of the turbine. It should be installed away from the home ideally in a power shed.

The amount of power available from a micro-hydro power system is directly related to the flow rate, head and the force of gravity. Once you have determined the usable flow rate (the amount of flow you can divert for power generation) and the available head for your particular site, you can calculate the amount of electrical power you can expect to generate.

This is calculated using the following equation[1]:

$$Pth = Q \times H \times g$$

Pth = Theoretical power output in kW
Q = Usable flow rate in m^3/s
H = Gross head in metres
g = Gravitational constant (9.8 m/s^2))

Example:
A site has a head of 10 m (33 ft.) with a flow of 0.3 m^3/s (636 cfm or 4755 gpm); the potential power output is given by Q X H X g (0.3 X 10 X 9.8), which is 29.4 kW.

1 Adapted from ***Micro-Hydropower Energy Systems*** published by Natural Resources Canada, 2004.

8.5) Other Applications

If you have a seasonal water source, combining a micro-hydro system with a solar PV system can supply you with year round power. When the water source dries up, the sun will help to offset energy consumption during those summer and fall months.

8.6) Maintenance and Warranties

Micro-hydro systems require regular maintenance: making sure the intake is not clogged, clearing out silt, checking for leaks.

There is a two-year warranty on most turbines. The wheel of the turbine will need to be checked annually.

As water pushes through the wheel of the turbine, spinning scoops are used to catch the water. Those scoops can start to dull over time and may need to be sharpened.

8.7) Frequently Asked Questions

Q) How do micro-hydro systems work?
A) In a micro-hydro system, the energy of moving and falling water spins a rotating shaft, called a turbine. This creates DC electricity, which is then converted to AC electricity, by way of an inverter, for use within the home.

Q) What is the best water source for a system?
A) A viable micro-hydro resource is dependent on the availability of falling water at, or near, the site of the electrical loads. It is the pressure of that flowing water that spins the turbine to produce electrical energy.

Q) How do I calculate the potential of my water source?
A) A simple formula can give you a rough idea of how much capacity your stream might have. You can measure the time it takes to fill an 18 litre bucket. Then use the formula described on **page 90**. A minimum of 108 litres a minute is generally required for a micro-hydro system to be effective.

Q) How much of the flow in a creek can I use for my system?
A) Only a portion, but a qualified installer will calculate what the minimum in-stream release will need to be, in order to sustain the natural ecosystem within the creek. This number is often expressed as a percentage of the mean annual discharge (% MAD).

Q) How much head do I need for a system?
A) The more the better. Due to the relationship of flow and head, more head is always better. Typically micro-hydro systems have head anywhere from 3 to 300 metres.

Pelton and turgo wheels, the typical spinning water-wheel component, were invented in 1870 and 1919, respectively. This technology has proven its reliability and functionality with more than a century of performance
- Home Power Magazine (Issue #146, Dec/Jan 2012)

8.8) Resources

BC Sustainable Energy Association, or BCSEA: The BC Sustainable Energy Association concerns itself with the sustainable use and production of energy in British Columbia. Their Sustainable Energy Directory provides links to micro-hydro installers and suppliers in BC.
www.bcsea.org

Canadian Hydropower Association, or CHA: Founded in 1998, the Canadian Hydropower Association is the national trade association dedicated to representing the interests of the hydropower industry.
www.*canadahydro.ca/*

Energy Systems and Design, Based in New Brunswick, Energy Systems and Design has been producing micro hydro electric machines and components since 1980. The website has a vast amount of information and resources on the technology.
www.microhydropower.com

BC Hydro: BC Hydro has produced an informative handbook that walks you through the many decisions that need to be made regarding operating a small hydro generation plant.
www.energyalternatives.ca/PDF/BC%20Hydro_small_hydro_handbook.pdf

Blue Living Ideas: "Living Off-Grid, Our Micro Hydro Alternative Energy", by Jennifer Lance, posted on March 24, 2009**.**
http://bluelivingideas.com/2009/03/24/living-off-grid-micro-hydro-alternative-energy-system/

Micro-Hydropower System: A Buyer's Guide (2004)
Published by Natural Resources Canada
www.canmetenergy.nrcan.gc.ca/sites/canmetenergy.nrcan.gc.ca/files/files/pubs/buyersguidehydroeng.pdf

Microhydro: Clean Power from Water (2003)
Scott Davis

The Micro-Hydro Pelton Turbine Manual (2000)
Jeremy Thake

8.9) Homeowner Checklist

- ☐ Do you have an appropriate, non-fish bearing water source?
- ☐ Is the water source reliable and within 200 feet of the home?
- ☐ Have you determined an appropriate space for the turbine?
- ☐ Have you calculated the potential power of the water source?
- ☐ Have you determined how much energy you would like to generate?
- ☐ Have you developed a budget for such a system?
- ☐ Have you found a qualified installation company?
- ☐ Has the installation company conducted a site analysis and provided system feasibility, power potential, cost and permits required?
- ☐ Has the installation company discussed the process for application to the BC Hydro net-metering program?
- ☐ Have you discussed with the installation company any special safety precautions, such as the set-up and access of batteries, hydrogen venting and other potential issues involving access to equipment by children, or other members of the family.

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