Homes, the Environment & Renewable Energy

or

Reducing Your Home's Carbon Footprint

These notes accompany the presentation given to the Rideau Environmental Action League hosted event 21 February 2008. The aim of the presentation is to share with homeowners results of research and experience working with renewable energies, and to show them how they might reduce their carbon footprint. Information about the relative economics, strengths and limitations of various renewable energy applications should give homeowners a good indication of where they can make the most cost-effective uses of their energy dollar.

The views represented herein reflect those of the presenter and are not necessarily endorsed by the Rideau Environmental Action League. This information is provided freely and is accurate to the best of my knowledge. Most data is from federal government and publicly available resources. Where possible, sources are indicated. Pricing data is dated from 2006 and early 2007 and is pertinent to the National Capital Region. Your comments and further suggestions on this matter are invited.

It is hoped that you can make good use of this information for its intended purpose: to reduce your reliance upon carbon while concurrently reducing energy costs and securing your future sources of energy.

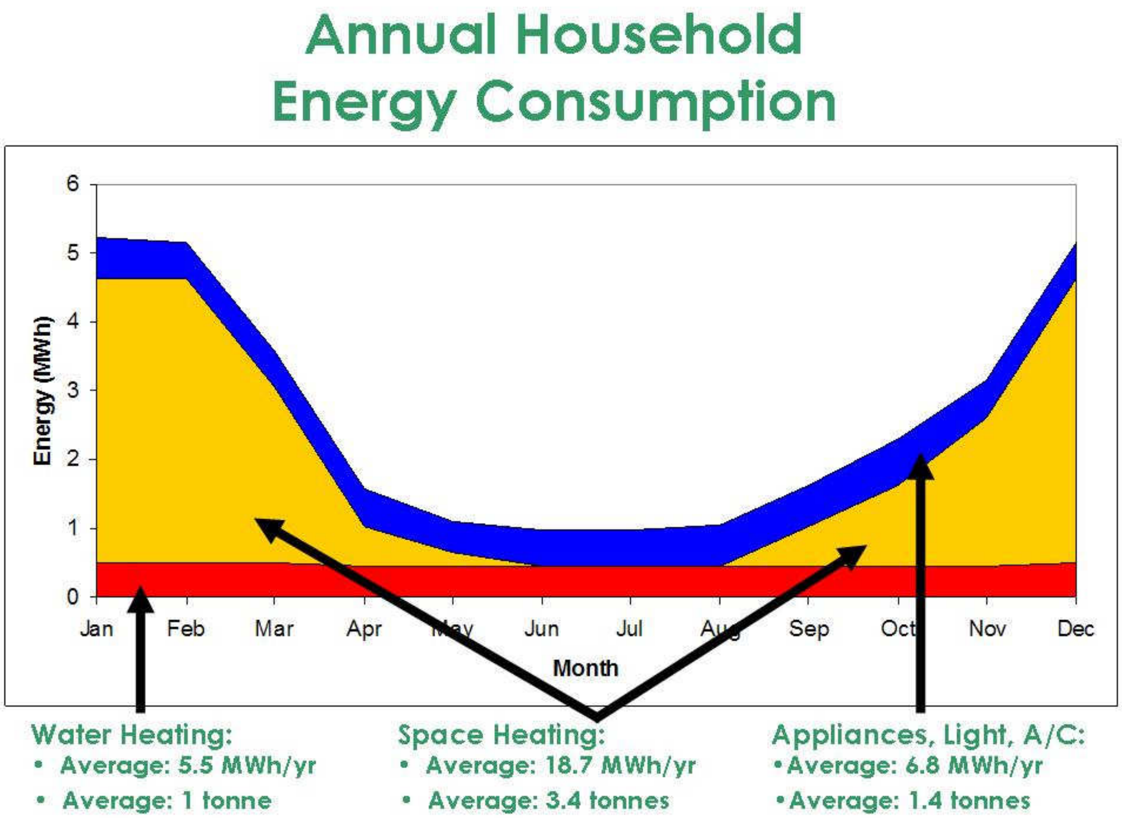
Sincerely,

Chris Weissflog
EcoGen Energy Inc
Office 613-288-8751
Cell 613-724-7674
chrisw@ecogenenergy.ca
www.ecogenenergy.ca

Conventional Household Energies

To assess the potential impact of renewable energies on our domestic use of energy we need to understand more about the conventional household energies we currently use. Specifically, we need to know how much of what energy we use and at what time of day and time of year. We also need to know how much it costs, what its future costs will be and what its environmental impact is. Your energy bill is a good place to start.

The following chart graphically illustrates the relative amounts of energy used in a home, and the greenhouse gas emissions (as per the national average). Results vary significantly from home to home.



Consumed Energy vs **Delivered Energy**:

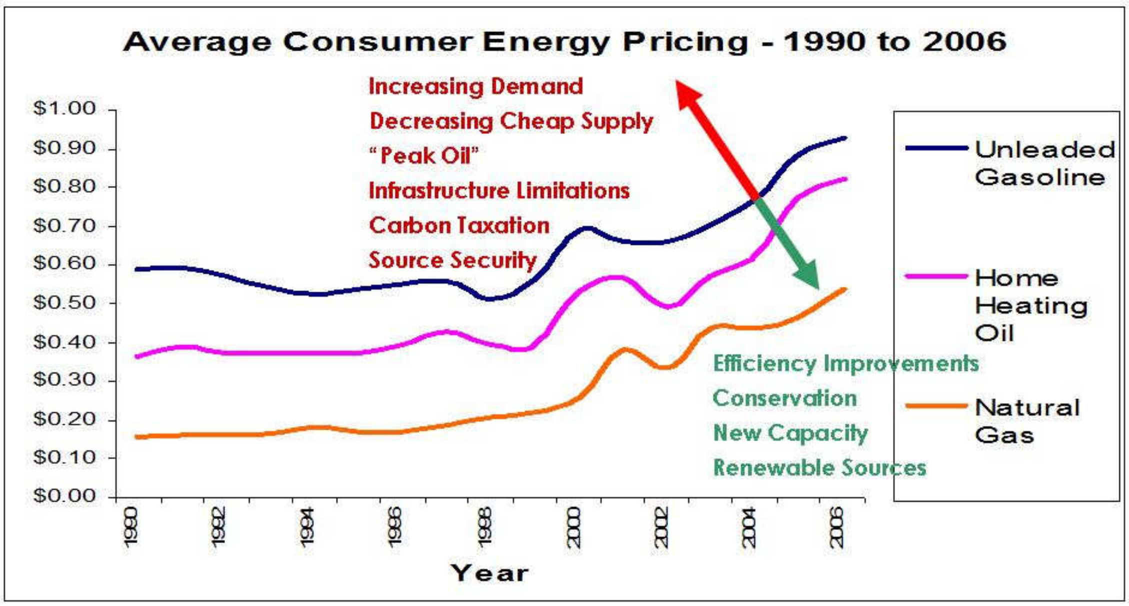
- **Consumed Energy** is the total embodied energy of a given fuel / energy form in its raw state (i.e. Natural Gas before it is burned)
- **Delivered Energy** is the amount our appliances extract and give us from that raw fuel / energy form and is determined by the appliance and other household efficiencies. Delivered energy is the amount of useful benefit we receive (i.e. hot water exiting the tap).
- Example: delivered energy exiting the hot water tank:

Delivered Energy = Consumed Energy x Tank Efficiency (AFUE)

Energy Costs (as of 2006)

	Natural Gas	Heating Oil	Propane	Grid Electricity
Cost / MWh	$55	$70	$100	$120
GHG / MWh	0.20 tonne	0.28 tonne	0.23 tonne	0.24 tonne

Energy Escalation is the term used to describe the inflation rate of energy costs and is shown on the following graphic. Energy prices have not always matched inflation. Most recently, energy prices have factored in the news very often and some analysts predict that it will be the major driver of inflation for the foreseeable future. Some factors determining future energy costs are listed.



Conventional vs Renewable Energy: "Pay-As-You-Go" vs "Pre-Paid"

Unless you put a monetary value on carbon, economic assessment does not place a value on your reduction of carbon emissions. If you are switching to renewable energy to reduce your carbon footprint, economic analysis should be used as one of a number of factors in your decision-making.

Any assessment of the economic value of a renewable energy decision requires understanding and forecasting of the following costs for both the conventional system and the renewable energy system (Lifecycle Cost Analysis):

- Capital (purchase / sticker price)
- Operating (future energy costs, maintenance and repair)
- Disposal Costs

Tools for economic assessment include:

- Net Present Value (NPV)
- Return On Investment (ROI)
- Internal Rate of Return (IRR)

- Simple Payback – crude and prone to underestimate the value of renewable energy if you believe that conventional energies will have a high escalation rate

Factors in any assessment include assumptions about the future, include:
- Energy Escalation Rate
- Inflation Rate
- Interest Rate

Conservation & Efficiency

These two concepts are critical to reducing your energy costs and environmental impacts:
- **Conservation:** is changing behaviour to consume less. It can often come without the loss of comfort, reduction in effectiveness or additional cost.
- **Efficiency:** is delivering the same effect (heated space, heated water, refrigerated food) with less loss & waste. It results in the same energy benefit or comfort that you are accustomed to.

Conservation is the first step to take as it reduces costs and emissions without cost to the homeowner, and establishes the new baseline for consumed energy demand.

Many homes have great potential to increase efficiency. There are grants of up to $10,000 for home energy efficiency improvements between the Federal and Provincial Governments. Ontario is currently waiving Provincial Sales Tax on Energy Star appliances.

Renewable Energies

Passive Solar

Passive solar is a building characteristic that maximizes solar energy gain during winter and minimizes it during summer. It evolves from the optimal placement of normal building materials and involves the following building characteristics:
- Building orientation and solar exposure
- Building ventilation and insulation
- Window type, area ratios and locations
- Thermal mass – location and amount
- Window overhang / shading
- Foliage / landscape design
- Weather
- Internal illumination levels
- Synchronization of room functions with daily living patterns

Passive solar must be a design consideration at the earliest stages of building conception. It is a designer competency that is worth spending the extra money to have a professional design your home or review and improve your plans. Passive solar pays back the owner for the entire life of the building. It is heavily influenced by the limitations of a building lot. Municipalities should be aware that factors such as street orientation can severely hamper the potential for a homeowner to capture and use free energy; in essence, municipalities can doom future generations to become greater energy consumers and carbon emitters than they otherwise need to be because of policy decisions (or a lack thereof).

Solar Pool Heating

The summer abundance of solar energy and the need for energy to heat pools coincides so well that this is one of the most cost-effective renewable energy technologies available. Purchase price is similar to other pool heating options, but solar has no energy cost and has no carbon emissions. Solar energy is dependent upon availability of sunlight so there will be a small fluctuation in the amount of free energy available. However, solar pool heating will allow the owner to begin using a pool about two weeks sooner in the year and continue to use it about two weeks longer than a pool without a heater. A solar pool heater can provide a dramatic improvement in a return on a pool investment without any associated environmental guilt; it increases the seasonal use of the pool by about 40% and heightens enjoyment by raising temperatures.

Heater Type	Installed Cost (approximate)	Annual Fuel Cost	10-Year Fuel Cost	10-Year Fuel & Installed Cost	Annual GHG Emissions (tonnes)
Natural Gas	$3,600	$700	$7,000	$10,600	2.5
Propane	$3,600	$1,300	$13,000	$16,600	2.9
Heat Pump	$4,800	$200	$2,000	$6,800	0.4
Solar	$4,100	$0	$0	$4,100	0

Solar Air Heating

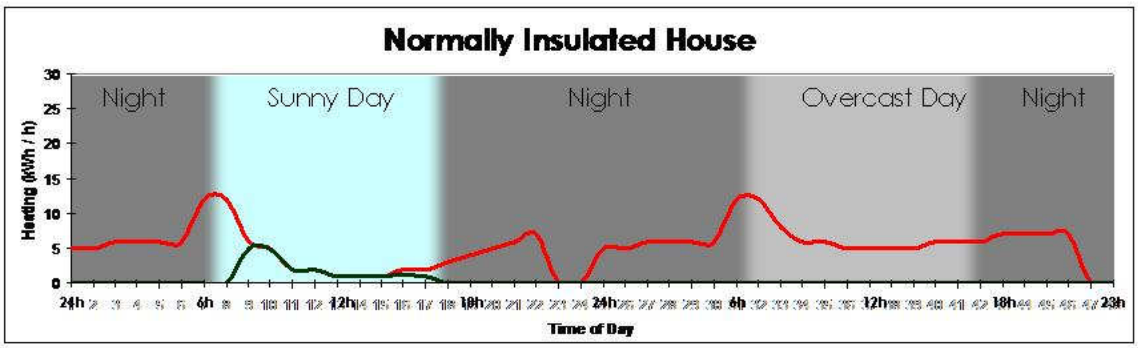
Solar air heating can be used to pre-heat the intake of fresh air or to boost the temperature of re-circulated air. It is commonly available as either:

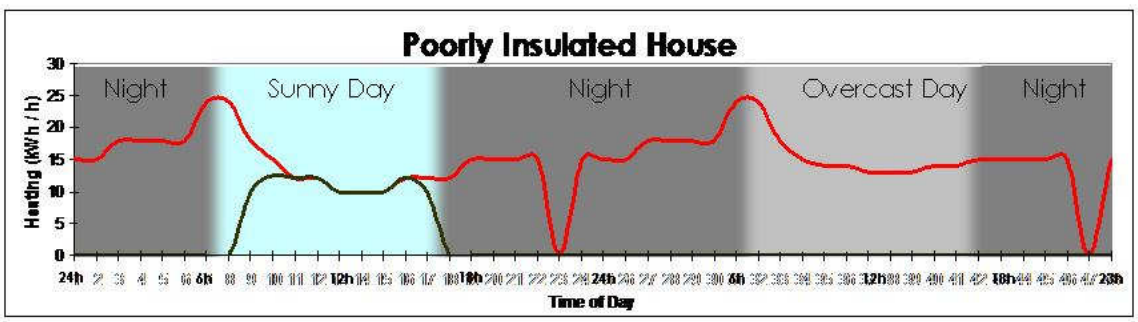
- a perforated building skin that turns sunlight into heat and pre-heats air passing through the perforations. As a skin, it also captures heat escaping the building and returns it in the incoming fresh air. The perforated skin is used in lieu of other cladding and its purchase is offset by that cost-savings. It can have a payback in as few as two or three years. It is commonly applied to industrial facilities that require large-volumes of fresh air and to buildings that do not have heat recovery ventilation.
- a glazed, boxed, air heater that creates a closed environment for sunlight to turn into heat and for the air to warm up before entering / returning into the building envelope.

Solar air heating is a method to provide partial heating energy relief for homes and other buildings. Naturally, it can only provide energy when the sun is shining. Normally it does not include any energy storage capacity, so you get energy only when the sun is shining. This active means of heating air is akin to adding "two-way" windows to the structure; when the sun is shining the device works like a passive solar home, bringing the warming effect of sunlight in. As with any passive solar home, too many windows (or too many active solar air heaters) will rise the temperature too high if there is not sufficient thermal mass to absorb the heat. (These devices do include thermostatic controllers.)

Solar air heating can be widely applied but careful attention must be paid to the building's existing mode and requirement for ventilation, as well as the building's thermal performance / heating requirements. Homes can also have specific time of day heating requirements, especially if the owner's habit is to set-back the temperature overnight. Careful orientation and placement of solar air heaters will balance the previous considerations with time of day requirements. There is a certain amount of work a homeowner can do on their own toward installation of a solar air heater, but it is recommended to employ a solar specialist for optimal system sizing, placement and economic performance. For the more adventurous, home-made solutions are not only possible but easy to do for workshops and out-buildings.

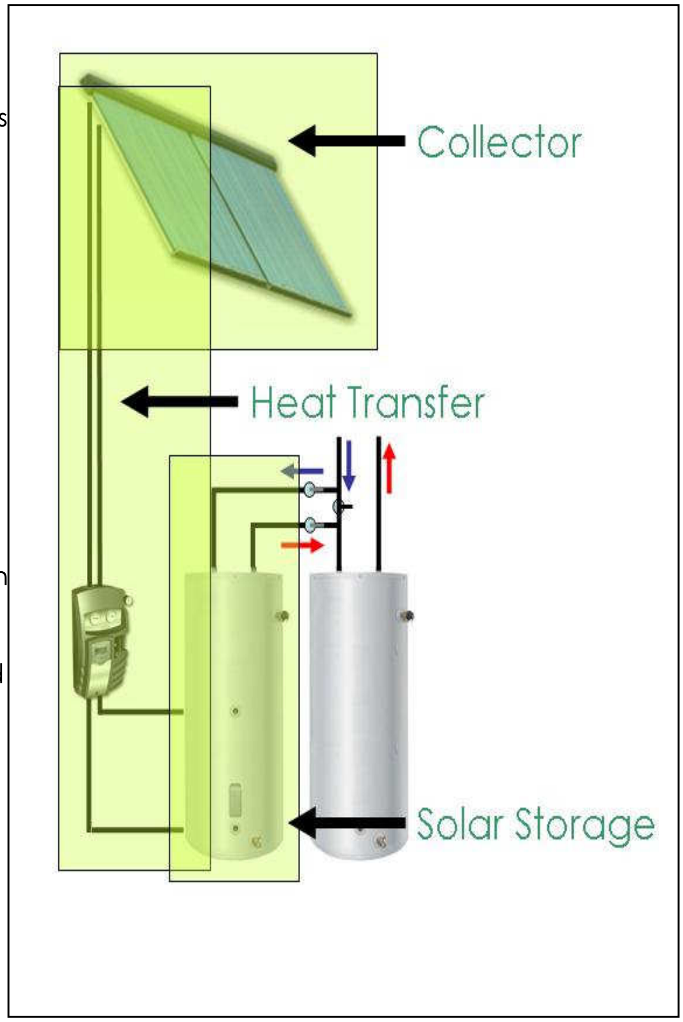
To give an idea of the variance possible, the following chart simulates the space heating energy requirements of two buildings – one well insulated, the other poorly insulated - with temperature setback overnight. It covers a two day period; one day sunny, other overcast and dark. The amount of energy that can be provided is shown under the curve on the sunny day and varies, as would the optimal sizes of systems and panel orientations between the two applications.





Costs of glazed solar air heating units run from $500 per square metre to up to $2,000, and there are economies of scale. On a sunny winter day, heat energy production can run from about 1.5kWh to 3 kWh per square metre, per day. There will also be days without production. A solar expert will provide analysis of your expected need and usable energy output for an optimized system.

Solar Domestic Water Heating



Domestic hot water is a universal feature of homes across Canada and constitutes 18% of our average household energy consumption on average. For larger families this can be significantly more of the energy budget. Solar domestic water heating is a method of pre-heating that water to provide energy relief. Therefore, you would keep your existing domestic water heater and add a solar system to pre-heat incoming water. The prevailing system design uses three main sub-system components consisting of:

- collectors that turn sunlight into heat energy;
- a solar storage tank that allows homes to accumulate enough energy for a daily cycle while the sun is shining; and
- a heat transfer mechanism that usually consists of a freeze protected heat transfer fluid, pump, heat exchanger and controller to bring heat from the collector to the solar storage tank.

There are two common types of solar collector in Canada:

- flat plate collectors – an insulated metal box with a flat metal absorber plate with fluid lines behind a sheet of glass; and
- evacuated tube collectors – absorbers (either flat or tubular) inside an evacuated tube (like a "thermos bottle") with a mechanism to transfer heat to a fluid either directly or by heat pipe.

Generally, the flat plate system is less expensive for a similar household size, but has greater losses during the colder seasons. Evacuated tubes perform well year-round but are a little more expensive. A solar thermal expert can advise on the most cost-effective solution for a household's individual needs. Generally, the following can be said:

- flat plate systems will provide up to 55% of a home's hot water needs and save 55% of its water heating greenhouse gas emissions; and
- an evacuated tube system will provide up to 70% of a home's hot water needs and save 70% of its water heating greenhouse gas emissions.

Hot water energy consumption varies not by the size of the home but generally by the number of people living in it. Cost varies by the type of energy used to heat the water and the water heater's efficiency.

With solar water heating, there are economies of scale. The greater the hot water consumption of the household, the larger the solar energy collection and storage requirement. Price, however, does not increase as fast as the system's energy productivity; larger systems produce energy less expensively. Consequently a household of six can enjoy significantly better economics than a household of two. The best economic benefits are enjoyed by larger households that heat water with propane, electricity and oil, especially older, less efficient models. If mechanical room space is a factor, solar tanks can be provided that have integral electric heating coils that boost water temperature when the solar system cannot provide sufficient energy.

Evaluating the economic benefit of various approaches can be complex. A simple price comparison can be made on a basis of cost per amount of energy delivery annually. If you believe that energy prices will rise faster than inflation, the system that provides a greater fraction of your energy will probably be the best investment. The same is generally true if your primary aim is reduction of your carbon footprint. If your primary use is during the spring and summer then a flat plate system is probably the better choice.

If you are buying a solar domestic water heater in Ontario today, homeowners are eligible for sales tax rebates and grants totaling $1,300 and more. Typical pricing of solar water heaters after rebates and grants is shown in the following table.

Household Size	Evacuated Tube	Flat Plate
2 Persons	$5,000 - $8,000	$4,000 - $6,000
4 Persons	$8,000 - $11,000	$6,000 - $8,000
6 Persons	$10,000 - $15,000	$8,000 - $12,000

Because solar domestic water heating is only beginning to penetrate the Canadian market in any scale, it's regulatory regime can be poorly understood by consumers and building officials alike. There are also many dealers and installers who may not understand it. The currently relevant standards are CSA F379.1 (the standard for packaged domestic systems) and CSA F383 (the standard for how an installation must be done). At present, CSA-International has announced that CSA 379.1 has been superseded by a "Technical Instruction Letter" or TIL numbered MSE 45. TIL MSE 45 is being used by the testing laboratories as the standard by which they are currently testing packaged systems for CSA certification. As of December 2007 there was only one system that had received certification and a number undergoing certification testing. As a result, most communities have instituted a policy proposed by the Canadian Solar Industry Association (CanSIA) to accept Engineer letters indicating that the standard of SDHW build meets the requirement of the CSA / TIL in their professional judgment.

CanSIA also has a program to certify installers for their knowledge of the regulatory regime and their understanding of solar science. CanSIA Certified Solar Hot Water Installers must undertake instruction and pass peer review. They need to either be plumbers or have completed a number of installations to gain their certification. It is the jurisdiction of the municipality if it will demand the installation to done by a licensed plumber.

More information about standards and dertification can be found on the CanSIA website at: http://www.cansia.ca/shw_inspection.asp

Wood & Pellets

In an effort to provide some value the following notes about wood and pellet stoves are included. EPA ratings for pellet stoves begin at 7 grams per hour of emissions and decrease with stove efficiency. The ratings measure the amount of particulate emission. The more efficient the stove, the less wood it burns for the same heating value and the less often it needs to be stoked.

Wood:

- EPA rating 7 grams/hour or less (1.8)
- 60% to 68% efficient
- 40,000 to 80,000 btu ($5,000 to $8,000)
- Free-standing or Built-In
- Consumed Energy: $60/MWh ($420/cord)
- Delivered Energy: $94/MWh

Pellet stoves provide a degree of convenience by the somewhat cleaner handling of fuel. There have been supply and demand issues with pellets that have led to an increase in its price and some shortages. Wood pellets compete with particle boards for the same feedstock; wood industry waste products like sawdust and woodchips. Pellet stoves can also be fed with dried grains and other biofuels. Comment: we need to be mindful of diverting food products to energy. Already the price of a loaf of bread has risen noticeably and biofuels are partially to blame.

Pellets:

- Not subject to EPA rating
- 27,000 to 50,000 btu ($3,500 to $6,200)
- Can use multiple fuels (wood, corn, grain, cherry pits)
- Consumed Energy: $55/MWh ($5.75 / 18 kg bag)
- Delivered Energy: ~$86/MWh

Geothermal Heating

Geothermal heating is a form of solar heating. It uses a heat pump system to collect heat energy that has been absorbed by the ground from the summer and fall where it is stored into the winter and spring. Geothermal systems can use closed loops to circulate fluid into the ground in a vertical loop (like in a well) or horizontal loop (like in a trench about 2 metres deep). Loops can also be circulated into bodies of water like rivers and lakes where they can get heat. Geothermal systems can also use open loops drawing water from the ground or body of water at one location and either depositing it on the surface or into the ground via another well. In either of these geothermal systems, the fluids or water come into the heat pump at ground temperature; have heat pumped from it via a refrigeration process, before it is returned at a cooler temperature.

There is another variation of the closed loop system called Direct Exchange or DX. With DX the refrigerant is expanded or compressed directly in the closed loop in the soil where the heat exchange occurs.

Because geothermal systems use a refrigeration cycle to provide heat they are also reversible; they can provide household cooling in the summer. They can also be purchased with the ability to provide a means to pre-heat domestic hot water. The domestic hot water pre-heater can be referred to as a "desuperheater". It only provides pre-heating during the seasons when the geothermal system is operating.

Geothermal purchase prices can vary considerably. Major price factors include:
- cost of drilling or trenching
- size / capacity of system, usually measured in "tons"

An installed system will normally cost over $10,000 and usually it will be in the $15,000 to $25,000 range when all costs are considered. Financial incentives include up to $3,500 from each Federal and Provincial Governments and PST rebate.

The ratio between the energy used to pump the heat and the heat energy derived is called the "Coefficient of Performance" or abbreviated as the COP. Common COP values range from 3.2 to 3.5 when all system operating energies are concerned.

To calculate the potential benefit your home might receive from a geothermal heating system you should calculate your delivered space heating and space cooling energy needs (in energy terms, like kWh or MWh). Take this number, divide by the COP to get the electrical energy needed to heat & cool with geothermal. Multiply that number by the cost of consumed grid electricity which is about 12¢ per kWh or about $120 per MWh to get an annual energy operating cost (at today's prices). Your carbon emissions can be calculated using 0.24 tonnes per MWh of grid electricity consumed. If you are a subscriber to a carbon-free electricity provider (i.e. Bullfrog Power), you can claim that your home is heated without carbon emissions.

If you are improving a home's envelope as well, it is always advisable to make the improvement one season before making a heating energy change. This way the new heating energy requirements can be measured and a potential buy of an overlarge geothermal system can be avoided.

Geothermal systems may require environmental impact assessment and certainly a building permit to install. You can begin by checking with your municipal building office. For residents living along rivers, you may have a conservation authority or other organization charged with environmental stewardship and regulation over the land you live on. It is wise to give them a call before you invest too much time thinking about geothermal.

One last thought, if all homes were to switch to geothermal energy there is potential for an incredible load on the electrical grid; one which the grid may not be able to support nor might there be sufficient seasonal generation capacity for. However, these are macro / strategic level issues that have not surfaced yet.

Photovoltaics - Solar Electricity Generation

Photovoltaics, or PV, is the generation of electricity from sunlight without moving parts. This is a proven and reliable method that has exceptional longevity, largely because it has no moving parts. Although the costs of an installation are relatively high, it can prove cost-effective when there is a requirement to bring electricity to a remote site. For homes, that can be from about a kilometer away from the closest grid access point, sometimes less.

Technology is constantly improving and it is projected that, between rising grid electricity costs and constantly dropping PV costs, PV will reach grid parity around 2013 to 2016 (when assessed as a life-cycle cost). There are technological advances in PV production that include nano-technology and printing processes which hint at increased efficiency (high outputs) and much cheaper production. The future outlook is for increased integration of PV into building materials, especially roofing surfaces like shingles.

PV can provide power to homes when connected to the grid or off-grid. Off-grid requires energy storage, usually in the form of deep-cycle batteries, but grid-connection does not require it. When grid connected, the grid becomes a storage method of sorts. Net metering is a program that allows the homeowner to be credited for putting power into the grid when production outpaces consumption and to receive it back when consumption is greater than production.

At present there is also the Standard Offer Program (SOP) that allows a homeowner to get paid for electricity at 42¢ per kWh for all the electricity provided by PV. The current contract is for 20 years. There are some one-time costs to joining the program.

Current economics of PV are illustrated in these turnkey installation examples (price will vary by dealer / supplier / installer):

- 1kW Grid-Tied (~ $14K), generates 1,280kWh (~$150 at grid prices) per year*
- 2kW Grid Tied ~ $23.5K, generate 2,560kWh (~$307 at grid prices) per year*
- SOP - $600 to $1400 Entry
  - 1kW generates ~$538 / year*
  - 10kW generates ~$5,380 / year*
- Off-Grid ("Batteries Included"):
  - $25K to $60K
  - Year-round needs back-up generator

Food for thought: PV generates electricity locally at times of day when electricity consumption is highest – as much as $1.30 per kWh is paid on the spot market by our energy providers at peak time. PV "shaves the peak"; providing high value energy to the grid, reducing the requirement to invest in large energy producing facilities. It also does so without generating greenhouse gases, a benefit not currently accounted for in our economic model. Because it is produced locally, it reduces the need of the grid to transmit energy long distances, in turn reducing the load on our grid, reducing the need to build additional grid infrastructure and reducing transmission losses which are currently around 9% (check your bill).

Wind Power

Generating electricity from the wind easily captures the imagination. It can however, polarize communities when there is the NIMBY phenomenon (Not In My Back Yard). There is huge potential for energy capture from the wind in Canada and a major movement to implement it. Wind is likely to remain a rural household option only.

The main factors behind the cost effectiveness of a wind energy solution are the following:

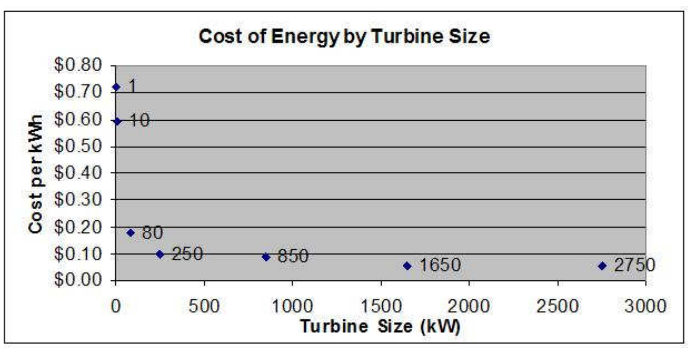
- Height of turbine – speed of wind increases rapidly and becomes more consistent with height above ground and obstacles. A turbine needs to reach well above ground turbulence from trees and houses. Unfortunately, this means great tower height or remote placement from a house, both of which increase cost significantly.

- Size of turbine – as turbine size increases its economic performance improves. Small turbines around 1kW to 10kW, have lifetimes of 10 to 15 years and need maintenance every year or two. The cost per unit of generating capacity is low. As turbine size increases, the cost per unit of generating capacity decreases very fast and turbines have longer lifespans.
- Location – some locations have very good wind resources and others do not. The best sites are usually fond on coastlines, on hilltops and in windy gaps in ridgelines.

Interior Eastern Ontario is typically not what is considered a good location for wind power. For homeowners, this means that wind power is generally not a good investment against grid electricity. It is intermittent and costly. PV is more predictable and less labour intensive. However, small turbines can be useful in an off-grid context as they can offset PV output by producing over night and in cloudy conditions, and through a general increase in production over the winter when there is less sunlight. A wind turbine will reduce the requirement for off-grid back-up generation.

The following chart illustrates some rough order magnitude costs and benefits of wind power in our region. The economics are of a commensurate level of accuracy. The main point to observe is that the economics of scale are not linear (not the same effect per dollar spent) and that the break-even point on an investment in wind is closer to $1,000,000 and provides far more electricity than a typical home consumes. This size of turbine belongs in the realm of a co-operative effort of perhaps a housing development or rural community.

Q&A



Size	kW	1	10	80	250	850	1650	2750
Height	m	18	30	30	50	50	80	100
Cost	$	$8K	$70K	$250K	$750K	$3M	$5M	$6.5M
Energy Output	MWh / Yr	1	8	79	378	1330	3771	4690
Lifetime	Yrs	10	15	18	20	25	25	25
Cost/kWh	$/kWh	72¢	59¢	18¢	7¢	10¢	5¢	6¢
Simple Payback	Yrs	64	68	28	12	18	12	12

The large turbine level of investment is out of the domain of most homeowners; in the millions of dollars. In this case, most capital is tied into wind investment schemes that move to the sites with the best wind to make the better return on investment.

As with other renewable energy systems, with wind there is a possibility that you will require an environmental study before being given building permission. In some areas these studies focus on the migration patterns of birds. There are other environmental factors of interest as well.

Household Renewable Energy Strategies

Once you have made your conservation and efficiency improvements, you are ready to introduce renewable energies to your home. If you are interested in making quick hits there are a few that are recommended as immediately economically viable in most circumstances:

- Solar pool heating – if you are currently heating your pool with gas, you might reduce your carbon footprint by as much as 30% or more (2.5 tonnes)!
- Solar water heating – reduce your total carbon footprint by 13% or up to 20% (2 tonnes) for large families.
- Solar air heating – if your house furnace or heating runs during sunny winter days there is potential for solar air heating to assist with your heating. A low-risk option is to add 2 to 4 square metres of collector to your wall. For any more you should have your heating needs assessed in detail by a solar specialist.
- Geothermal – get the grants and rebates and consider subscribing to a renewable energy electricity provider.

If you are about to build, you should strongly consider the following:

- #1 – Passive Solar design. The potential to save energy and environmental costs is huge!
- #2 – Passive solar with active solar technologies like:
    - Solar domestic hot water
    - Geothermal* (initial builds are not eligible for Federal and Provincial retrofit grants, but a home more than 6 months old is…)
    - Photovoltaics
    - Solar air heating – note that if your home is passive solar, it is unlikely that solar air heating will be able to provide much usable energy
- #3 – Net-Zero Energy through integrated renewable energy systems. You will need to consult renewable energy and building design specialists to achieve this.
- Also, when building, don't forget to use efficiency products like:
    - waste water heat recovery;
    - low-flow shower heads;
    - pipe wrap;
    - air sealing around windows;
    - high efficiency heat recovery ventilation; and
    - good amounts of insulation!

Good luck and don't hesitate to ask questions!