

HARNESSING SOLAR ENERGY

Why?

How?

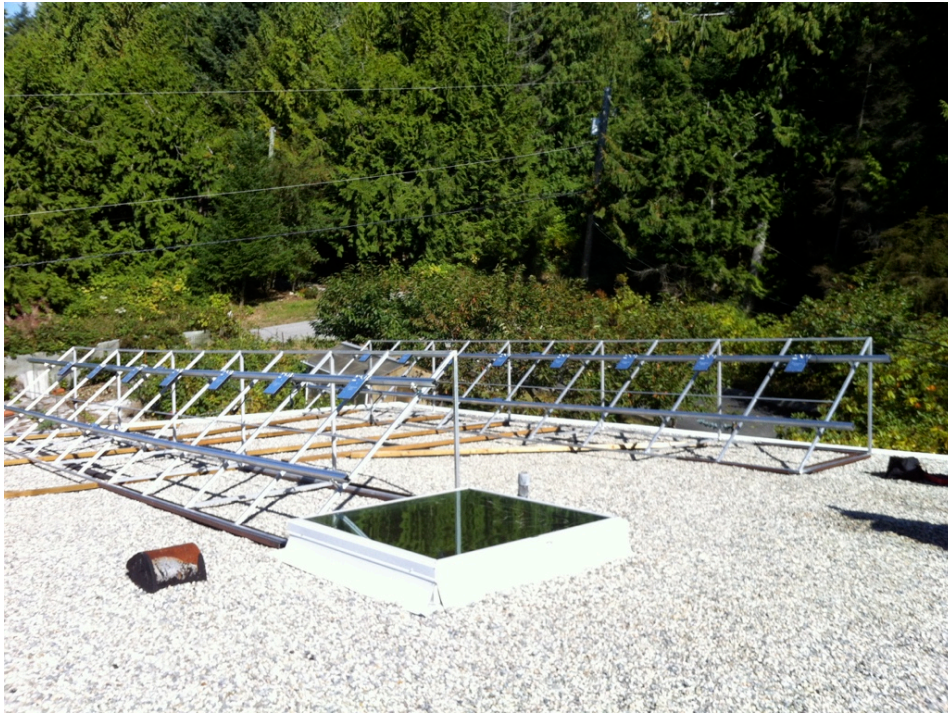
When?

A course for ElderU
by Gerry Pageau, P.Eng.

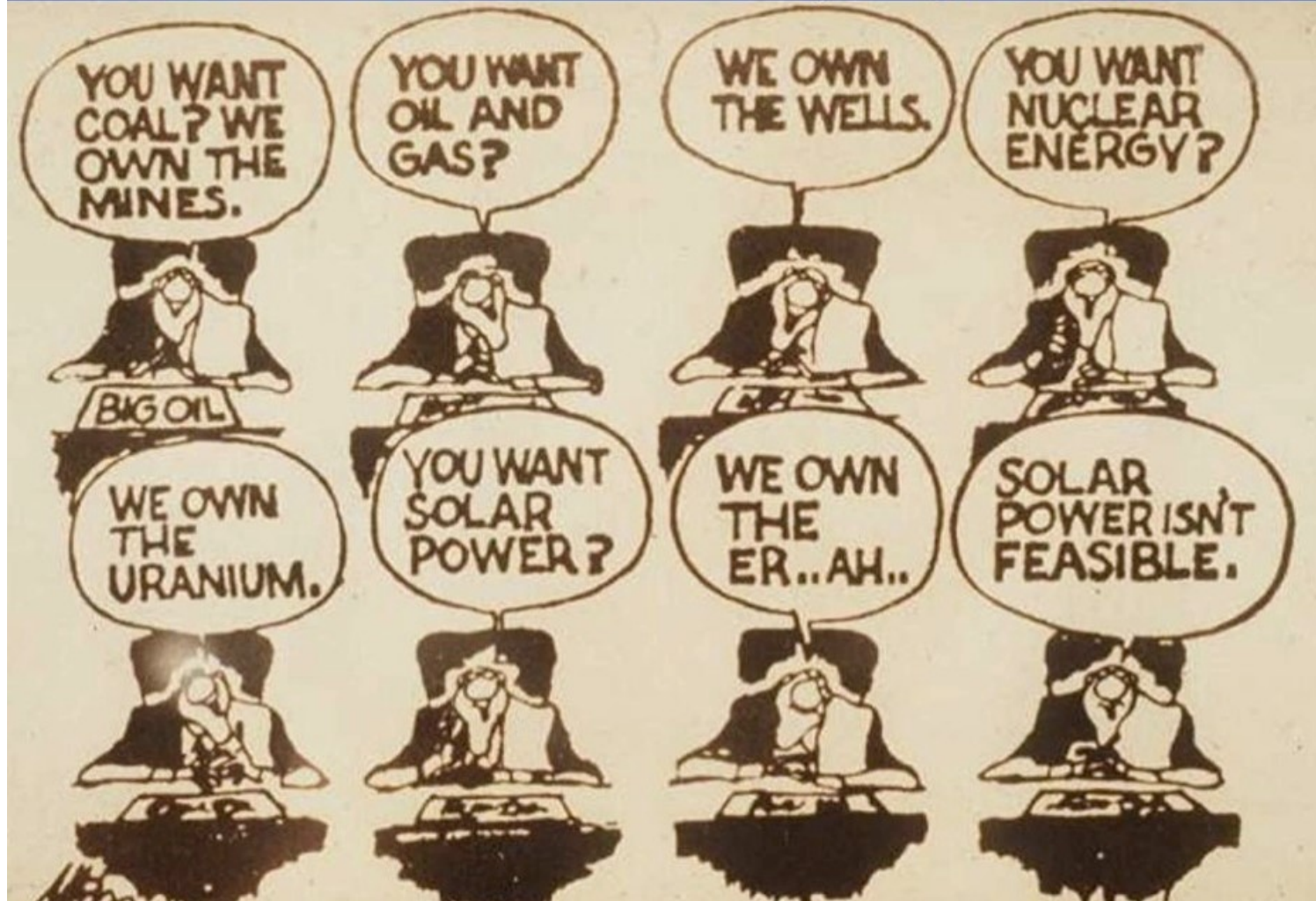
Course Highlights

- Global context: what is the big picture?
- Saving and making power: what are the options?
- Analysing your site: does it have what it takes?
- Look at various solar systems:
 - 12 V DC system for RV or cottage
 - Off grid 120 V AC for house or cottage
 - Grid-tied 240 V AC for house
 - Solar hot water
- Hands-on lab with small off-grid system.
- Take-home tools for site analysis and spreadsheet for payback estimation.

This course will teach how Solar Systems are built so you can decide what options you want, how much to do yourself and what to contract out.



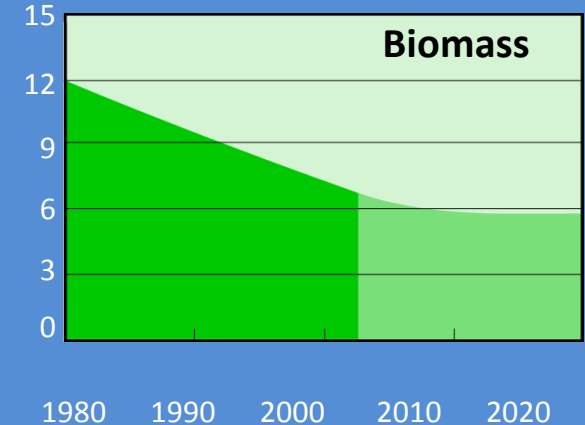
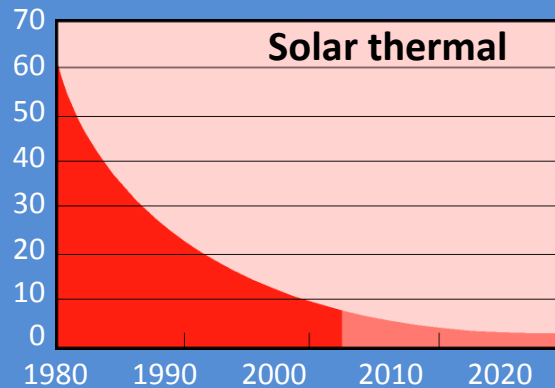
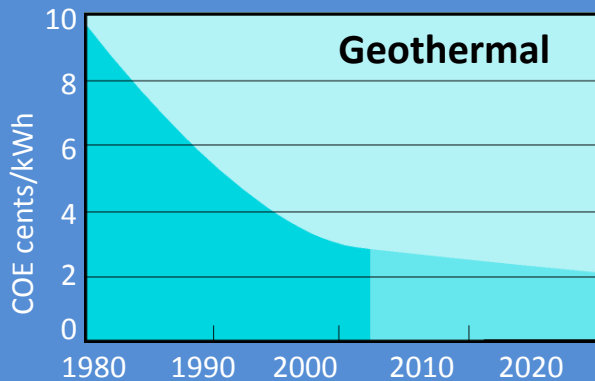
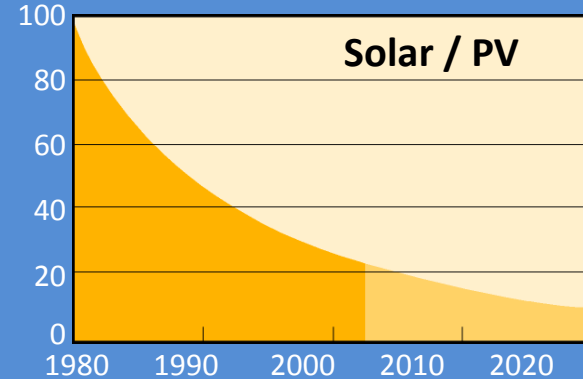
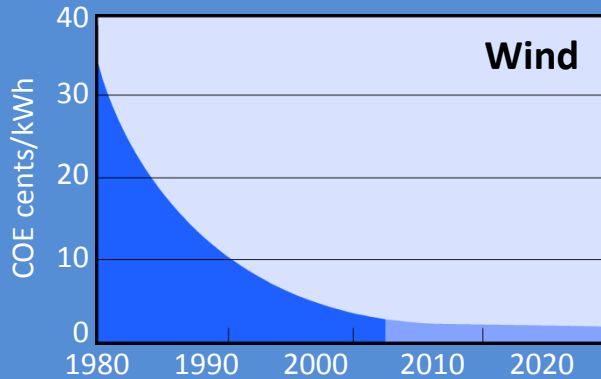
Cartoon from 1979... Has anything changed?



Net-metering introduced in 2014
Return on capital cost now positive!

Driving Down Technology Costs

Levelized cents/kWh in constant \$ (2000)¹



Source: NREL Energy Analysis Office

¹These graphs are reflections of historical cost trends NOT precise annual historical data.

Updated: October 2002

Why Renewable? What are the issues?

- Air, land, and water pollution
- Climate Change (AKA Global Warming)
- Rising energy costs
- Centralized control of resources/infrastructure
- Energy Security
- Limited fuel supplies and peak oil (Coal, Oil, Gas, Uranium)
- Resource exploration, extraction, and processing related environmental degradation

Air Pollution and Energy

- Pollutants that come from the combustion of fossil fuels include:
 - sulfur dioxide (SO₂), nitrogen oxides (NO_x), ground-level ozone, particulate matter (PM), carbon monoxide (CO), carbon dioxide (CO₂), volatile organic compounds (VOC) including benzene, some heavy metals and a number of other pollutants.
- Criteria Air Contaminants such as SO₂, NO_x, VOCs:
 - The cause of serious air issues such as smog and acid rain.
 - Many VOCs are known or suspected of having direct toxic effects on humans, ranging from carcinogenesis to neurotoxicity.
- Particulate Matter
 - Linked to aggravated cardiac and respiratory diseases such as asthma, bronchitis and emphysema and to various forms of heart disease.
- Ground level ozone
 - Linked to pre-mature mortality and increases in hospital admissions and asthma symptom days.
 - Can significantly impact vegetation and decrease productivity of some crops. It can also injure flowers and shrubs and may contribute to forest decline in some parts of Canada
- Heavy metals such as mercury and lead:
 - Can be transported by the air and enter our water and food supply.
 - Poisonous in low concentrations and can bio-accumulate in body tissues.
 - Electricity generation is the largest uncontrolled industrial source of mercury emissions in Canada.

CARBON DIOXIDE'S RELENTLESS RISE

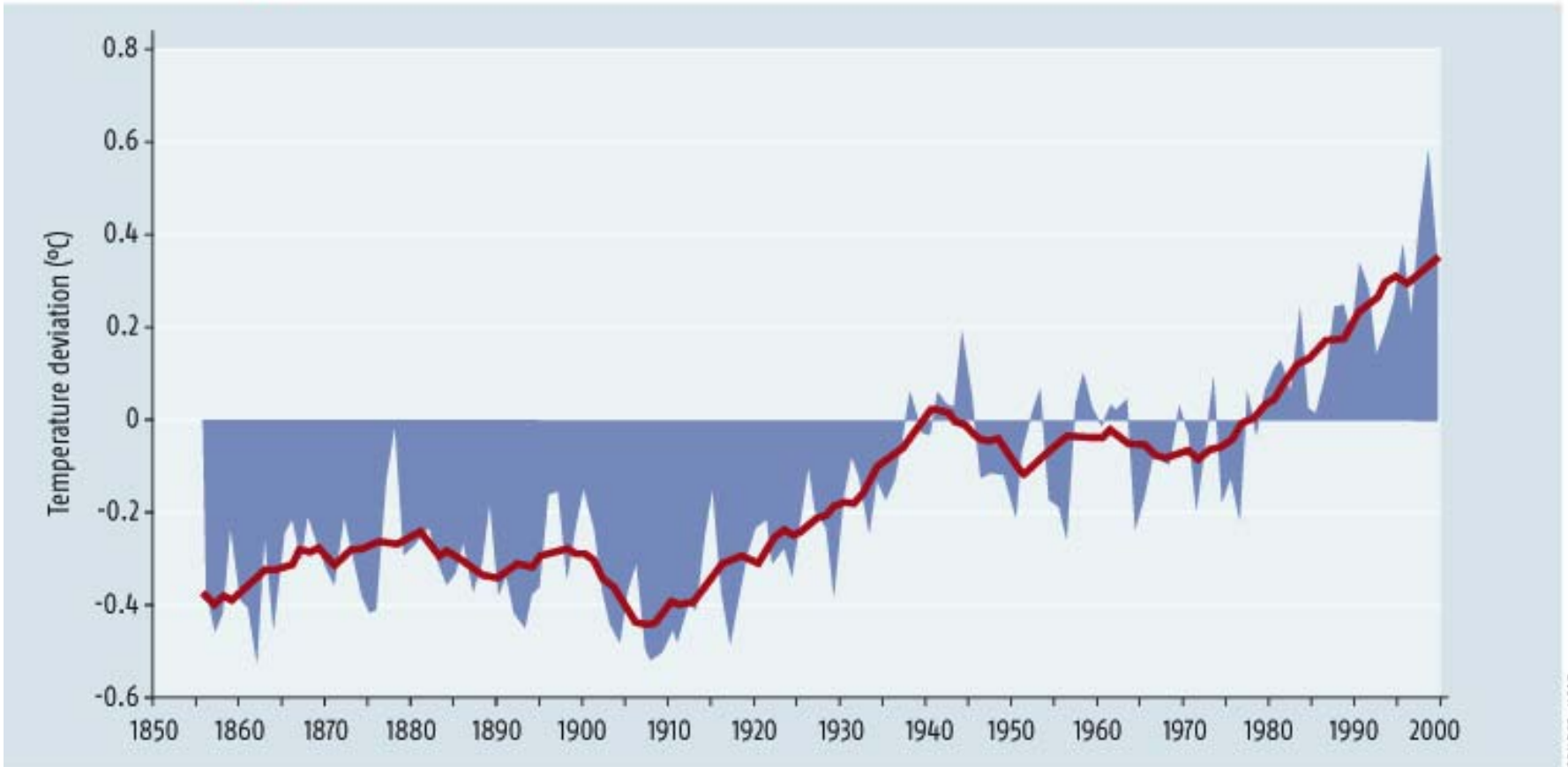
Atmospheric CO₂ concentrations are now 35 per cent higher than pre-industrial levels, as indicated by readings taken at Mauna Loa in Hawaii



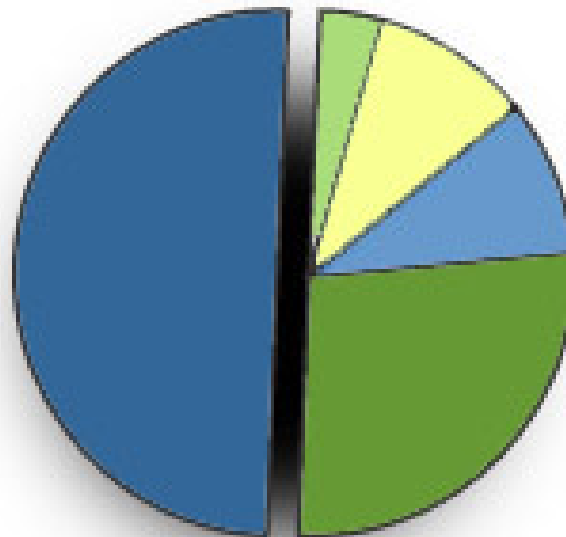
THE WORLD IS GETTING WARMER






Temperature plotted as the deviation from the 1960 to 1990 average

● Yearly deviation ● 10-year smoothed trend



Personal GHG Emissions From Energy Use in Canada



 Passenger Road Transportation	49.9%
 Space Heating and Cooling	29%
 Water Heating	11.1%
 Appliances	7.5%
 Lighting	2.4%

Heating Fuel Energy and GHG emissions including Ground Source Heat Pump

Fuel	50 GJ of Energy Per Year				100 GJ of Energy Per Year			
	Low efficiency	Tonnes of CO2	High Efficiency	Tonnes of CO2	Low efficiency	Tonnes of CO2	High Efficiency	Tonnes of CO2
Oil	\$1,976.44	5.67	\$1,317.63	3.78	\$3,952.88	11.34	\$2,635.25	7.56
Electricity	\$1,321.64	7.54	\$1,255.56	7.17	\$2,643.27	15.09	\$2,511.11	14.33
Natural Gas	\$1,086.36	4.73	\$628.95	2.74	\$2,172.73	9.45	\$1,257.89	5.47
GSHP	\$627.78	3.59	\$418.52	2.39	\$1,255.56	7.17	\$837.04	4.78

www.fallsbrookcentre.ca

New Brunswick historical costs. Note NB electricity supply was about 64% fossil so lots of CO2 unlike BC which is mostly hydro power.

Saving energy is easier than making it!

- The payback for replacing incandescent light bulbs with CFL (or LED?) is far better than installing solar or wind system.
- Replacing 20 yr. old fridge with new Energy Star model will beat solar or wind.
- If you heat with oil or electric furnace, the payback for replacing it with a heat pump, especially ground source (geothermal), exceeds solar or wind generation.

Output of 5.75 kW Solar Array on Sunshine Coast (Lower Rd & Hwy 101)

Solar Power Produced by Month		
Month	kWh Produced	
Jan-2015	175.7	
Feb-2015	339.0	
Mar-2015	513.8	
Apr-2015	808.0	
May-2015	1052.0	
Jun-2015	1069.5	
Jul-2015	1039.9	
Aug-2015	884.8	
Sep-2015	712.2	
Oct-2015	449.2	
Nov-2015	278.0	
Dec-2015	<u>102.9</u>	
Total	7425.1 kWh/yr	
System peak power	5.75 kW peak	
	1291 kWh/yr per kW peak	

Heating Fuel Energy and Cost

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On Sunshine Coast, to produce 100 GJ of energy per year, a 22 kW solar array would be needed. \$60k - \$70k

Actions you can take now

- Use less of everything
- Recycle and compost whenever possible
- Buy Fresh, Buy local, Buy Organic
- Less grass, more garden
- Plant some trees
- Harvest rain water
- Turn it off when you're not using it
- Make energy conservation and efficiency a priority in all your daily decisions

Behavior and Choices

<u>Transportation</u>	<u>At home</u>
Drive less (carpool, public transport, bike, walk, telecommute)	CFL lighting, low flow showerheads, prog. thermostats
Don't Idle (10 seconds)	Insulate / weather seal
Drive the Speed limit!	Energy Star Appliances
Keep your vehicle tuned and tires inflated	Warm or Cold wash, hang dry clothing
Buy small and efficient	Consider a more efficient furnace

Clean, Renewable, Green

- Nuclear claims to be clean when it comes to air pollution.
- Large Hydro calls itself renewable.
- Green Energy is a label used to describe energy from sources that respect the environment.
- The Environmental Choice Program Certification promotes electrical energy sources that have greatly reduced environmental impacts.
 - The Program recognizes technologies that use naturally occurring energy sources such as wind and sun, and power sources that, with the proper controls, add little in the way of environmental burdens such as small run-of-river hydro and certain energy from biomass.

Green Energy Certification

www.environmentalchoice.com

- **Certification Criteria: *All Sources***
 - The facility must be operating, reliable, non-temporary and practical.
 - During project planning and development, appropriate consultation with communities and stakeholders must have occurred, and prior or conflicting land use, biodiversity losses and scenic, recreational and cultural values must have been addressed.
 - No adverse impacts can be created for any species recognized as endangered or threatened.
 - Supplementary non-renewable fuels must not be used in more than 2.00% of the fuel heat input required for generation.
 - Sales levels of ECP-certified electricity must not exceed production/supply levels.
- **Certification Criteria: *Specific Sources (in addition to that listed above)***
 - Solar (cadmium containing wastes must be properly disposed of or recycled)
 - Wind (protection of concentrations of birds including endangered bird species)
 - Water (compliance with regulatory licenses; protection of indigenous species and habitat; requirements for head pond water levels, water flows, water quality and water temperature; and measures to minimize fish mortality and to ensure fish migration patterns)
 - Biomass (use only wood wastes, agricultural wastes and/or dedicated energy crops; requirements for rates of harvest and environmental management systems/practices; and, maximum levels for emissions of air pollutants)
 - Biogas (maximum levels for emissions of air pollutants; and leachate management)
 - Other technologies that use media such as hydrogen or compressed air to control, store and/or convert renewable energy Geothermal technologies

Overview of Green Technologies

- Bioenergy
- Run of River Hydro
- Generating electricity with wind turbine
- Ground Source Heat Pump
- Solar Thermal Applications
 - Home hot water heating
 - Pool water heating
- Generating electricity with solar PV array

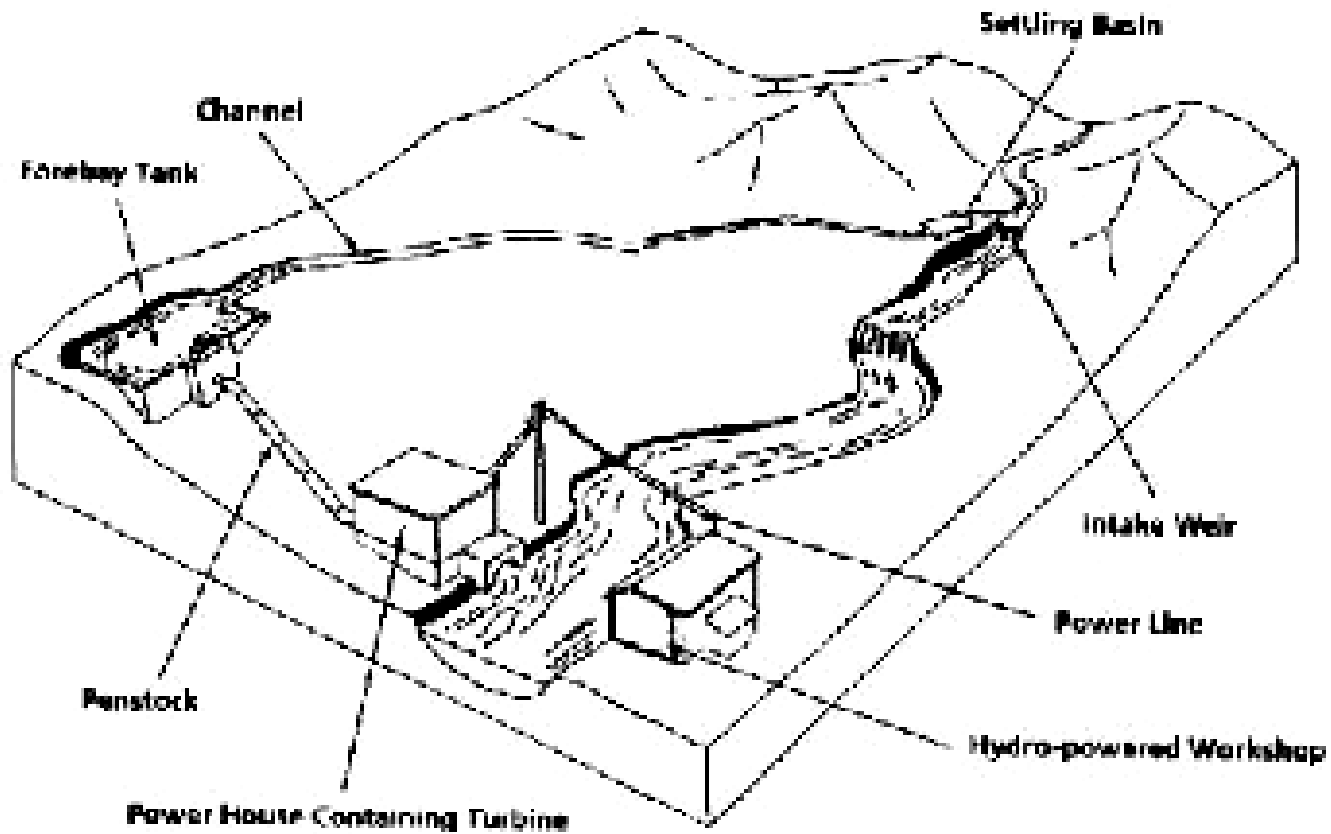


Biomass Energy



- Energy from organic materials (solar photosynthetic energy) like trees, grasses, agricultural crops or other biological material
- It can be used as a solid fuel to run boiler and turbo-generator, or converted into liquid or gaseous forms, for the production of electric power (fuel cell), heat, chemicals.
- Bio-refinery concept.
- Examples: wood, ethanol, bio-gas (methanol), plant oils, biodiesel
- In theory it is carbon neutral. But how is this stuff grown? Sustainable production methods and harvesting?

Micro-Hydro Energy



Micro Hydro

- A good approximation of the Power available to a battery charging micro hydro system is given by:

$$\text{Power [Watts]} = \frac{\text{Net Head [ft]} \times \text{Flow [USGM]}}{14}$$

14

- Hydro turbines & generators for AC only micro hydro systems are more efficient, so the above power equation needs to be modified:

$$\text{Power [Watts]} = \frac{\text{Net Head [ft]} \times \text{Flow [USGM]}}{9}$$

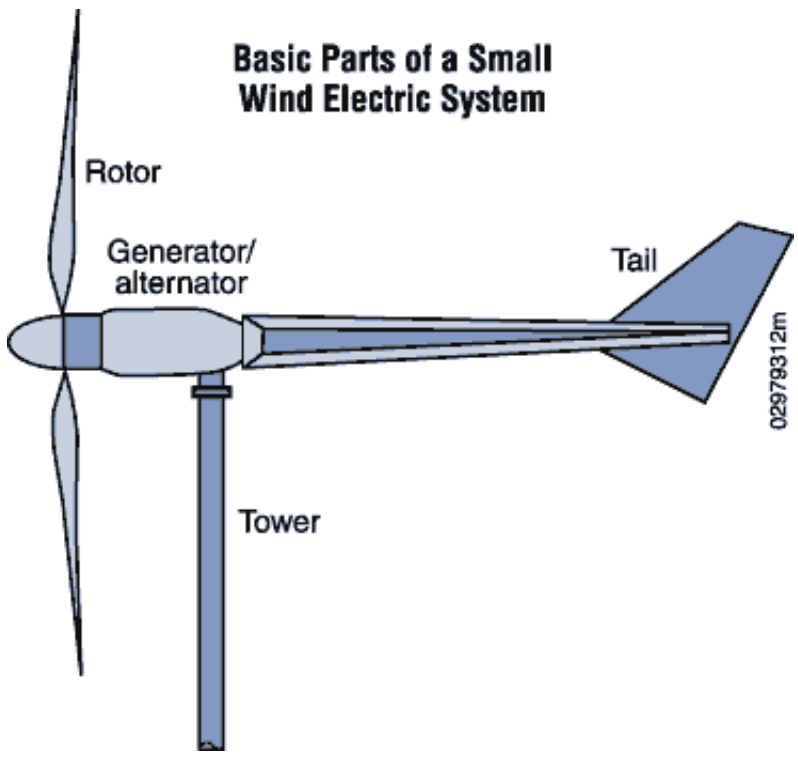
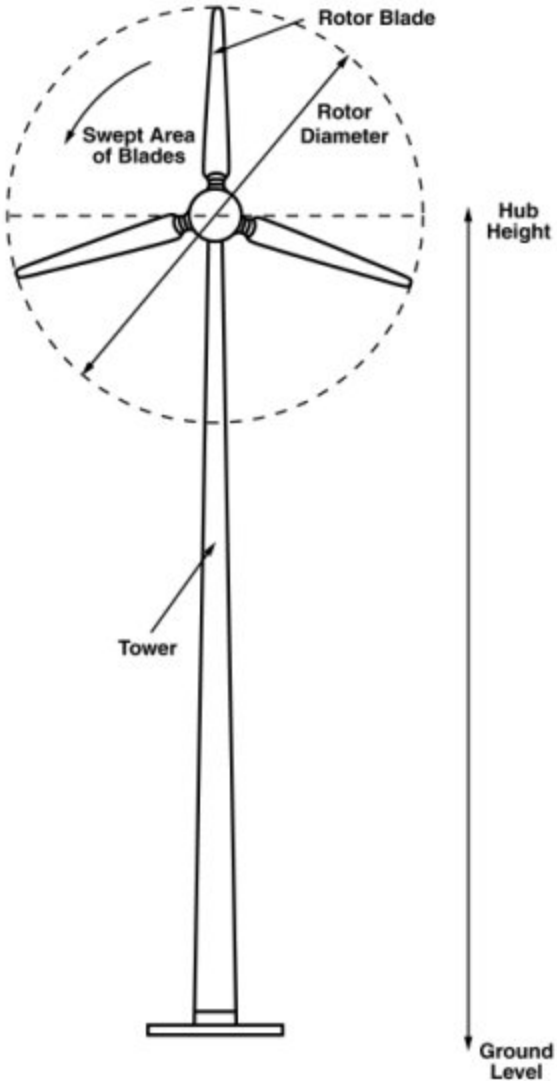
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- **1 cubic ft / sec = 450 USGM = 28.3 liters/sec**
1 psi = 2.31 feet of head = 0.7 meters of head

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Wind Turbines



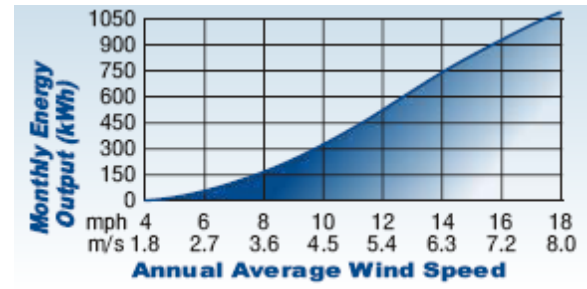
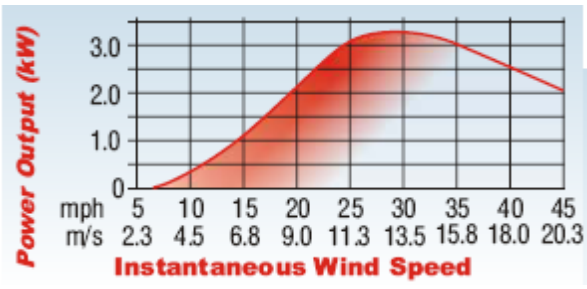
Example Wind Turbine Specs

Rotor Diameter:	15 ft. (4.5m)
Weight:	155 lbs (70kg)
Shipping Weight/Dimensions:	Body: 295 lbs (133.8kg) 36 x 25 x 32" (914 x 635 x 812mm)
	(2 boxes) Blades: 38 lbs (17.2 kg) 88 x 12 x 6" (2235 x 305 x 152mm)
Mount:	5" schedule 40 (12.7cm)
Start-up wind speed:	7.5 mph (3.4m/s)

Note start-up wind speed 7.5 mph

To produce 6,500 kWh/yr, an average 12 mph wind speed is needed

Kilowatt hours per month:	538 kWh/mo @12mph (5.4m/s)
Warranty:	5 Year Limited Warranty
Survival Wind speed:	120 mph (55 m/s)



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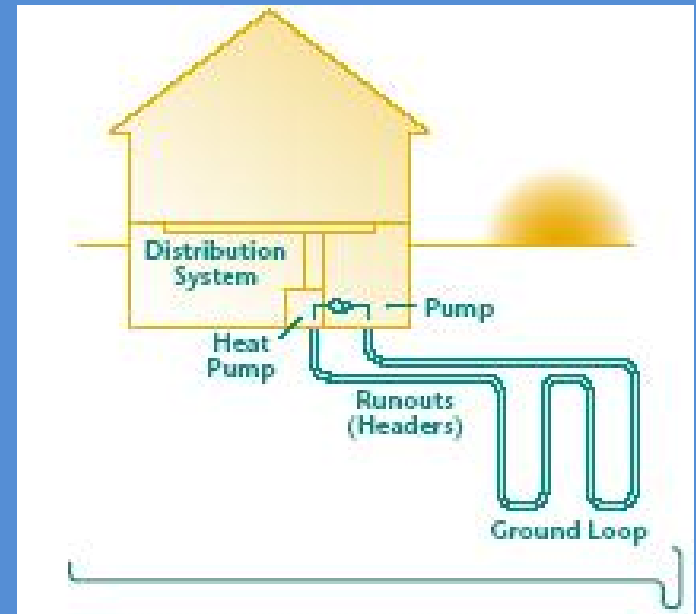
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Geothermal

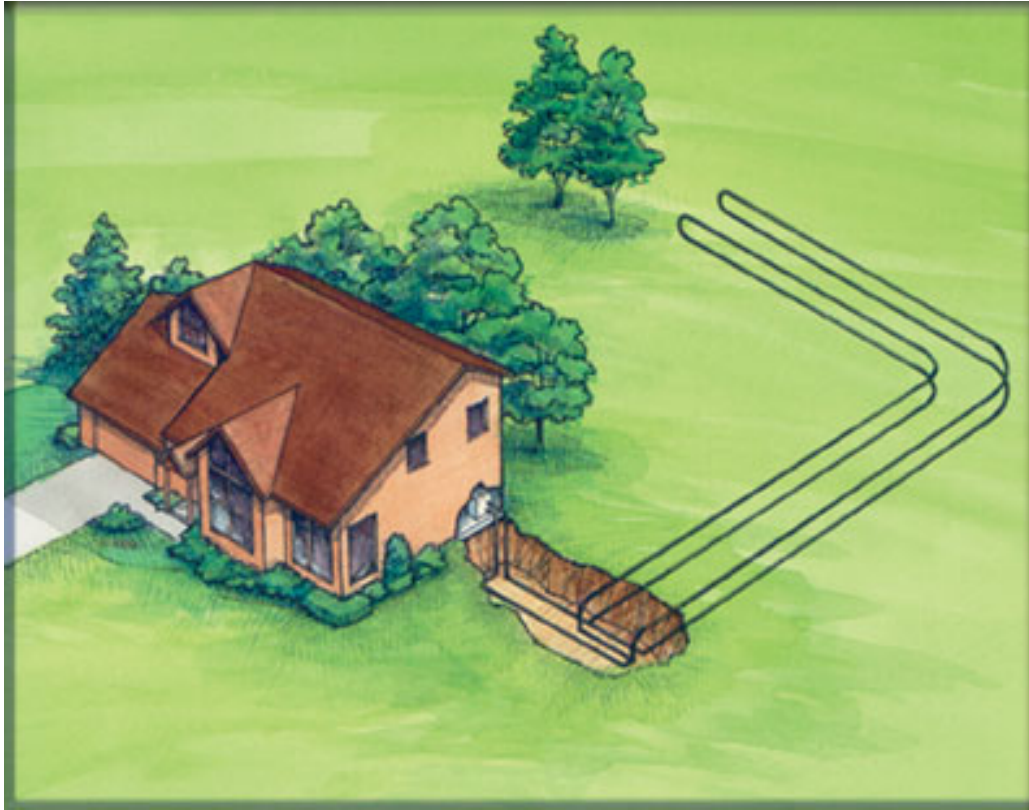
- <http://www.geoexchange.org/animation/flash-dsl.html>
- A heat pump can move 3 to 4 times more heat to or from a building than the energy required to operate it.
- The heat pump supplies more than 2/3 of your energy requirement from free energy stored in the earth and reduces your heating cost by at least 66%
- Ground source compressors operate at a 3.5 to 1 ratio whereas air source heat pumps often see a compression ratio of 8 to 1.
 - Water to air heat pumps
 - Water to water heat pumps
 - HVAC system components

Geothermal Energy

- Ground source heat pumps offer a %25 - %50 reduction in heating and cooling energy costs.
- But where does the electricity come from?
- %60 fossil electricity in NB, %30 generation efficiency, %5 lost in transmission ...

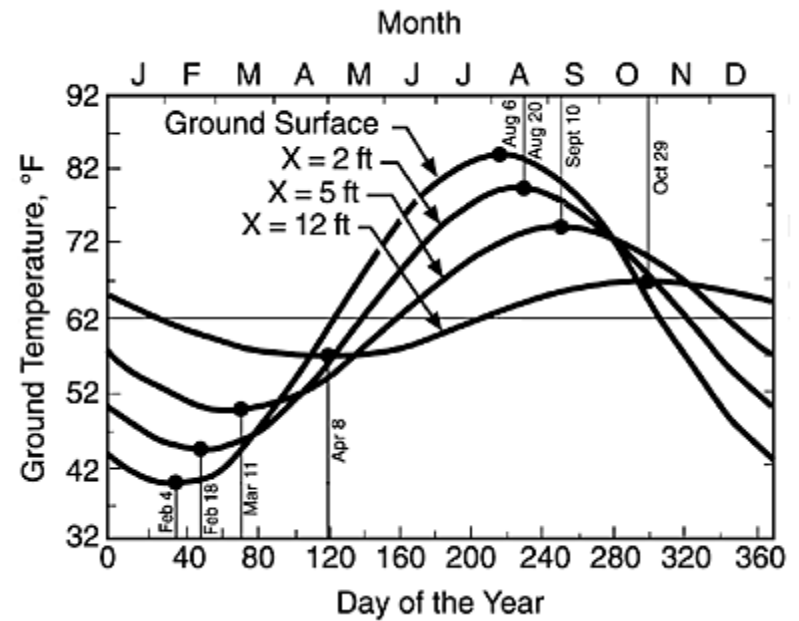
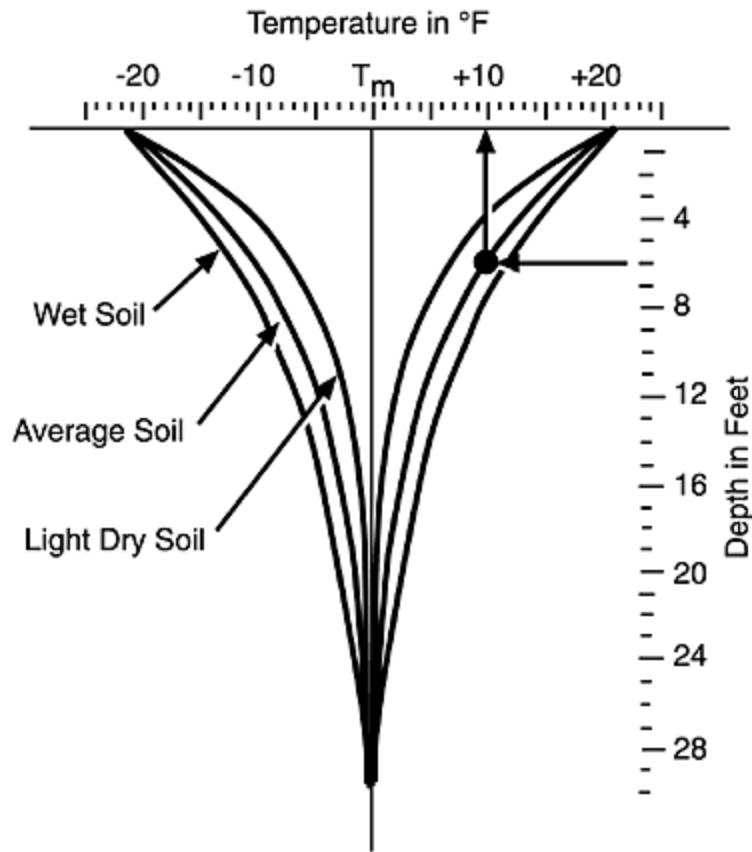


Horizontal Ground Loops

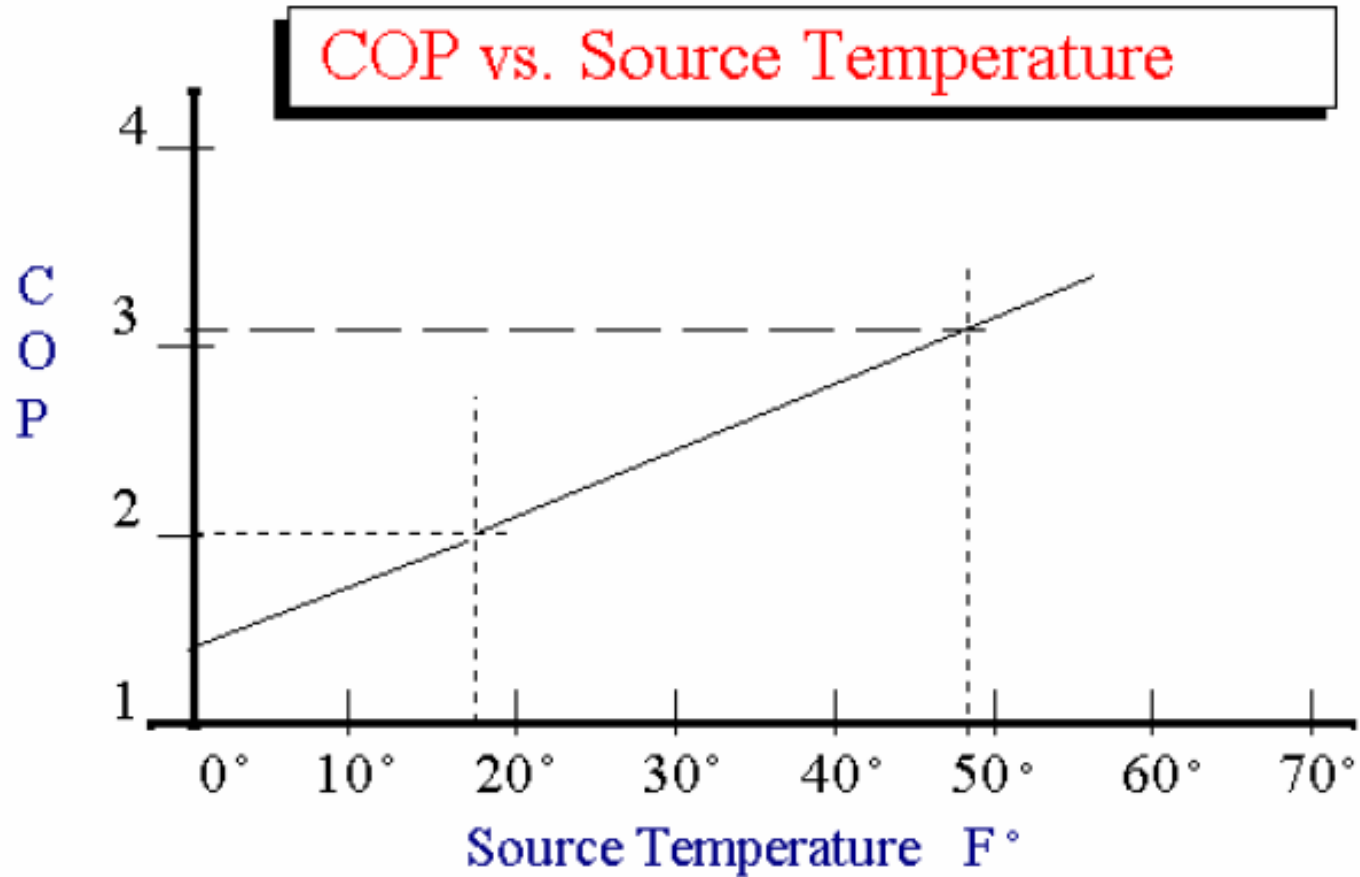


- Trenches are normally four to six feet deep and up to 400 feet long,
- 500-600 feet of pipe is required per ton of system capacity.
- Normally, a run of pipe is laid at five feet then looped back over itself at three feet once the bottom pipe is covered with soil.
- 8 – 10 foot spacing is recommended

Seasonal ground temperature at different depths



Coefficient of Performance



Basic Cost Comparison

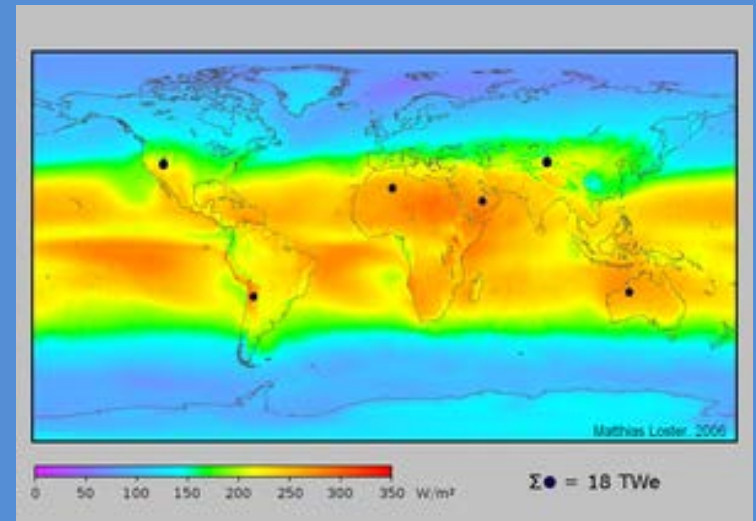
- A typical 2200 sq. ft. home in New Brunswick will consume 29,900 Kilowatt hours and cost approximately \$ 1794.00 annually to heat with electric heating.
- With an energy savings of 2/3 the cost of electric heat, the GHP will cost only \$ 598.00 a saving of \$1,196.00 each year the system is in operation.
- In a capital cost comparison with electric forced air heat, if the heat pump system cost \$6,600.00 more to initially install, then the simple payback would be 5.5 years.
- This payback does not take into consideration the of central air conditioning or additional savings made with the domestic hot water option.
- The additional monthly payment on an average 25 year mortgage at an interest rate of 7.25% would be approximately \$47 however the average monthly saving would be \$100.00. Therefore the GHP would actually be putting \$ 54.00 extra in your pocket each month.

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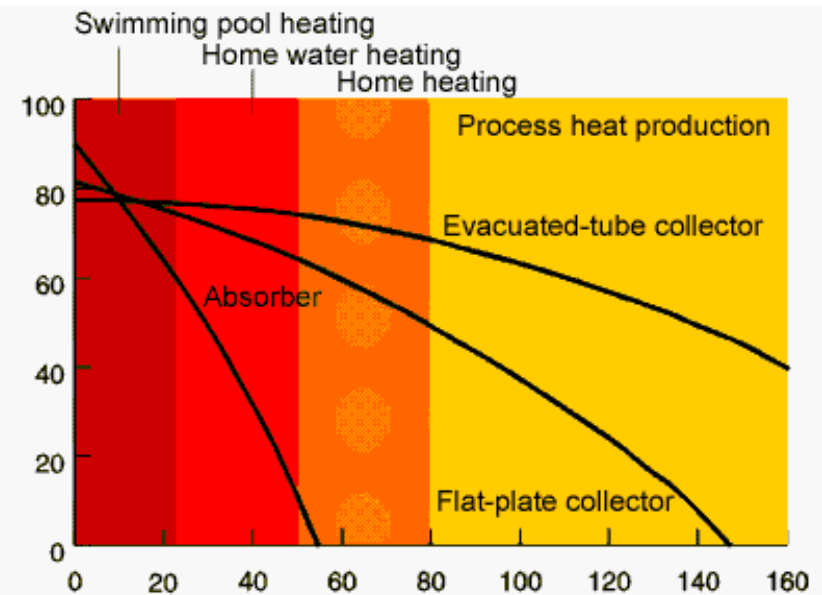
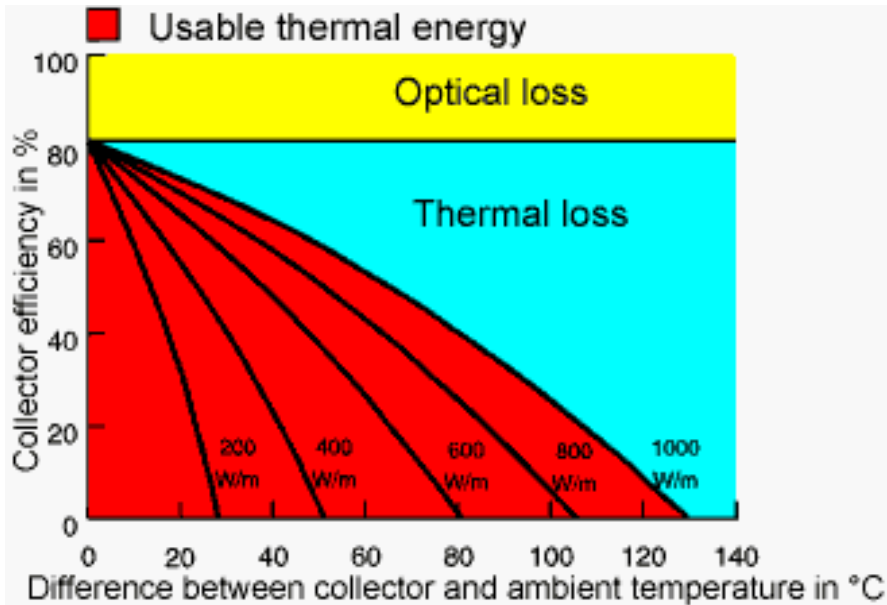
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Solar Energy

- Almost all renewable is solar
- Solar radiation reaches a unit of area in space above the atmosphere at $1,366 \text{ W/m}^2$, Of the energy received, roughly 19% is absorbed by the atmosphere, while clouds on average reflect a further 35% of the total energy.
- The generally accepted standard is for peak power of about $1,000 \text{ W/m}^2$ at sea level.
- In North America the average power of solar radiation lies somewhere between 125 and 375 W/m^2 , between 3 and 9 $\text{kWh/m}^2/\text{day}$.
- Actual power available depends on efficiency of collection.

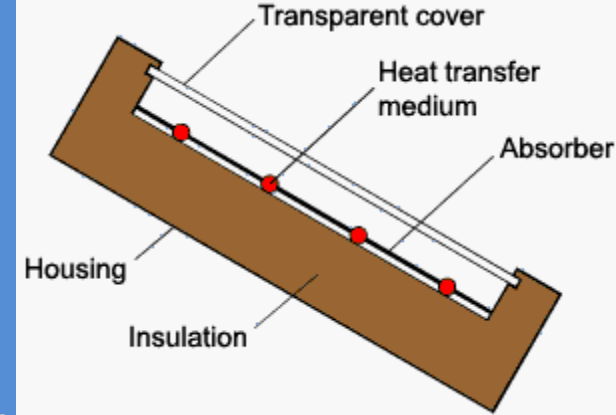


Thermal Collector Performance



Type of Collector	Conversion Factor	Thermal Loss Factor in $W/m^2 \text{ } ^\circ C$	Temperature Range in $^\circ C$
Absorber (uncovered)	0,82 to 0,97	10 to 30	up to 40
Flat-plate collector	0,66 to 0,83	2,9 to 5,3	20 to 80
Evacuated-plate collector	0,81 to 0,83	2,6 to 4,3	20 to 120
Evacuated-tube collector	0,62 to 0,84	0,7 to 2,0	50 to 120
Reservoir collector	about 0,55	about 2,4	20 to 70
Air collector	0,75 to 0,90	8 to 30	20 to 50

Flat Plate Collector



- Absorber:

- Often Copper tubing on aluminum plate
- Galvanically applied selective coatings include black chrome, black nickel, and aluminum oxide with nickel, or vacuum applied Titanium-nitride-oxide.

- Glazing:

- Prevents convection losses of collected heat.
- Usually an iron-poor solar safety glass is used as a transparent cover, as it transmits a great amount of the short-wave light spectrum.
- Very little of the heat emitted by the absorber escapes the cover

- Frame

- Typical frame materials include aluminum and galvanized steel; sometimes fiberglass-reinforced plastic is used.

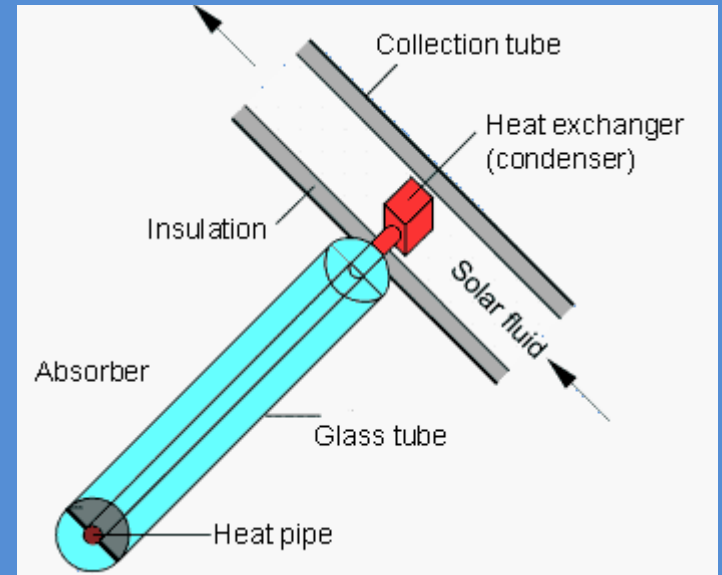
- Insulation:

- Lessens the heat loss through conduction. Insulation is usually of polyurethane foam or mineral wool; sometimes mineral fiber insulating materials like glass wool, rock wool, glass fiber or fiberglass are used.

- Flat collectors demonstrate a good price-performance ratio, as well as a broad range of mounting possibilities (on the roof, in the roof itself, or unattached).

Evacuated Tube Collector

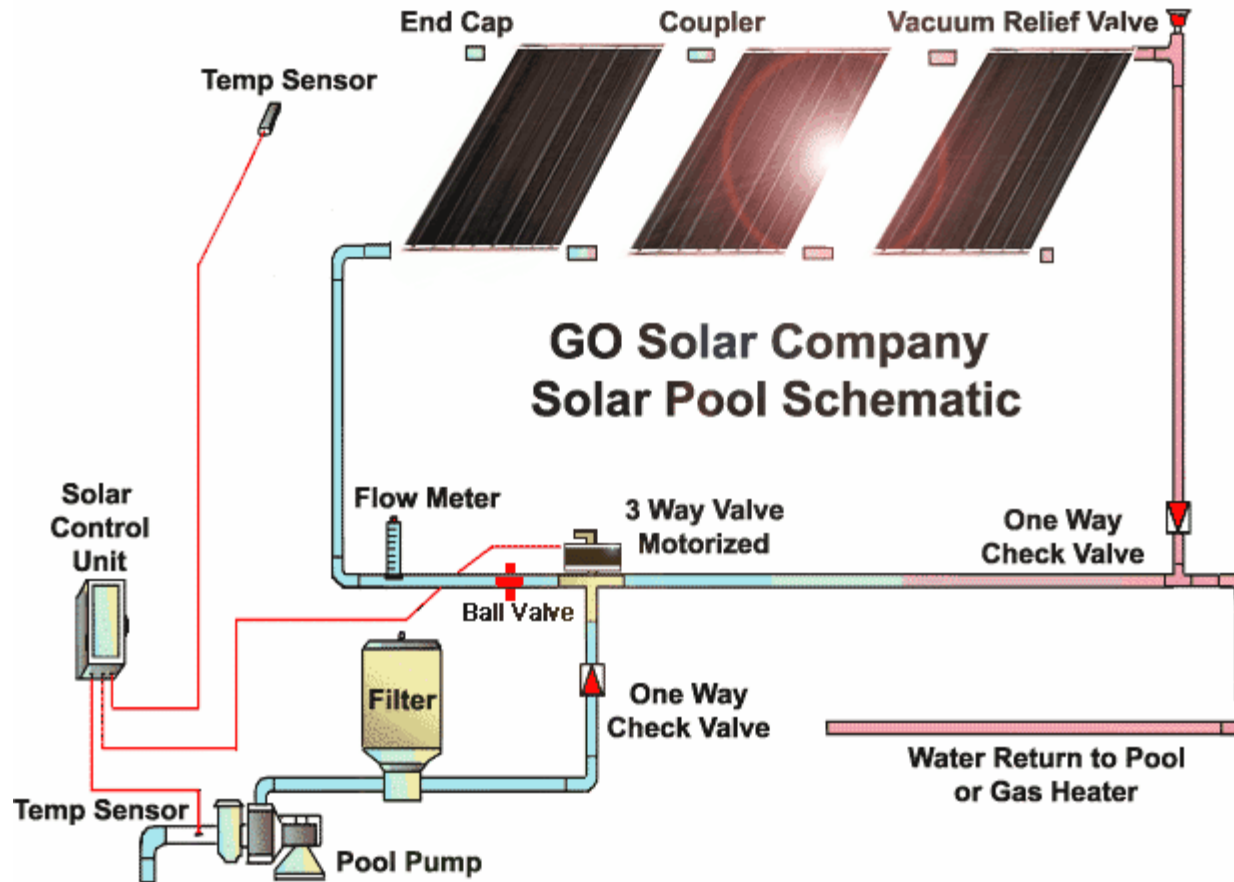
- In this type of vacuum collector, the absorber strip is located in an evacuated and pressure proof glass tube. The heat transfer fluid flows through the absorber directly in a U-tube or in countercurrent in a tube-in-tube system.
- Several single tubes, serially interconnected, or tubes connected to each other via manifold, make up the solar collector.
- A heat pipe collector incorporates a special fluid which begins to vaporize even at low temperatures. The steam rises in the individual heat pipes and warms up the carrier fluid in the main pipe by means of a heat exchanger. The condensed liquid then flows back into the base of the heat pipe.



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Solar Pool Heating



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