How to “Go Solar” in Vermont

A publication of the **Northeastern Vermont Development Association**

Created by Ben Luce, Ph.D., with support from the

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Comments and suggestions on this guide are welcome: Please send email to ben.luce@lyndonstate.edu.

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About the NVDA: Formed in 1950, at the same meeting where U.S. Senator George D. Aiken coined the term "Northeast Kingdom" to describe Caledonia, Essex and Orleans counties, the Northeastern Vermont Development Association has served the people, municipalities and businesses of this region as both the Regional Planning Commission and Regional Development Corporation.

As the Regional Planning Commission, NVDA assists municipalities, organizations, committees and individuals with a wide variety of planning and technical services. From assisting municipalities with regulatory options, to administering grants, creating maps, and implementing transportation and natural resource plans, NVDA is actively working with land use issues in the region.

As the Regional Development Corporation, NVDA works on infrastructure improvements, assists companies relocating to the area, helps existing businesses to grow, and administers revolving loan funds. NVDA also fosters key partnerships with the Small Business Development Center, the Northeast Kingdom Collaborative, the Northeast Kingdom Travel and Tourism Association, and the various Chambers of Commerce in the region.

Please visit www.nvda.net for more information.

Introduction to Solar Energy Systems

Solar energy systems are becoming common in Vermont. This guide provides essential information in a step-by-step format for evaluating the feasibility of and for obtaining photovoltaic (solar electric) and solar hot water systems in the Green Mountain State. There are also separate guides in this series for obtaining power from small wind energy systems, and heat from wood stoves, pellet stoves, and geothermal heating systems. Please visit www.nvda.net to obtain these.

Why Invest in Solar?

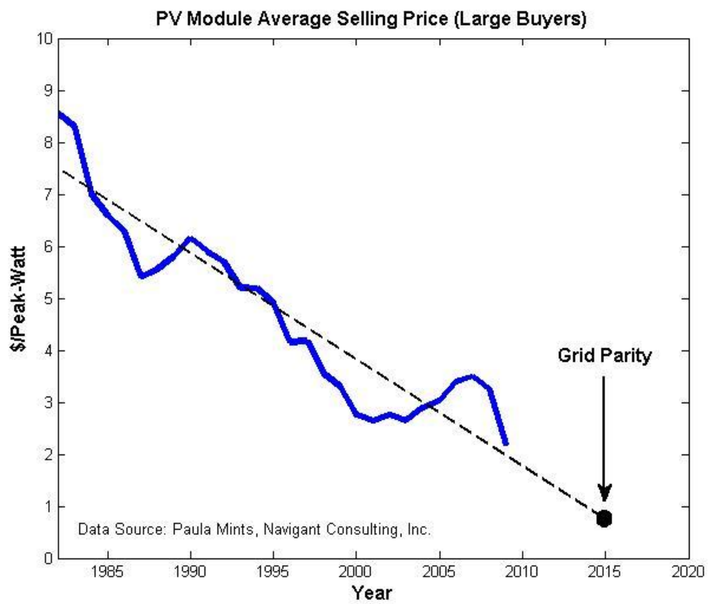
Solar energy is by far the largest, most easy accessible renewable energy resource on Earth, and has real potential to significantly reduce use and dependence on conventional energy sources in the near future. An amazingly large flux of approximately 120,000 trillion watts of solar power is continuously absorbed by the Earth's surface and atmosphere, 7500 times larger than the roughly 16 trillion watts our present civilization consumes. It follows that all of civilization's energy needs could be supplied from the solar resource alone, in principle.

Use of solar energy is not new. Ancient civilizations often made good use of solar energy, for example by orienting buildings and window openings to make maximize use of sunlight. Tinkerers, scientists, and engineers have been actively developing solar energy collector systems of various types for centuries. This rich history has been nicely documented in the book "A Golden Thread: 2500 Years of Solar Architecture and Technology[1]". More recently, over the past 100 years, much experience has been gained with solar hot water systems and solar electric systems. As a result, a solar heated and powered future is rapidly becoming a real possibility, and is already a reality for many people.

[1] Ken Butti and John Perlin, Cheshire Books, 1980.

Cost of Solar Energy

Solar hot water, passive solar design, and solar hot air systems are already cost effective applications of solar energy, with "**payback times**" ranging from a few years to little over a decade. Although solar electricity is not yet directly competitive with retail power prices, a historic convergence of the cost of **photovoltaic** (PV) generated power with retail electricity rates is occurring. Photovoltaics in fact appear to be on track to reach "**grid parity**", that is, to be cost competitive widely with US retail power prices, as early as 2015, as the following graph suggests (grid parity will be reached when modules cost about $1/watt and the total installed cost is about $3-4/watt).



With the various financial incentives available today, PV power is already roughly break even in some places (Vermont's incentives are not this generous at present).

In any case, one reason to utilize solar energy is that some forms of solar energy use are already cost effective or nearly so, depending on the application and location.

Another reason to invest in solar are the environmental benefits. Solar energy systems have negligible environmental impacts compared with conventional energy sources, and even in comparison with other renewable energy sources. Solar energy systems do require energy to manufacture and mining to obtain materials, and some require the use of toxic chemicals in their manufacture. But these impacts are generally well controlled and minimized to acceptable levels today, at least in the US[2]. Buyers of imported products should inquire into the standards associated with particular products or countries of origin, and avoid those with questionable origin.

Solar energy systems pay back their "**embodied energy**", that is, the energy utilized to manufacture them, rather quickly, usually on the order of a few years[3]. This implies that solar energy systems are very effective at reducing or avoiding greenhouse gas emissions, as well as the emission of other pollutants associated with conventional energy production such as particulates, nitrous oxides (NOX), sulphur dioxides (SOX), mercury, and uranium. Solar is also effective at reducing the impacts of conventional energy extraction, e.g. mining and drilling impacts. The components of solar energy systems are also generally recyclable.

Types of Solar Energy Systems

Determining what type or types of solar energy systems to install is an important step. This can be somewhat complicated decision and depends on primarily on several factors:

- Your reasons (or goals) for using solar energy
- The characteristics of your site, including the characteristics of your buildings
- How much you would like to invest initially, and over the longer term
- The financial incentives available in your area
- The availability of installation services

Before considering these factors in detail, one must first become familiar with the different types of systems.

There are basically two kinds of solar energy systems to consider:

Solar Thermal Systems, which deliver either hot air or water for space heating and/or for domestic hot water heating.

Photovoltaic (PV) Systems, which provide electrical power.

[2] According to the National Renewable Energy Lab (NREL Report No. 520-24617): "By using well-designed industrial processes and careful monitoring, PV manufacturers have minimized risks to where they are far less than those in most major industries. All of these risks fall well within the range already protected by OSHA and similar regulations.

[3] http://www.nrel.gov/docs/fy99osti/24619.pdf

Solar Thermal Systems

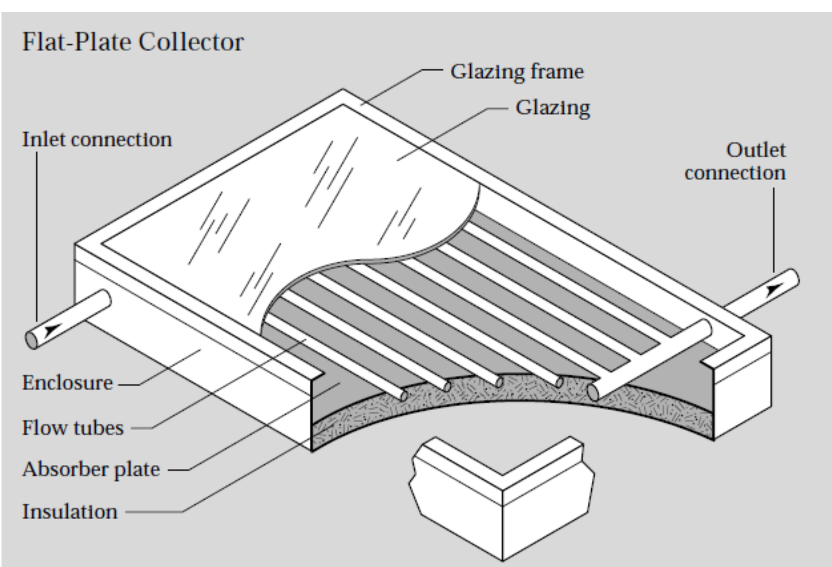
Solar hot water systems are by far the most common form of solar thermal systems, although **solar hot air systems** can also be used for providing supplemental space heat. Both types of systems are generally cost effective and are mature technologies.

Solar hot water systems can be used for offsetting domestic hot water heating costs, and also for offsetting home space heating costs. Systems designed primarily for only providing domestic hot water are sometimes configured so that any "extra" heat captured is utilized for space heating.

Solar Thermal Collector Types

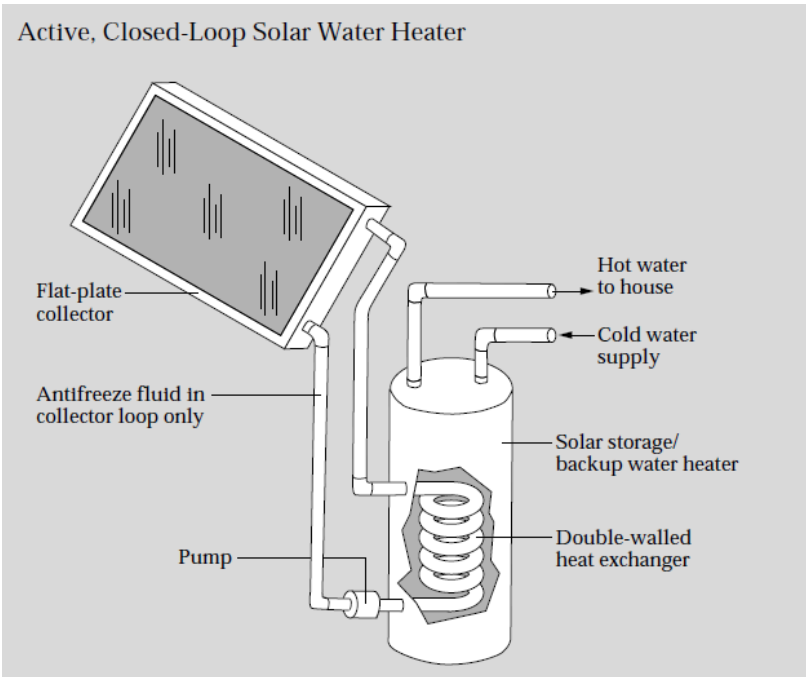
Solar hot water collectors in Vermont can provide close to 100% of domestic hot water needs for a home in the summer, and substantially less (~40%) during cloudy periods in the colder months, with an annual average of roughly 60%-70%. Note that these figures suggest that a back-up heat source will still be required in most cases.

There are two basic types of collectors in use on solar hot water systems today. One is the time-tested "**flat plate collector**", which consists of a flat aluminum box with a tempered glass cover. Solar heat is absorbed by black absorber plates inside the box, which is then removed by a fluid, usually water or a water-glycol mixture, flowing through copper pipes which are bonded to the absorber plates. Thermal losses are minimized by insulation in the sides and back of the collectors, and with special coatings on the absorber plates.



(Graphic from Dept. of Energy: DOE/GO-10096-050)

The heated fluid then passes through a "**heat exchanger**", which is usually a set of coiled pipes with high surface area located inside or around the outside of a storage tank, where the solar heat is then absorbed by the cooler water in the tank. The now cooled fluid is returned to the solar collector. The complete loop it makes is called the "**solar loop**".



(Graphic from Dept. of Energy: DOE/GO-10096-050)

A typical flush-mounted "flat plate collector".

Another common type of solar hot water collector is the "**evacuated tube collector**", which consists of a set of long, evacuated glass tubes which each contain an absorbing plate. Heat is transferred from the absorbing plate to a manifold assembly at one end of the tube by conduction and by the convective cycling of a refrigerant contained in a hollow by closed pipe that runs along the back of the absorbers. The heat is then carried away by water or a water-antifreeze mixture flowing through the manifold.

A typical flush-mounted "evacuated tube collector".

Flat panel collectors are typically somewhat cheaper than evacuated tube collectors, but evacuated tube collectors can have higher efficiencies in cold weather and/or lower light conditions for the same water input temperature, and vice versa in warm and/or bright weather. Both types should be considered, and both seem to function well in Vermont (we know of no definitive evidence that the efficiency characteristics of evacuated tube systems fully outweigh flat plate collectors in Vermont's climate). Flat plate collectors generally have a use life-time of 25 years. Evacuated tube collectors are newer, and less is known about their longevity, which might be problematic, especially if the more inexpensive versions are used. It is possible to determine when tubes have lost their vacuum (part of their backside turns white). In any case, it is always wise to invest in high quality, and if possible, time tested products. The warranty terms of components should also always be carefully considered when choosing a product.

System Types and Protection from Freezing and Overheating

Vermont is cold in the winter time, and so freeze protection for collectors is essential. Solar systems can also be damaged if allowed to overheat, for example, if no use of hot water occurs for a prolonged period, or if there is no circulation in the solar loop due to loss of electricity. Overheating can degrade the glycol, which besides becoming less effective as anti-freeze can be become acidic and corrode the system from the inside, and in some cases directly damage the collector or other components. There are a number of strategies utilized to prevent freezing and overheating, which are embodied in the different *system types*. We next discuss the two most commonly used types in Vermont.

One system type are "**drain-back systems**", which avoid problems with both freezing and over-heating by allowing the **solar loop**, that is, the loop carrying the liquid that passes through the collector and then later the heat exchanger, to fully drain and fill with air when a) there is no solar heat available, or b) when the water in the storage tank is hot enough, or c) when there is no electricity for pumping or if the pump should simply fail. These systems typically utilize a small secondary drain-back tank, called a "**drain-back reservoir**", which allows the portion of the solar collection system which is located outside the thermal envelope of the building to fully drain of water. This type of system does not require the use of an anti-freeze. Drain-back systems are somewhat challenging to design and install, as even small mistakes can lead to water failing to drain and freezing and damaging the system. The electrical power required to pump the water in the solar loop, which is unpressurized, can also be up to five times greater than in a pressurized (non drain-back type) solar loop, although this load can be decreased significantly by placing the drain-back reservoir at a relatively high position, when this is possible. Despite the initial design and installation challenges, though, this type of system can work well and can operate for decades with little or no maintenance.

Another type is the "**pressurized glycol system**" which utilizes a water-antifreeze mixture to prevent freezing. A benign (food-grade), high-quality **propylene glycol** can and should be used as anti-freeze, usually in a 50/50 mix with water. There is no mixing of the water-antifreeze mixture in the solar loop with the hot water in the tank that is utilized by people, but a nontoxic glycol is still desirable. The mixture is usually replaced every 3-15 years. The better the over-heating protection (see next), the longer the mixture will typically last.

These types of systems can overheat if there is no use of hot water, or if a loss of electricity occurs, of if the pump fails. On strategy is to provide a “**heat dump**” for the extra solar heat, which involves diverting extra heat somewhere else. For example, some systems are configured to dump the extra heat into a hot tub, or to a heated slab or driveway, while others simply allow some of the hot water produced to drain (10-20 gallons/day, typically, when the system is not being used). A less sophisticated approach is to simply cover the collectors while the system is not in use.

Many pressurized glycol systems today power the circulation pump for the solar loop with a small photovoltaic module. This way, the pump continues to operate even if the (grid) power goes down.

Purchasers of systems should confer carefully with the installer (if one is used) about how over-heating protection is to be accomplished.

Thermal Energy Storage and Back-up Heat

In some systems, the hot water tank to which the solar heat is delivered is the same tank from which the hot water is drawn. This makes it difficult, however, to simultaneously minimize use of back-up energy while maintaining a ready source of hot water. For example, after running showers in the morning, one would have to wait for the tank to heat up again, or run the back-up heat source right away, which would negate the usefulness of the solar system.

One way to deal with this issue is to design the installation so that the back-up heat is delivered only to the upper part of the hot water tank. For example, a tank can be outfitted with **dual heat exchangers**: One heat exchanger, which is fed by a boiler, is installed in the upper part of the tank, while the solar feeds a second heat exchanger in the bottom. Because water can support a fairly large temperature gradient (stratification), this can leave some cold water remaining in the bottom of the tank for the solar system to heat.

Alternatively, a separate “**solar storage tank**” can be installed to which the solar loop delivers its heat. The output of this tank is then fed into the hot water tank. In this way the solar system **pre-heats** water for the hot water tank. If there is not much sunlight, then, and only then, will the back-up heat be utilized.

System Size and Cost

The cost of a solar hot water system depends on the choice of components, system size, and installation details.

An adult typically utilizes approximately 20 gallons of hot water per day. A smaller household, around 1-3 members, can therefore usually be accommodated with a 50-60 gallon hot water tank, whereas a larger household will need a capacity of 80 gallons or more.

A square foot of collector will heat roughly 1.25 gallons per day in Vermont on average. This then implies that a smaller household will require a collector area of at least 33-40 square feet, which can be accomplished with a single 4' by 8' or 4' by 10' flat plat collector. This would be minimal, however, as having just this one will likely tend to underperform in winter.

Solar hot water systems which are utilized primarily for domestic hot water, and with one or two collectors, will generally cost somewhere in the range of $8000-$11,000 before incentives, fully installed.

Federal and State incentives can lower this cost substantially (typically approximately 40%).

With this information, we can roughly estimate the "payback time" for a solar hot water system. Usage patterns can influence payback times for solar hot water systems strongly, so an exact "payback time" cannot be assigned to a particular system without definite assumptions or data about the usage pattern. The payback time will also depend strongly on what type of heating energy we are offsetting – oil, natural gas, or electricity.

In general, though, it is safe to assume that the **simple payback time** will range from 10-20 years with a 40% total incentive included, depending on the back-up fuel used, and somewhat conservative estimates of future oil and electricity prices. Note that this is substantially greater than some quote.

We can see more precisely how such an estimate arises as follows (this discussion may be skipped):

Suppose a solar hot water system costs $8000 before incentives. With a 40% total incentive, this will cost approximately $4800. Suppose also that heating oil costs average out to $3.00/gallon during the lifetime of the system (an assumption which may prove to be very conservative). Assume also that the system avoids having to heat approximately 50 gallons of water per day on average with oil (roughly 60% of the 80 gallons per day) through a temperature increase of 70 ^{o}F. Using the fact that 1 BTU raises the temperature of 1 lb of water 1^{o}F, and that 1 gallon weighs 8.34 lbs, this works out to save roughly 50 x 70 x 8.34 = 29,190 BTU/day on average. Heating oil has an energy content of about 139,000 BTU/gallon. Suppose we assume that only 90% of this can be used to the heat water directly, then we find this system saves (29,190) /(139,000 x .9) = .23 gallons of oil per day, or 85 gallons per year, or $255 per year.

So the simple payback time is therefore $4800/$255 = 19 years. If oil is $4/gallon on average, the payback time drops to 14 years.

If instead we assume that the system offsets electrical heating costs instead, and an electrical price of $.13/kWh is assumed (a common if not universal residential price in Vermont), then, using the fact that 1 kWh=3412 BTU, and assuming the system saves 29,190 BTU/day again, we find that the system saves about 29,190/(3412)= 8.6 kWh per day, or about $408 per year.

So the simple payback time in this case is $4800/$408 = 12 years.

Larger Solar Thermal Systems

For a system designed to provide a significant amount of space heat to a building, for example by contributing heat to a "**under-floor**" or "**radiant floor**" heating system, a rough rule of thumb is that the solar collection area should be 10%-20% of the floor area to be heated. Note that such a system is not compatible with high temperature heating systems such as baseboard systems: The temperature output of a solar thermal system will generally be under about 150 ^{o}F, which is too low for radiator or baseboard systems to deliver heat rapidly enough by this means. Under-floor (radiant) systems, on the other hand, can operate well with solar heat, as long as the solar heated liquid is firstly properly "mixed down" using a temperature sensitive **mixing valve** to ensure the correct input temperature for these systems. The "**thermal mass**" of an under-floor system which delivers heat into a concrete slab (preferably insulated underneath) also avoids the need for a large hot water storage tank.

Siting and System Orientation/Tilt

For a solar hot water system designed for providing domestic hot water for a typical family, your site should possess a roughly south-facing location large enough for such a collector array which will receive unobstructed sunlight throughout the year from at least the hours between 9 am to 3 pm. To see how to make such an evaluation in detail, see the step below entitled "Evaluate Your Site".

Collectors can be mounted on roofs, off the sides of buildings, and on the ground, so there is quite a bit of flexibility as to the exact siting. Ground mounts provide a high degree of accessibility, especially if the ability to remove snow occasionally is desired and snow will fall off free-standing panels, that is panels that are not flush with a roof, more easily. On the other hand, roof mounts are convenient for keeping the collectors out of the way, and also putting them out of reach.

The orientation of the collector with respect to South, and the angle at which the collector is titled are also important factors. Solar thermal collectors are usually installed with fixed (unalterable) tilts, due to the rigidity of pressurized plumbing components. Vermont also receives a significant amount of snow. Flat plate collectors tend to shed snow fairly well, because sunlight diffusing through snow can still be absorbed by the collectors, and will often warm them up enough to melt snow. Evacuated tube collectors will warm somewhat and shed snow to some extent, but may need slightly more assistance (use a broom, not a shovel).

As a general rule of thumb, thermal collectors tilted at an angle of 45^o or more from horizontal will tend to shed snow reasonably well. On the other hand, a tilt much greater than this will tend to under-utilize summertime sun, so a tilt of 45^o, which is the approximately the latitude of Northern Vermont, is a fairly good orientation from the standpoint of maximizing annual production. Significant variation is permissible, however, so that steeper or less steep roofs may still be used. Note that "latitude tilt" is a commonly used rule of thumb for fixed tilt solar collectors, but may not fully take into account local weather patterns. In Northern Vermont, an angle of approximately 38^o will maximize annual production assuming no blocking from snow (based on simulations of solar systems with "Typical Meteorological Year" data for Montpelier).

Photovoltaic Systems

Photovoltaic systems, or "PV Systems", are an increasingly popular source of local renewable electricity generation in Vermont. This technology produces electricity instantly when sunlight is absorbed by it. PV panels are actually called "**modules**". Each module is made up of PV "**cells**" (some thin film modules available today are effectively one large "cell"). Many modules together constitute a **PV array**. Some systems have more than one array, which together are often also collectively called "the array". Arrays can be mounted on rooftops, or ground-mounted, either on frames or poles (pole-mounted).

A 5 kilowatt PV system, on two pole-mounted arrays.

Off-Grid and Grid-Tied (Net-Metered) Systems

In "**off-grid**" PV systems, the DC electricity produced by the arrays is stored with batteries, and then usually converted to AC power with an "**inverter**" (some systems use the DC power only, directly from the batteries, which requires the use of DC-only loads). Alternatively, in a "**grid-tied**" PV system, the DC power is converted to AC with an inverter that synchronizes its output precisely with the power grid and feeds the PV power directly into the power grid. Grid-tied systems are usually a better choice at locations where grid service already exists, because these systems are more inexpensive and more environmentally friendly, because no batteries are required, and because all of the solar power gets used, unlike an off-grid system which wastes solar energy once the batteries are fully charged.

Grid-tied systems in Vermont, by Law, can be "**net-metered**", meaning that the system owner's electric meter is replaced with a reversible electric meter, and this electric meter literally runs backwards whenever the system is producing more than the owner is consuming. Any net energy generation credit is carried over to the next billing period for up to a year, although any credit not used within a year is credited back to the utility. This latter part means that a system should not be oversized to produce more than the owner consumes on an annual basis.

Under net-metering all the solar power generated will effectively offset grid power at the full retail rate, even if the system's output is not enough to fully reverse the meter at some times. This is because any PV power produced will at least cause the meter to run more slowly, so that overall the meter ultimately measures a lesser amount of consumption equal to the system's total output.

Vermont also allows the aggregation of many different electric meters to be net-metered with a single large system. In this case, the meters are read separately and the net amount is calculated by subtraction.

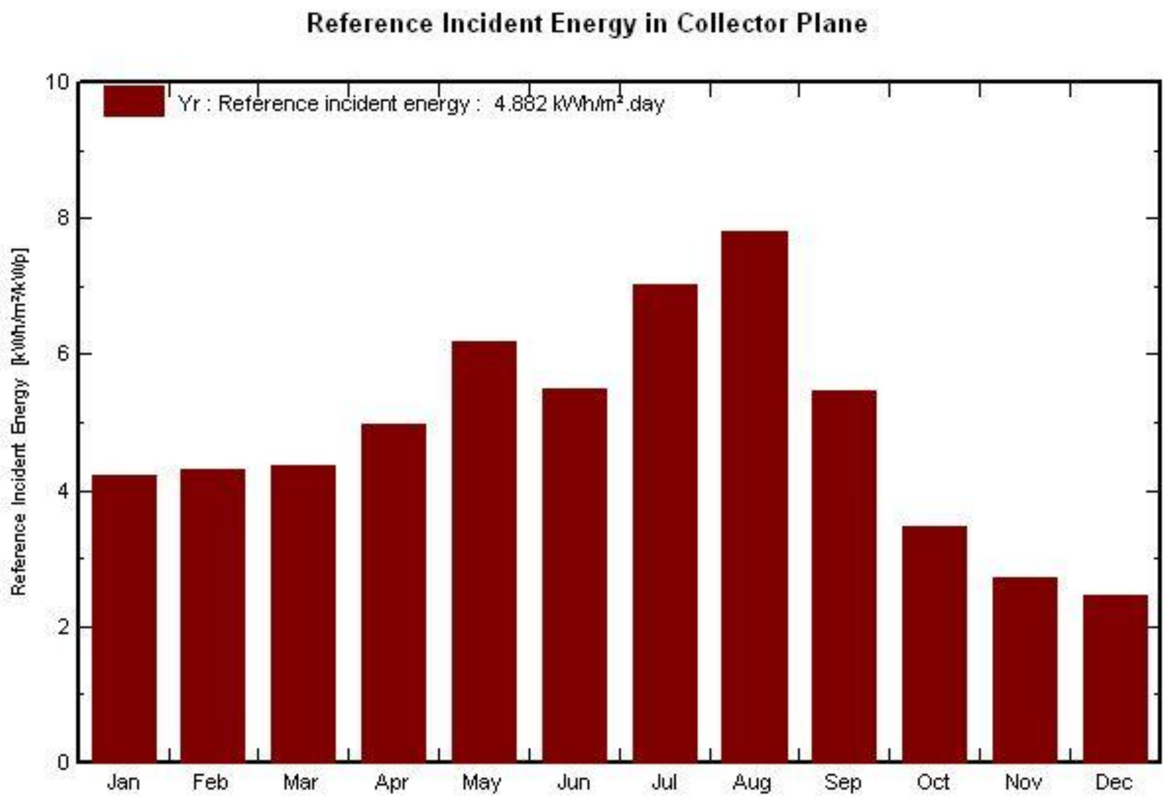
Longevity of PV Components

Most PV modules today can be expected to have a useful lifetime of at least 30 years, and most have warranties guaranteeing that they will produce at least 80% of their originally rated output capacity for 20 years. Inverters typically have warranties with shorter terms, ranging from a few years to a decade or more in some cases. Warranty details should be checked carefully before purchasing a system.

Most off-grid systems will need to have the batteries replaced every 3-8 years, depending strongly on the electrical usage patterns, PV system capacity, the use or absence of back-up generation, and the capacity and type of batteries used. Non-sealed lead acid batteries will also require regular addition of distilled water (sealed batteries do not).

PV System Production Potential in Vermont

To gain some idea of how much power a PV system can produce at different times of the year in Vermont, the following graph shows the incident solar energy available on a tracking PV system in northern Vermont during a "Typical Meteorological Year". The Vermont resource is particularly strong in the summer, as could be expected. It declines substantially in the latter months of the year, but is reasonably strong from January to March, perhaps unexpectedly to many.



A good rule of thumb is that a 1 kilowatt (1000 watt) PV system in Vermont can be expected produce the following amounts of useful electrical energy per day on average:

System Type	Average Daily Production (kWh)
Fixed Tilt (no seasonal adjustment)	2.9
Seasonally Adjusted Tilt	3.2
Tracking Array	3.5

Note that systems may produce more or less than these (approximate) figures, depending on the precise orientations utilized, exposure to sunlight reflected from snow, how much snow coverage occurs, the particular choice of components (e.g. the efficiency of the modules and inverter), etc.

PV Systems and Snow

PV arrays do not shed snow as well as solar thermal collectors, because they cannot effectively store up heat from sunlight diffusing through the snow. For this reason, systems that can be seasonally tilted, or tracking systems, are highly recommended. Rooftops can still be used however, and snow removal can be accomplished where the installation allows.

PV System Cost and Payback Times

Fixed tilt grid-tied PV systems today can be installed for costs ranging from about $6000-$10,000 per kilowatt of peak capacity, not including incentives. Off-grid systems generally cost more, due to the extra cost of batteries, battery box, and larger wire gauges.

The "**up-front cost**" (with or without incentives factored in) can be translated into a "**levelized cost per kilowatt-hour**" and a "**simple payback time**", which provide two different avenues to consider the cost. The levelized cost depends on what assumptions one makes about the time duration over which the cost is to be levelized, and may include or exclude factors such as financing costs, insurance, etc. The simple payback time depends on the upfront cost and also the expected average retail cost of electricity, and to a lesser extent on other factors, such as whether the inverter will need to be replaced, or how often batteries are replaced (for off-grid systems).

Two straightforward estimates are presented here for the simple payback time and simple levelized cost per kWh to convey a clear idea of these concepts, and typical numbers for today's costs. Incentives will also be factored in.

Suppose a 3 kilowatt, fixed tilt system has total installed system cost of $18,000, before incentives, or $6000 per kilowatt, which lies at the lower end of system cost's today. We will assume this system has a useful lifetime of 25 years.

The Vermont PV rebate incentive, if equal to $1/watt, would deduct $1000 per kilowatt, or $3000 from the cost, reducing the system cost to $15,000. (See the section below on incentives for more information about the state rebate).

Next, the 30% Federal Solar Tax Credit would further effectively reduce this to $10,500.

Using the table above, we assume this produces produces 2.9 kWh/day per kilowatt on average, or 8.7 kWh/day in total on average. The simple levelized cost over 25 years would therefore be:

$10,500/(365 days/yr x 25 yrs x 8.7 kWh/day) = $.13/kWh.

This is approximately the cost of retail electricity for many residences in Vermont today (although some utilities charge substantially more). Without incentives, the levelized cost would have been approximately 22 cents/kWh.

We now examine the simple payback time. This is given by the total cost of the system divided by the estimated annual savings. Assuming a retail electricity cost to be $.13/kWh, we have:

$10,500/(365 days/yr x 8.7 kWh/day x $.13/kWh) = 25 years.

This result, not surprisingly, turns out to be exactly the same as the useful lifetime we assumed for the levelized cost because in this particular example the levelized cost turned out to be the same as the assumed retail electricity cost in this case.

If we redo this estimate without incentives (i.e. a system cost of $18,000), the simple payback time increases to 44 years, which is likely significantly longer than the useful life of the system.

Anyone considering a PV system should check their electric bill, or with their utility, to determine their actual price of electrical energy. If the price is substantially greater than $.13/kWh, then the payback time will be substantially shorter.

Step 1: Evaluate Your Site

Determining the direction of true-south, at least roughly: Orienting a collector exactly towards true-south, and without exactly the optimal tilt, is not critical. Facing somewhat East will favor morning production, while facing West will favor afternoon production, and there will typically be some loss of overall annual production with either, but variations of up to plus or minus about 15^{o} will not be very significant.

An accurate knowledge of true-south is still an important starting point. Estimates of the direction of true-south can be obtained in the following ways:

- Consult a map, or use an aerial photo obtained with Google Maps at (http://maps.google.com/). This can give you quite an accurate determination, because one can often zoom in on a particular building.
- Use the direction of Polaris (the “North Star”) on a clear night.

- Use a compass. Here, note that true south is slightly different from magnetic south. In Northern Vermont, magnetic north points approximately 15^o west of true north, or equivalently, true south points approximately 15^o east of true south.

In general, it's a good idea to use at least two different methods, and cross check them.

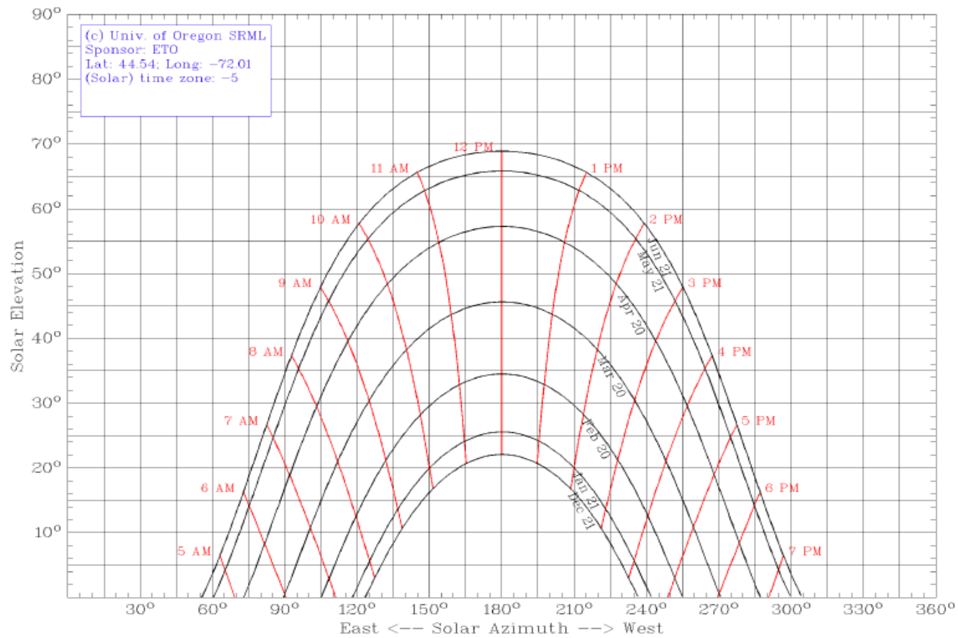
Determine if obstructions shade your site(s): This can be a non-trivial task in some cases. Professional installers are adept at this evaluation and it might be easiest to simply seek a quote together with a site evaluation. If you are interested in proceeding, though, here are some ways to do this.

Suppose you have a particular site in mind. One way to proceed is to use "sun-angle data" directly to analyze what obstructions might shade a particular spot on a solar collector. These angles give the direction of the sun at any particular day and time, and are summarized by the curves in the following graph for a latitude of 45.54^o, which is quite representative for sites in Northern Vermont. The graph was generated with the (easy-to-use) online sun angle calculator at http://solardat.uoregon.edu/SunChartProgram.html.

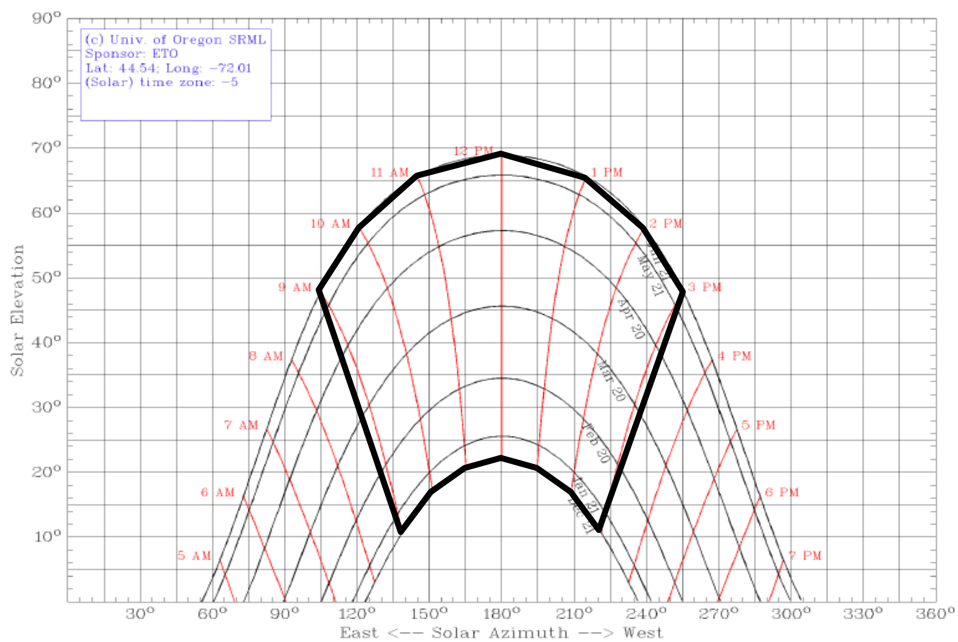
Each curve gives the path of the sun on a particular date, the dates for which are indicated on the graph. The horizontal axis of the graph corresponds to the "azimuth angle" of the sun as measured horizontally from due north (so that true south corresponds to 180^o). That is, it specifies which direction to face. The vertical axis of the graph corresponds to the "elevation angle" of the sun above the horizontal.

Across the set of curves lie a set of intersecting lines that correspond to the time of day. These times are actually "solar time", which means the time as referenced to the time 12 pm as being the time when the sun is precisely due south. At any site, the solar time will be offset some number of minutes depending the precise longitude of the site.

So, for example, one can read of the graph that the maximum elevation of the sun (at solar noon) on summer solstice (June 21st) is about 69^o, and slightly over 22^o on winter solstice (December 21st). And at 10 am (solar time) on May 21, the sun is located approximately 54^o east of south, and elevated 55^o above the horizontal.



An adequate solar site will have no obstructions from at least 9 am – 3 pm, which corresponds to the window shown below:

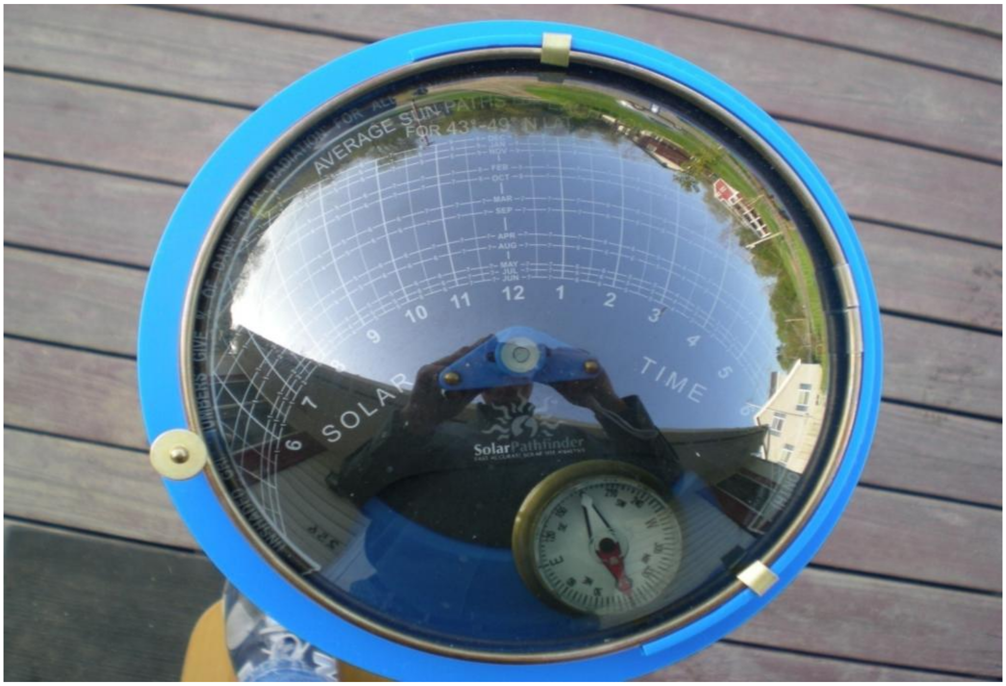


One can utilize the angle markings on a compass, or a properly oriented protractor, to compare the azimuthal angles of obstructions (relative to a particular solar collection point) with the sun-angles. The elevation angles of obstruction can likewise be obtained with a protractor oriented with a level. It is possible to purchase elevation angle measuring gauge at most hardware stores that have a gravity weighted needle in place of a level.

The above procedure is somewhat tedious and inexact. A much easier approach is to obtain a cleverly designed device called a "Solar Pathfinder", which can be located online at http://www.solarpathfinder.com. These cost several hundred dollars, but fortunately one of these can often be borrowed from a professional solar installer, or perhaps a local college or other institution with a solar energy related program.

The following photos show a Solar Pathfinder being used, the first at a sight which has very substantial shading during certain months and times of day, and the other at a site which has only a small amount of shading during the December. To use the pathfinder, one first uses its built-in compass (and knowledge of the magnetic declination) to orient the compass, and the built in level to level it. Then one looks straight down it (or takes a photograph straight down), and examines the superposition of the reflection of obstacles (that is, the "horizon") with the sunchart underneath. This sunchart has similar markings to the sun-angle chart shown above, but it distorted in just such a way so that the dates and hours during which obstacles shade the location of the pathfinder can be read off easily.

A site with lots of shading by trees



A fairly clear site, with some shading in December

Ground mount sites are clearly much easier to evaluate with a Solar Pathfinder than rooftop sites. Extreme caution (with respect to personal safety) should be used if attempting to utilize a Solar Pathfinder on a roof. This is quite possible, but it may be best to leave this task to a professional installer.

One way to avoid having to make an evaluation from the roof is if an evaluation from the ground in front of (to the south) of a roof site shows no shading from obstructions, then it may follow obviously that there will be no shading of sites on the roof from obstructions either.

Obstructions *on the roof* should also be considered carefully, such as chimneys, other sections of roof that may be raised up at different angles, etc. These kinds of obstructions can sometimes be somewhat difficult to evaluate, especially if the roof is not oriented exactly south, and here the Solar Pathfinder can be especially helpful (but of course still requires getting up on the roof). Professional installers may have modeling software or other means to answer these questions without doing so.

Step 2: Determine what incentives you are eligible for

Solar Hot Water Systems

Incentives for solar hot water systems in Vermont are administered by the **Vermont Small Scale Renewable Energy Incentive Program** (http://www.rerc-vt.org/incentives/index.htm). Descriptions of the incentives, and links to forms (which you will likely NOT need to fill out – see below), can be found at the link above.

Vermont is actually somewhat problematic when it comes to solar hot water incentives. As of this writing, Vermont's PV incentives are somewhat unpredictable because they change regularly and depend on the depletion of particular funds, and the application process can be complex for novices. As of this writing, the State Legislature is also presently considering a new package of incentives.

Do not let these facts discourage you, however. By law, Vermont's solar hot water incentive must be obtained through an installer that is officially registered in Vermont's Solar & WInd Partnership Program. This means that the paperwork for the state incentive must and will be handled by the installer.

This Program also requires the participating installers to meet a variety of quality and technical installation standards, such as proof of good quality installations and training, use of certified components, etc.

The Vermont incentive for solar hot water systems is based on how many BTUs of thermal energy the collectors are rated to produce under certain conditions. Specifically, it depends on the "Collector OG 100 Rating" under "Clear C conditions" as determined by the most recent SRCC ratings, where SRCC refers to the Solar Rating and Certification Corporation, which rates solar thermal collectors in the US. The SRCC ratings can be found at http://www.solar-rating.org/ratings/ratings.htm.

For example, the Clear C rating of a "Gobi" 408 001 collector, a flat-plate collector which is manufactured by Heliodyne, Inc. is 34.2 kilo-BTU/day. The boiler plate (rating sticker) for this collector (which is available from the SRCC site along with tables summarizing the ratings of all the rated collectors together) is shown below.

SOLAR COLLECTOR CERTIFICATION AND RATING SRCC OG-100	**CERTIFIED SOLAR COLLECTOR**	
	SUPPLIER:	**Heliodyne, Inc.** 4910 Seaport Avenue Richmond, CA 94804 USA
	MODEL:	408 001
	COLLECTOR TYPE:	Gobi Glazed Flat-Plate
	CERTIFICATION#:	2007027C

COLLECTOR THERMAL PERFORMANCE RATING

Megajoules Per Panel Per Day				**Thousands of BTU Per Panel Per Day**			
CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY	CATEGORY (Ti-Ta)	CLEAR DAY	MILDLY CLOUDY	CLOUDY DAY
A (-5 °C)	46.4	35.0	23.7	A (-9 °F)	43.9	33.2	22.5
B (5 °C)	42.3	31.0	19.7	B (9 °F)	40.1	29.3	18.6
C (20 °C)	36.1	24.9	13.9	C (36 °F)	34.2	23.6	13.2
D (50 °C)	24.0	13.8	4.2	D (90 °F)	22.8	13.1	4.0
E (80 °C)	13.1	4.4	0.0	E (144 °F)	12.4	4.1	0.0

As of this writing, Vermont offers an incentive of $1.50 per 0.1 kilo- BTU/day (or 100 BTU/day), up to $3000 total for residential systems, and up to $15,000 for commercial/industrial systems. Note that this incentive will be reduced once the total amount of claimed incentives reaches a certain level (20,000 kilo-BTU/day). Information about how much has been subscribed can be obtained at

http://www.rerc-vt.org/incentives/index.htm.

In any case, the current incentive can be calculated for a given system by first computing the following number:

Incentive Estimate = Total Rated Output x 10 x $1.50 = $____________,

And then finding the the lesser value of the above or $3,000 for residential systems or $15,000 for commercial/industrial systems.

For, example, suppose a residential system employs two of the Gobi 408 001 collectors. Then, given that the Clear C rating is 34.2 kBTU/day, and we have two collectors, we have:

Incentive Estimate = 2 x 34.2 x 10 x $1.50 = $1026.

This is about a 13% incentive or less, depending on the system cost.

Next, the Federal Government currently offers a 30% tax credit on solar hot water systems. This credit is relatively easy to claim, especially for any brand new, professionally installed system. Conversely, note that neither the state rebates or federal credits apply to used equipment.

So together, the state and federal incentives will decrease the system cost by approximately 40%.

Incentives for photovoltaics

Incentives for PV in Vermont are administered by the **Vermont Small Scale Renewable Energy Incentive Program** (http://www.rerc-vt.org/incentives/index.htm). Descriptions of the incentives, and links to forms (which you will likely NOT need to fill out – see below), can be found at the link above.

Vermont is actually somewhat problematic when it comes to PV incentives. As of this writing, Vermont's PV incentives are:

- Relatively small as compared with programs in many other states and countries;
- Unpredictable because they change regularly and depend on the depletion of particular funds;
- Are a complex process for novices;
- Some special PV packages are offered by some installers, for example programs which effectively sell customers PV power, or lease systems to customers, and which do not necessarily related directly to the incentives offered to those who purchase systems directly in the more conventional way.
- As of this writing, the State Legislature is considering a new package of incentives, so the current situation is likely to change substantially.

Do not let these facts discourage you, however. By law, Vermont's PV incentive must be obtained through an installer that is officially registered in Vermont's Solar & WInd Partnership Program. This means that the paperwork for the state incentive must and will be handled by the installer. This Program also requires the participating installers to meet a variety of quality and technical installation standards, such as proof of good quality installations and training, use of certified components, installing of utility grade electrical meters for system monitoring, etc.

Grid-tied (net-metered) systems in Vermont must meet particular standards, which any professional system installer should know and follow. Specifically, all net-metered systems must comply with all applicable requirements of Vermont Public Service Board Rule 5.100, and must obtain and provide a "Certificate of Public Good" from the Vermont Public Service Board. **NOTE: The CPG must be obtained before installation commences.**

As of this writing, Vermont offers $.75 per watt for PV systems up to 10 kw, and $.60 per watt for commercial or industrial systems ranging from 10 kw to 25 kw.

For up-to-date information on this incentive, including links to forms visit:

http://www.rerc-vt.org/incentives/index.htm.

Note that there are many rules governing this rebate (described at the above two sites), including having to first obtain the CPG from the Public Service Board for any grid-tied system. The installer must in fact fill out parts of the rebate application form, and working closely with the installer on every step of the way is highly recommended. Also, site preparation and system installation cannot commence until the CPG is approved, a process which can take up to about 5 weeks. Note that pole-mounted grid-tied systems in particular require notification of adjacent property owners and municipal authorities in addition to the Public Service Board and your utility, who have a 10 day window in which to file comments or request a hearing.

Vermont also offers a Solar Business Tax Credit (which cannot be taken along with the rebate). We will only discuss the rebate route here, because the SBTC is currently in disarray as of this writing.

Finally, the Federal Government currently offers a 30% tax credit on PV systems. This credit is relatively easy to claim, especially for any brand new, professionally installed system. Conversely, neither the state rebates or federal credits apply to used equipment.

Step 3: Finance Your Solar System

Solar systems are relatively expensive, and most people will need to finance them. On the other hand, they are not nearly as expensive as a mortgage. The following table provides the total cost of interest relative to the principal cost (the amount borrowed), assuming monthly payments over different loan terms in years, and for two different compounded interest rates:

Total Cost of Interest Relative to Principal				
	Term of Loan			
Interest Rate	5 yrs	10 yrs	15 yrs	20 yrs
5%	13%	27%	42%	58%
7%	19%	39%	62%	86%

So, for example, if one purchases a $15,000 dollar system (say, after incentives are subtracted), and finances this amount with a 5% interest rate with 10 year loan, then the cost of interest relative to principal is 27%, so the total price one will ultimately pay, including interest, will be:

Total Cost = $15,000 + .27 x $15,000 = $19,050.

This is a substantial increase. ***The table also shows the value of keeping both the term of the loan and interest rate as low as possible:*** A five year loan is loan represents less than half of the total interest of a ten year loan.

Some communities in Vermont have designated themselves as "**Clean Energy Assessment Districts**", and are preparing to offer **PACE (Property Assessed Clean Energy) loans**. These loans will offer relatively low-interest rate loans, and enable borrowers to pay back the loans via their property tax. The latter means that the loan is essentially attached to the property, not the borrower, which will make it easier to automatically transfer the loan to subsequent owners (if any). To find out more about PACE loans, and whether you are eligible, visit www.veic.org/pace.

Step 4: Locate an Installer and Apply for the Rebates

The whole sequence of installing a system is therefore basically:

1. Find an installer and agree on a system size and design. See the website of Renewable Energy Vermont (www.revermont.org) for a list of Vermont installers. It is strongly recommend that you spend some time checking into a prospective installer. Ask to visit some of an installer's projects, and speak with the owners.

2. Work with the installer to develop a detailed design for your system, down to the specific components and their brands (this information will be needed for the next step).

3. Work with the installer to fill out the application forms for the Certificate of Public Good (needed for grid-tied PV systems) and then the state and federal rebates. Be sure to follow all of the associated rules for these applications, especially notification of adjacent property owners (needed for pole-mounted PV systems).

4. Place a down payment on your system. If a CPG is necessary for your project, you should be able to arrange terms such that your down payment will be refunded in the CPG is denied for some reason.

5. When and ***only when*** the permit and rebate reservation are issued, commence with the installation.

6. Complete the requirements for the rebate: The check will arrive in a month or so (hopefully).

7. Claim the solar tax credit on your federal tax form.

Step 4: Monitor and maintain your system

For PV systems, it is recommended that you monitor your systems performance by keeping a record of how many kilowatt hours the system has produced. This can usually be read from a small screen on the inverter, and many systems are installed with a utility grade meter on the output. Either means (or both) should be adequate. If read from the inverter, simply record the total number of kilowatt-hours produced on a regular basis, along with the date. If read from a meter, simply record the number displayed by the meter and the date. Later on the numbers associated with any two dates can be subtracted to determine the amount produced during the period between them.

Solar hot water systems can be tested from time to time in a simple manner: When you expect some clear, sunny days, simply shut down the back up heat source. You will learn quickly whether or not your system is functioning well.

Pressurized loop solar hot water systems will usually have a pressure gauge, and most have some kind of temperature gauge or measure. Keeping tabs on this can also help alert you to any problems.