

Solar Energy Analysis Tool User's Guide

General Information

Understanding what is provided

The guiding star for this effort was to create a free tool that would provide reasonably good, site-specific, solar savings information that a non-technically orientated home owner could use. In addition, since its creation was pro-bono, it could not become an unreasonable burden to build.

Understanding this intent should help calibrate expectations with respect to the plainness of the interface, and absence of input flexibility in some cases. Nevertheless, over 20 years experience went into its creation, and I intend to use it for my own home (which is already passive solar).

Understanding what is required

Although every effort has been made to make this tool easy to use, solar calculations have many variables, such as: latitude, declination from solar south, seasonal variations in clear-sky conditions, monthly variations in solar angles, glazed surface area, number of layers of glass, tree shading, re-radiation of heat through glass during times of non-solar gain and potentially, night-insulation. When fuel savings are added, one must include the heating and hot water systems' overall efficiencies, energy content of fuels and their cost. In short, a certain minimal number of questions have to be asked in order to obtain reasonably good, site-specific information.

Use Agreement

This tool is essentially share-ware. You are welcome to copy it as often as you like, and give it to friends, enemies and relatives. However, it is not public property; and it is an infringement of copyright (RCS Energy Services (c) 2007) to incorporate it into another program or use it commercially. A license is available for commercial (non-personal use) use. Lastly, although this tool is relatively thorough, and incorporates standard energy related algorithms, no warranties, neither expressed nor implied are provided.

This file is narrow so it can be viewed while using the tool.

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Data Input

The following are presented in the same order as the questions in the tool.

Clear Day Weather Data

The codes are indexed to weather tables and latitude data to refine calculations. The more clear days, and more direct the angle of the sun's rays, the more solar energy reaches the surface. The input is also indexed to *Degree Day* information which helps determine how much warmth will leave the space at night. This box must have a code.

Location Adjustments

The accuracy of results will diminish as one goes beyond the Massachusetts border. Results for areas of NY, CT, RI, NH and VT within 35 miles of MA should be reasonable (check which county in MA is closest). If you wish to use this tool for areas outside this range, please forward local or regional weather data including: seasonal sky cover data"; monthly solar heat gain data for a south facing vertical surface; and Degree Day data the resourcetechnology.org website. Once there, E-mail this information to "info." Adjustment factors will be estimated and forwarded as time allows. (This data really isn't that hard to get.)

Glazing (windows)

The codes are indexed to the insulating value of the windows (glazing), and their restriction to solar energy and heat loss. The more layers, the more insulation and impedance to the sun's rays. In order to keep data input easy while still meeting most needs, only one selection is allowed. If the space has both single and double paned windows, run the program once for each, then add the results.

The R value input for window coverings may require an introduction. The R value of a material is its ability to impede heat flow. The higher the R value, the less heat we lose. For example, the punky, fibrous, rigid insulation with the shiny, foiled surface has an R value ranging from 7.1 to 7.7 per inch of thickness.* Blue board has an R value around 4.5. Blanket type, inside insulations can also vary widely; ranging in R values from, say, 3 to 6 depending on composition.

Rigid panels can offer R values ranging from 4 to 7, but can be either more cumbersome to handle or mechanically challenging to install. Although blanket style, inside, window insulation can be the most expensive, and technically the least effective, their aesthetics and ease of use usually render them the system of choice. Also note that most of the savings come from the first few “R”s. The reason for this would take yet another paragraph to explain. It should not be difficult to obtain the specific R value of a system once it has been selected, either by asking the seller or by checking the manufacturers literature. Heat loss calculations include evening and cloudy day losses.

*This type of insulation should not be used indoors.

Shade-Free Area Factor for Walls

This question is important and requires some thought. You are asked to estimate how much of a surface is exposed to direct sunlight.. You don’t have to supply information about all windows and walls, only those which pertain to your solar project. In many cases you’ll have to average across many windows. That’s OK, just do your best, but remember, the analysis you get can only be as good as the information provided. As a very course rule of thumb, a single deciduas (leafy) tree will let about twice as much solar energy through in the winter as summer.

It is important to remember that you are inputting a decimal value that represents the part of the surface exposed to the sun, not the amount shaded!

Example of data input:

	East
November - April	1
May & October	.9
June - September	.7

The box at the left indicates that the East facing windows have full sun from Nov. through Apr, 90% for May and Oct., and, 70% from Jun. through Sep.

Surface Area

This applies to the total square footage of glass facing a given direction. For example, if you have 8 south facing windows that are six square feet each, you would enter “48” in the box under the word “South.” Any data entry in this table should have information in the previous table (Shade-Free Area Factor for Walls) for windows facing the same direction.

For example, if you input “48” under “South” in this table, then the “**Shade-Free Area Factor for Walls**” table should have shade-free data under “South” as well.

To convert from square inches to square feet: If necessary, measure the dimensions in inches, multiply the width times the height, then divide that answer (product) by 144 to get square feet. There are 144 square inches in a square foot.

Space Heating Information

Enter the temperature you would ordinarily heat the space between 3:00 P.M. and 9:00 A.M. during the heating season. This information is used to calculate heat loss through glass during periods with little or no solar gain. It is also used for night-time window insulation calculations.

Take a moment to look over the Heating Systems section; information entered here effects fuel use and CO₂ savings. Most should know what type of heating system they have, and what fuel provides space heat (see Heating System Codes and Fuel Codes on the data input screen).

“Heating System 1 and Heating System 2.”

Enter the “*Heating System Codes*” and “*Fuel Codes*” as indicated on the screen. If you only have one heating system, then only enter data for the system on the left (Heating System 1).

“Enter the contribution of each here”

If you only have one system, enter 1 in the left column. If more than one, enter a best-guess contribution, in terms of heat provided by (not cost of fuel of), each system. The value must be entered as a decimal. For example, 60% would be expressed as 0.6.

“Enter fuel cost per unit here”

What does it cost, in dollars and cents, for each unit of fuel you buy. For example, \$2.00 per gallon of heating oil, or, \$0.168 per kilowatt hour (kWh) of electricity (take care to omit transmission charges when calculating electric fuel costs).

Building a Greenhouse

If you wish a greenhouse analysis, you should only input data that directly relates to the greenhouse (in other words, leave out (or delete) information about the rest of the building). **IMPORTANT** - If you enter a "1" in this box, it will tilt all south-facing glass to 60 degrees from horizontal (as opposed to 90 for a standard wall). Thus the space will get more solar gain. It is assumed the greenhouse will be within 25 degrees of solar south. *Solar south, in Leverett, is about 13 degrees west of magnetic (compass) south.* Greenhouse wall savings will appear under "Windows and the like" in the "Results". If the greenhouse will have a 35 to 45 degree roof, include that data in the next section. Again, a greenhouse must be run as it's own structure; the results may not be as accurate as for a heated building.

Using Your Roof to Capture Solar Energy

Put a "1" in the box at the right if you wish to utilize roof solar energy for: space heating, hot water and/or solar cells (photovoltaics).

Enter the "Shade-Free Area" data for the roof as described in "**Shade-Free Area Factor for Walls**" above.

Enter the *Roof Area Declination from Solar South*.

At 25 degrees off solar south, 91% of the sun's heat rays can still be captured; at 30 degrees it drops to 85%; by 45 degrees it's down to 71%. The Savings potential drops off rapidly after 45 degrees. You will either need a magnetic compass, or accurate house plot plan, to determine solar south. *Solar south, in Leverett, is about 13 degrees west of magnetic (compass) south.*

Input the code number that represents the declination (variance) of your roof from solar south. For example, if it's 21 to 25 degrees, enter code number "2". As indicated above, you will be able to get the vast majority of the available energy until the declination exceeds about 38%. Nevertheless, as the declination increases, exposure time, as well as efficiency, decrease. The cost-effectiveness of building at greater declinations may increase with the cost of fuel; but, construction costs may increase as well.

Direct Space Heating

Enter the square footage for Southerly facing roof glazing. This is for direct gain for space heating; ie. the upstairs bedroom of a cape.

Enter the distance in feet from the floor to the bottom of the window. Do not enter a number smaller than "3". The air around high windows, skylights and the like is warmer than air at shoulder level; so night-time heat-loss will be greater for high windows.

Solar Hot Water

Enter the total square footage for Southerly facing panels. Multiply the number of panels times their size in square feet (144 inches in a square foot). Enter the answer in the box as directed.

Enter the code number that best matches your current hot water heating system. Look at the table, then enter the number that best describes what heats your domestic hot water.

Enter the per-unit fuel cost to heat hot water. How much do you pay per gallon, CCF or kWh to heat domestic hot water? For example, if propane, enter the cost of one gallon of propane.

Photovoltaics / Solar Cells

This program assumes the installation of standard silicon wafers to generate electric current, and an inverter to convert it to AC (Alternating Current). The conversion of solar energy to electricity is assumed to be around 7% efficient with this technology, while its conversion to AC is assumed to be around 90% efficient. If you know the collection and conversion efficiencies of the proposed equipment, multiply them together (for example 0.07 for wafers X 0.9 for inverter = 0.063) then enter the product where indicated. If you do not know, leave blank and the program will use a default.

Enter the total square footage for Southerly facing panels. Multiply the number of panels times their size in square feet (144 inches in a square foot). Enter the answer in the box indicated.

Enter the per-kWh cost of electricity. As of July 2007, if you live in Leverett, it's about \$0.17 per kWh. This value can be obtained from your electric bill; it's called the "energy charge". Take care to omit transmission charges when calculating electric fuel costs.

The last data box () is only to be used if you have specific information about the component energy performances of the proposed system. If you do, multiply the conversion efficiency times the inverter efficiency. If you will use DC directly, you don't need to include the inverter, but you may need to account for battery losses and energy loss over wires.*

Results & Other Information

What the Results Mean

Understanding the Results

Accurately estimating solar heat savings in dwellings is tricky at best. The straight forward part is presented in the "Results"; where the amount of solar energy entering the space is converted to units of heat called "BTUs" (British Thermal Units, for those who have to know). This value is indexed to the fuel energy content and heating system inefficiencies to provide savings (ie. 200 gallons of propane and \$400). **That is exactly, and only, what the space heating results mean.**

To explain further: If the sun heats the space to 80 degrees F, and the results say you would save 200 gallons of propane, are you really saving that much if you would have only heated the space to 68F? Obviously not, some of that "extra heat" is being lost through the windows, roof and walls; and some is lost through infiltration. The greater the difference the temperature, the greater the heat loss.

Nevertheless, it's not a totally wasted. Much of the "extra heat" is absorbed by floors, walls, furniture and the like; and will be re-radiated after sun-down. All this can be determined mathematically, but the amount of data entry and calculating required would be considerable. The easy solution is this rule of

thumb: the south facing glass (for walls) should not exceed 12 percent of the floor space unless thermal storage will be used. There are books covering this topic; my favorite is “The Passive Solar Energy Book” by Edward Mazria. Solar hot water and solar-cell (photovoltaics) estimates are more true-to-life since these sorts of issues are far less pronounced.

What does “heat loss” mean

Here heat loss means, the energy lost through the glass between 3:00 P.M. and 9:00 A.M. during the heating season; and, heat loss during estimated cloud cover (including precipitation). If you entered a value in the box “*Enter R value here*” for window coverings. That number has been included in the heat loss calculations. Do not include an R value for air films, the program does that automatically.

Wood heat and CO2 production

*** Many consider CO2 production via wood-burning stoves environmentally neutral. However, in the short-term, it contributes to atmospheric CO2 levels the same way as fossil fuels. There are many pluses and minuses to burning wood for heat, most of which go beyond this tool.