

# Evaluating Solar Power

Department of Process Engineering

By: Christian Marshall

*Abstract - Solar energy can be a source of sustainable, low-carbon, renewable energy. Two common methods of capturing solar power are solar water heaters and photovoltaic cells. Solar water heaters convert solar energy into thermal energy in the form of hot water. Photovoltaic cells convert solar radiation into electricity by using the potential difference across a specialized cell. How to choose a method, the advantages and disadvantages of each method, and a first pass economic evaluation will be discussed in this Engineering Bulletin.*

## I. Solar Water Heaters or Photovoltaic Cells

The choice between solar energy collection methods is largely dependent upon what form of energy is desired. For most facilities, it is a question of the energy consumption pattern. An ideal energy consumption will have a continuous draw during sunlight hours. Examples of good electric demand include significant lighting or HVAC, frozen/refrigerated warehousing, continually operating process equipment, and electric boilers. Examples of good thermal demand include continuous process steam and hot process water loads. Most retail or office buildings will not have a sufficient thermal demand (aside from certain seasonal patterns), and need only consider photovoltaic cells.

## II. Solar Water Heaters

Solar water heaters produce a continuous stream of hot or pre-heated water. The lower the temperature of the water produced, the more energy collected due to higher efficiencies. Most solar water heaters are designed to generate temperatures of 120°F, which balances energy efficiency with usable temperatures.

Solar water heater systems may be operated by natural convection or forced circulation. Natural convection systems are less capital intensive and are most common in private residences. Forced circulation systems use pumps to circulate water through the panels, and generally include a basic control system to regulate temperature. Most production facilities use

forced circulation due to higher energy outputs and the availability of maintenance personnel. A system will typically include a hot water tank for surge capacity. This surge capacity allows some flexibility for uneven usage, and the size is balanced against capital expense.

## III. Photovoltaic Cells

Photovoltaic cells are grouped together in modules, which are commonly referred to as panels. Solar panels produce direct current when exposed to sunlight. As an example, for a two-story retail or office building in Florida, photovoltaic panels covering one-fourth of their rooftop may be able to fully power their lighting needs on an average sunny day.

A standard photovoltaic system will include an inverter (to convert DC to AC), batteries, and connection wiring and systems may be used for on-grid or off-grid power. On-grid power produces electricity that is sold and transferred to the electric company which handles all downstream transactions. On-grid producers are generally “credited” for energy produced, and a common contract terminology is “buy all/sell all.” A facility producing on-grid power is being supplied power from the grid, and as such, has uninterrupted power supply regardless of the solar panel operation.

Off-grid power produces electricity that is consumed exclusively onsite. Any power produced which is not immediately used or stored in batteries is lost. Off-grid power has the advantage of directly replacing electricity that would have been purchased, generally at peak rates. However, peak power availability during solar non-production (e.g., cloudy days) may be provided from the local grid at a premium. If the power company must maintain the capacity to produce and deliver power which is typically not consumed, it may charge a usage premium or add a monthly “availability surcharge.” This cost may be avoided if the solar power in question is a small fraction of total usage, or if electric usage is reduced when the solar panels are not

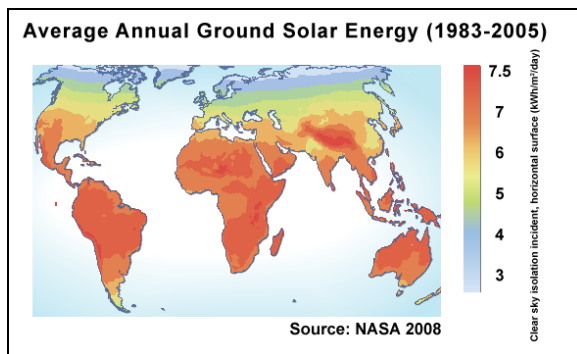


operating. The fees charged may be negotiated as part of a contract with the local utility.

#### IV. First Pass Economic Evaluation

Evaluation of solar collection will vary with the goal desired. In terms of economic payback, certain conditions help optimize results. First pass critical conditions include availability of ground level sunlight and usage of energy during sunlight hours. If these two conditions are met, a detailed economic evaluation should be performed. The exception to these conditions is an "On-Grid" photovoltaic system. Since electricity produced is purchased by the local electric company, the onsite electricity consumption patterns are immaterial.

Ground-level sunlight is a direct contributor to economic feasibility. The historical availability of ground-level sunlight by region is seen in the below graphic "Average Annual Ground Solar Energy." This graphic indicates the average amount of solar energy that will hit ground level. A linear relationship exists between ground solar energy received and energy available, such that a system receiving an average of 6 kWh/m<sup>2</sup>/day will produce 50% more energy than an identical system receiving an average 4 kWh/m<sup>2</sup>/day.



In comparison, the efficiency of energy captured per unit area varies widely between systems. The available rooftop square footage combined with the system efficiency will be a potential limitation on total energy produced. Another example, an average large food processor in Florida may find that up to 10% of their electricity consumption could be replaced with energy from solar panels that cover one-third of their rooftop. Yet for most facilities, the critical number is the ratio of energy produced to installed cost, not efficiency per square foot. A low-efficiency system will capture less energy

than a highly efficient system but may cost substantially less. If the installed costs are favorable, the system with a lower per foot efficiency may be the more economical choice. The lower energy production would, however, decrease the total amount of "green" energy produced.

The second critical parameter is steady energy usage during peak sunlight hours. Although this parameter is less important for a photovoltaic cell that produces "On-Grid" power, it is vital for all other users. A solar collection system that requires "surge" capacity for uneven usage, whether batteries or hot water tanks, requires significantly more capital cost. If energy usage is uneven, sporadic, or does not occur during daylight hours, the cost of an energy storage system creates a significant barrier to economic justification.

If the two initial conditions are favorable, a detailed economic evaluation can be performed. A detailed analysis will start by determining the amount of energy that can be readily consumed by the facility. The energy consumption will be correlated to an average annualized energy consumption and reduced by a factor to allow for variation in energy production. The average annualized energy consumption will determine the maximum size and associated cost of a proposed solar energy system. The average annualized energy of the system will be correlated to the cost of the energy replaced and compared to the overall installed cost.

Solar collection systems are difficult to justify with traditional financial expectations, in which simple payback may be expected within or less than two to three years. Simple payback periods for solar typically range from eight to 20 years, with the shorter paybacks occurring when facilities are receiving an average six kWh/m<sup>2</sup>/day and have energy expenses over 8.5 cents per kWh or \$14 per Decatherm. Payback is further complicated by the fact that less expensive solar systems may require substantial capital repairs within 10 years. Despite this, many companies have implemented solar collection units justified at least partially with sales/marketing value, a hedge against rising energy costs, or for the future value of carbon credits.

## V. About Carbon Credits

Implementing sustainable systems such as solar power (wind, hydro and biofuels are other types of so-called “clean energy”) enable companies to earn Carbon Offset Credits (COCs) or “green” credits, which allow them to lessen the impact of their overall carbon emissions. However, several issues currently exist with these credits:

- The credit for energy produced may be less than what is being charged for energy usage, or may include a premium as a “green” energy source.
- The “owner” (e.g., the company or the electric company) of any carbon credits or green energy initiatives must also be negotiated along with the contract when building a solar power system.

At this time, the system to validate and sell carbon credits or “green” energy in the United States is not consistent throughout the country and lacks regulation, and therefore, the associated credibility regulation can bring. Although potential legislation, such as the proposed greenhouse gas “Cap and Trade,” may create a value for carbon credits in the future, today it is difficult to quantify a value

## References

1. NASA 2008. Average Annual Ground Solar Energy.

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