Solar Power Generation: Boon or Boondoggle

Polls consistently show that Americans think well of obtaining electrical power from the sun. It's free, and there's so much of it. All we have to do is capture a tiny fraction of what falls on Earth, and our energy needs are met. Or so the story goes.

While there is a good bit of truth in the story regarding solar power, we find, as usual, that the devil keeps getting into those details. We might question why — in light of solid public support, years of subsidized development, dozens of taxpayer-financed pilot plants, media hype, and political grandstanding — solar electricity only increased from an invisible 0.014 percent of the electricity generation in the United States to an unnoticeable 0.021 percent over the period 1998 to 2008, the last figures available.

In considering those devilish details, let us first look at the two basic methods of converting sunlight to electricity, examine a few examples of existing and proposed generating plants, and then attempt to evaluate whether this is a wise star for us to be hanging our energy hat on.

Thermal Generation

Obviously even the hottest tropical sun won't boil water, so all solar thermal generators are based on *concentrated solar thermal* (CST) generation, which is exactly what the name implies: concentrating light to produce heat. As children, many of us were fascinated by how a magnifying glass could burn a hole in a leaf, giving us our first experience with CST. Current CST power generation operates on that same principle, although mirrors are used instead of a magnifying glass.

The most common CST method is known as a *trough*. It gets its name from the parabolic shape of the solar collector — it is a lengthy, rounded trough made of mirrors that focus the sunlight on a blackened metal tube, which is located at the focal point of the parabola, through which special oil (usually Therminol) is pumped. A heat exchanger transfers heat from the 700oF oil to water, producing steam to drive a turbine generator, just as in a fossil-fuel or nuclear plant.

Troughs are oriented north to south so that a servo can rotate them to follow the sun during the day. The efficiency of the system is the product of the optical efficiency (percent of incident sunlight captured) times the thermal efficiency (percent of solar radiation absorbed by the receiving tube), times the thermodynamic efficiency of the Rankine cycle generator. Howard Hayden in his book *The Solar Fraud* estimates these as 71 to 80 percent, 35 to 50 percent, and 35 percent respectively. Thus the efficiency of producing electricity from solar energy is approximately 10 percent.

The peak insolation (solar energy striking a surface — in this case, Earth) used for calculating peak power outputs from solar power is considered to be 1,000 watts per square meter. (This number represents a theoretical insolation; it cannot actually be found on Earth.) From this we see it takes about 1,000 square meters (10,000 square feet) of mirrors to produce one megawatt of electrical energy. A 100 MW solar power plant (one-tenth the capacity of a typical nuclear plant) using mirrors that are 10-feet “tall” would then require 100,000 linear feet of parabolic trough — just shy of 19 miles.

The materials required for such a facility are awesome. Not just the mirrors, but the plumbing, wiring, hundreds of tons of structural materials, and thousands of tons of concrete foundations. The late Petr Beckmann calculated that a solar plant would not be able over its lifetime to produce enough energy to build another solar plant of comparable size.

Maintenance is another problem, according to the aforementioned Dr. Hayden, who notes that to maintain system efficiency the mirrors (a million square feet in the example above) must be washed every five to 10 days, and pressure washed about 25 times per year — a problem exacerbated by usually being located in the desert where water is not exactly gushing from the ground.

A second method of CST generation is generally known as a *tower*. Here, a number of mirrors (heliostats) are focused on a “receiver” that absorbs the energy and transfers it to some heat-transfer medium such as Therminol. Using molten salt is under consideration as a heat-transfer medium because its high specific heat would allow the plant to ride through short periods (up to a few hours) of intermittent cloudiness without having to shut down the generators.

An early (1981) pilot project of the tower design was Solar One, unfortunately destroyed in 1986 when 240,000 gallons of Therminol caught fire. It was rebuilt as Solar Two in 1995 and claims to produce a peak of 10 megawatts of electricity from its 130 acres of mirrors. With a capacity factor of 0.16, however, it converts solar energy into an average of 1.6 megawatts.* To produce the same power as a 1,000 MW nuclear plant, the solar facility would need some 127 square miles of mirrors.

Photovoltaic Conversion

With CST generation a large part of the solar energy is lost in the process of driving a turbine generator. Photovoltaic (PV) cells don’t require mechanical generation, but instead convert sunlight directly into electricity.

Most PV cells are made from crystalline silicon and “doped” with small amounts of impurities that change the characteristic of silicon from an insulator to a “semiconductor.” When photons of sunlight having a certain range of energies strike atoms of the impurities, electrons are jarred loose and flow through “holes” in the silicon. These electrons are brought by metallic leads to terminals where they are sent into the world to operate a calculator, light your sidewalk, or serve many other purposes.

The amount of current and voltage (the product being power) produced by a single cell is very small, so the cells are connected in series with the voltages being additive. These are pre-connected with a few protective electronic components and mounted in a frame, thus becoming “solar panels.” We see these sold online and elsewhere for rooftop installation. Many sales pitches of them are so obviously a scam as to embarrass a Nigerian banker: “Buy our $40 manual and for only $200 you can buy the parts at your hardware store to build a solar power panel that will cut your electricity bill in half!” Others are honest on technical grounds concerning hardware, but tend to overstate the resultant system performance and understate the difficulty in putting the pieces together.

Typical of a high-quality device is the BP Solar 3220 N module, which produces a maximum of 220 watts of electrical power when the sun is directly overhead so that the sunlight strikes the solar cells perpendicularly, with insolation of approximately 950 watts/square meter or 95 watts/square foot. The panel is 65″ x 39″ (18 square feet) and can be bought online for $632.

While there is little doubt that BP's information is correct, one should realize that only in the tropics, on a clear day, at noon do we ever see such high values of solar energy. Moreover, a momentary, location-specific, instantaneous power value (220 watts in this case) is of little importance, as we are looking for the energy produced over a day (watt-hours or kilowatt-hours) at the location where the panel will be installed.

The electrical output of this panel is very sensitive to location, season, orientation of the panel, cleanliness, and other factors. For Albuquerque the yearly average insolation is 240 w/m2; that reduces the output of this panel from 220 watts to 55.6 watts. Over 24 hours the panel would produce 1,334 watt-hours of electricity or 1.334 kilowatt-hours (kWh), worth about 13 cents. Unless the panel is on a tracking device to seek the sun, and unless it is kept extremely clean, the output would likely be at or below one kWh/day, resulting in a *capacity factor* of 18 percent. The average household electricity usage in the United States is over 900 kWh/month or 30 kWh/day. Thus 30 of these panels would be required for the average household.

Since the output of PV cells is direct current (DC), batteries can be used for storing the power until it's needed. Some 60 car batteries or 30 "deep discharge" batteries would be required to store a day's energy. That's the good news. The bad news is that DC can't be used in household appliances. Incandescent lights can be powered on either AC or DC, but not the soon-to-be-required fluorescent bulbs. Consequently, not only must there be a DC regulator, but also an electronic inverter to convert the DC power to usable AC. If you're serious about "sticking it to the utility," then your inverter must be synchronized with the power line and have safety features to prevent endangering utility workers.

As we move up to a full-scale solar plant, most of the same problems apply, although servo motors will definitely be used to follow the sun. Florida Power and Light's recently opened Desoto plant — billed as the largest solar photovoltaic plant in the country — is rated at 25 MW peak. The company has estimated the power produced over a yearly period to be 42,000 MW hours. Those who know there are 8,760 hours in a year and can do long division can quickly figure out that electrical energy coming forth from the plant averages 4.79 MW. Hmm, they advertise 25 MW, not mentioning that the plant has a 19-percent capacity factor. Moreover, they also conveniently forget that, unlike the home system that can store the electricity in semi-convenient batteries, this power cannot be stored for when it's needed, and because of the vagaries of the weather (it could get cloudy at any time, effectively turning off the power), other *non-solar* power plants must always be kept running to back up the solar plant, which means that the solar plant does not replace any standard power plant. Because the conventional plants must be kept online, ready at a moment's notice to take the solar load, backup plants are called "spinning reserves."

The PR hoopla also tells us that Desoto will power 3,000 homes. How is this calculated? The Energy Information Agency statistics show the average Florida household (2.5 persons) uses about 15,000 kWh of electricity per year. Desoto's output is 42,000 MWh per year, divided by 15,000 kWh equals 2,800 households, a reasonably close approximation. But how many households will Desoto really power? Unless you're talking about electrical service in Third World countries where power is only on a few hours in the afternoon — zero. The PV solar panels start producing minimum power an hour or two after sunrise, produce their highest output through the late morning and early afternoon (provided no clouds, haze, thunderstorms, etc.), and start dropping off rapidly a few hours before sunset. The 3,000 homes will actually receive their power from reliable, non-intermittent sources — with a bit of icing from the solar plant. And it is very expensive icing.

Florida Power and Light's figures show this plant cost *someone* $150,000,000. On capital projects such as this, stockholders should be investing money to build the plant, selling the electricity, depreciating their investment, and making an honest profit, owing to the fact that they risked their capital to build the plant. Unknown deals and subsidies make details of financing this plant an unknown quantity. But let us assume that investors put up $50,000 for each of the 3,000 households (equaling the $150 million cost to build the plant), and they expect to have it paid back at (say) six-percent interest over the expected 25-year life of the plant.

Ignoring the operating costs — and cleaning 90,500 mirrors on a regular basis is not like picking up the bathroom when you leave — just the amortization of the capital cost for each householder would be $322 per month and would be on that line that says "Base Bill" or "Customer Charge." Electricity would cost extra.

Who's Driving This Solarmobile?

Knowing the preceding truths about how solar power plants are rated, how much power they actually generate, and how they must be backed up with spinning reserves, what should we infer about the following?

• In 2008, California's largest utility, Pacific Gas and Electric (PG&E), announced it was buying all the power from the proposed 250 MW California Solar Ranch. (The owner of the "Ranch" is Sunpower. Don't you bet they were surprised when they got the order?)

• In New Mexico, Southwestern Public Service Company (a subsidiary of Xcel Energy) announced in December that it was buying 50 MW of solar power from SunEdison.

• Tampa Electric Company received approval from the Florida Public Service Commission for a 25-year contract to buy solar power from Energy 5.0's proposed 25 MW plant.

• On February 21, APS (Arizona's largest electric utility) announced plans to build the Solana Generation Station — a 280-megawatt concentrating solar power plant. APS will be buying 100 percent of the power produced by Solana.

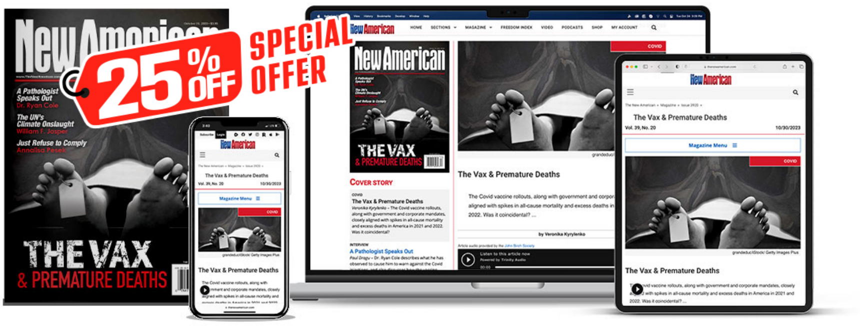
Are the above utilities eager to buy "solar electricity" because it is so reliable or such a bargain? Consider that the Palo Verde nuclear plant just outside Phoenix generates 4,200 MW of power day and night, rain or shine, and then ask why APS would want to buy an average of 53 MW from a solar plant. Cheaper? Well, no. Nuclear power is 1.65 cents per kWh, and the contract with Solana is for 14 cents, almost 10 times higher — when the sun shines and the power is available. Could it be that the Arizona Corporation Commission's mandate that the state's regulated utilities provide 15 percent of their electricity from renewable energy sources by 2025 has something to do with the decision to spend *$1 billion* on a plant that is a wasteful use of ratepayers' money?

California, New Mexico, Florida, and Arizona are just a few of the states forcing the owners and ratepayers of utilities to buy expensive "part-time" power that destabilizes the electrical grid while not replacing a single kW of conventional power generation. Such mandates take resources from those who would be productive and give them to those who produce an unwanted or unnecessary product, leading to unemployment for many. Green jobs destroy twice their number of productive jobs, as we have learned from Spanish studies about that country's green-energy nightmare.

It is time that government got out of the power-generation business and allowed market forces to maximize our access to energy. And those miles of parabolic troughs… should make some really great water slides.

* The capacity factor of a power plant or other energy producer is defined as the percentage of power actually generated over a year when compared to the power that would have been generated if the plant had been operating continuously at 100 percent capacity over the year.

— Photo by Randy Montoya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