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Debunking Solar Power Myths:

Misconceptions About Solar System Metrics Could Hamper Solar Success

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In response to Ontario's very favorable feed-in tariff, there's been a "gold rush" of companies hopping onto the solar bandwagon. For a company such as Hybridyne, which supplies hardware to this industry, there is a concern that the investors paying for these new solar installations might find themselves disappointed with the low yield they could experience. Such disappointment is a potential threat to the solar industry as it may lead to unfavorable publicity or possible lawsuits, which could discourage future adoption of solar technology.

At the core of this problem are several widely held misconceptions about the yield of photovoltaic (PV) systems. These beliefs concern both the metrics used to measure yield and some of the factors that influence yield. In this discussion, yield is defined as the number of kilowatt-hours delivered per year by a solar array and thus the potential number of dollars to be earned by the customer under a power purchase agreement (PPA).

To ensure the financial success of solar power installations, a clear understanding of the concepts and metrics relating to yield must be understood by those involved with the development, installation, and purchase of these systems. On the customer end, that includes investors, while on the development side it encompasses engineers responsible for subsystem components such as power inverters.

There are five particular myths concerning yield that I will try to debunk here. These concern metrics for solar array cost, how solar arrays should be amortized, efficiency versus efficacy, proper positioning of solar panels, and array mounting techniques.

One of the key issues that will be considered is the impact of a "less than perfect" solar environment like that found in the northern and eastern United States and most of Canada. It can be argued that there are more places on the globe with marginal solar conditions than places where solar works perfectly. Overlooking this consideration can lead to sub-optimum yields for solar power installations.

Myth One: The Key Metric For Solar Array Cost Is "Dollars Per Watt"

Most domestic investors don't understand (yet) that there are fairly large differences in the productivity of solar arrays. Therefore, it is easy to sell them the concept that "our array is the same nameplate size as that other possibly more expensive one, but it's cheaper, so it's better."

This "dollars per watt" mentality sometimes works well in jurisdictions where government incentives (which are based on so much per installed nameplate watt) make the system's production after start-up less important. But if the investor is expecting to experience a financial return based on the quantity of electricity produced, then the overall productivity of the array is paramount.

To illustrate, let's imagine two similar arrays of the same nameplate size (for example, 250 kW.) We'll call them array A and array B.

Let's say that array A is 20% cheaper. Many will conclude that clearly this is the winner since it saves hundreds of thousands of dollars at the time of purchase. Therefore, return on investment (ROI) is higher. Yahoo!

But let's also assume that array B, the "expensive" one, produces 10% more electricity per year because it has a higher Capacity Factor. (The term Capacity Factor refers to the array's ability to generate power over a wider range of operating conditions. For more on Capacity Factor, see reference 1.) Then, two questions arise: How many years will it take to recover the apparently higher cost of the array? And how much difference will that extra 10% of annual production make to the owner over the lifetime of the array?

The answers will depend on the purchase rate of the electricity, which is always in dollars per kilowatt-hour (kWh). But keep in mind the long potential lifespan of the array: a well-built array with high-end componentry will easily generate electricity for 30 to 40 years (see the discussion on myth two below.)

Conclusion: The metric by which arrays should be measured and compared is dollars of investment per kilowatt-hour produced over the useable lifetime of the array.

Myth Two: Solar Arrays Should Be Amortized Over The Length Of The First PPA

In terms of investment, the solar array is typically defined as the complete solar generating facility, including the land/roof, panels, racking, and electronics. When financing solar arrays, the common practice appears to be one of amortizing the project only over the length of the first power purchase agreement (PPA), which is usually 20 years. This seems to presuppose that the array loses all value at the end of the PPA. We don't think that's true for several reasons.

If the jurisdiction that is offering the PPA needs the electricity now, isn't it reasonable to assume they will still need it 21 years from now? Aren't they likely to offer another PPA? Who thinks the cost to generate—and therefore the retail price—of electricity is actually decreasing? Even if the PPA rate decreases, the array will have long since paid for itself and will continue to earn income at whatever PPA rate is then available.

Most solar panels are guaranteed for 25 years. Will they suddenly disintegrate after that or is it more likely that they will keep generating for many years thereafter, even if at a degraded rate? A decent solar panel should generate electricity for at least 30 to 40 years.

How long will the inverter last? Reputable companies offer 10- to 20-year warranties, and even after that the electronics should work well. To relate this to an older industry, compare solid-state solar inverters to solid-state uninterruptable power supplies (UPSs) developed for datacenters.

The electronics and componentry of both devices are very similar. In fact, some are made by the same people in the same plants. There are currently many UPSs still in service after 30 to 35 years. Two of the major factors in the life of the inverter are maintenance and its operating environment. These are very much overlooked elements in the cost of operation, and are both preventative measures against premature inverter failure.

Conclusion: It is entirely technically reasonable to amortize the financing of a well-engineered solar array over 30 to 40 years, not just 20.

Myth Three: The Important Metric In PV Power Electronics Is "Efficiency"

Efficiency is a measure of the energy lost by any device, compared to the energy passed through or provided to the load. In the case of power electronics, efficiency is the measure of electricity lost as heat. While important, efficiency is not as critical as *efficacy*, which is defined as how well or effectively the machine does its job with *all* of the available energy presented to it.

Well, aren't efficiency and efficacy the same thing?

No! Efficiency measures losses—efficacy measures yield. Efficiency only comes into play when the inverter is actually running. Efficacy is measured over the whole conversion cycle over the whole year. An inverter that is "on" longer and more often during the year will potentially generate more electricity. Therefore. its efficacy will be higher. For an in-depth discussion, please see reference 2.

To illustrate the difference, the graph below shows the output of a typical array on a typical day—during which the sun is occasionally obscured by clouds (insolation vs. illumination.) For most areas outside any "sun belt" region, many days throughout the year will show this less-than-perfect illumination.

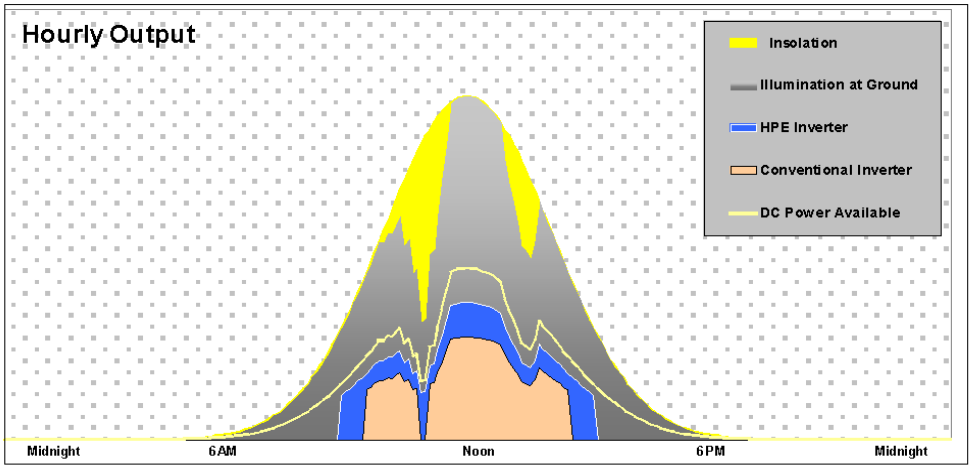

Figure. Electricity production as a function of time, solar irradiation levels, and inverter performance.

- The main body of the graph in yellow shows the sun's irradiation, unimpeded by ground-based weather.
- The gray area shows the illumination at the ground, after occlusion by typical weather.
- The pale yellow line shows how much dc power is generated by the PV panels from the illumination available at the ground.
- The pink area shows the total kilowatt-hours generated by a conventional inverter with standard efficacy. Notice that even though the PV panels are generating dc energy, the inverter power output does not truly follow that potential-power line. The inverter turns on later in the day, turns off earlier in the afternoon, and often turns off when the clouds pass over.
- The larger blue area represents the total kilowatt-hours generated by an enhanced inverter with higher efficacy. It turns on sooner, stays on later, and still generates some electricity even under the cloud cover.

Simply put, a high-efficacy inverter like the enhanced inverter referenced in the graph will be "on and running" more of the time. It will "wake up" earlier in the morning as the illumination increases, will stay on later in the day as the illumination decreases, and will stay on longer when a cloud passes over. In addition, a high-efficacy inverter will stay on more days in the fall, winter, and spring when the days are shorter and illumination is decreased.

Clearly, the longer an inverter is converting power, the more power it will generate, and the higher the annual yield of the complete PV system. We have documented head-to-head comparisons where the enhanced inverter generates 30% more per year than a conventional inverter on an identical array. For a discussion of how enhanced inverters work, see reference 3.

It should be noted that there is an established way to measure efficacy of an entire PV system whereby efficacy is expressed as "kilowatt-hours per year, per dc installed kilowatt." This figure is often provided by "prediction" software like PVWatts and RETScreen.

The problem, of course, is that this software does not take into consideration the possibility of an enhanced inverter that will turn on and stay on at lower voltages. Thus, the maximum "acceptable" efficacy (in Ontario) is often believed to be about 1000 to 1100 kWh per year per dc installed watt. However, we have several arrays running in which the efficacy is often greater than 1300 to 1400 kWh per year per dc installed watt.

Conclusion: If you care about how much money the array earns, pick an inverter with high efficiency, but more importantly, one with higher efficacy.

Myth Four: Aim The Panels High (Low Tilt Angle) To Capture The Summer Sun.

One practice which seems logical but which is inimical to yield is to aim the panels high to optimize the capture of energy during the summer when the sun path is higher in the sky.

Our contention is that this practice wastes yield over the total year for the following reasons:

- The farther you are from the equator, the shorter the summer is. At the latitude of the northern states or southern Canada, true summer is only about three months long.

- Summer can be one of the worst times for PV solar energy production. Check the specifications of your solar panels—their performance decreases by 0.35% to 0.55% for each additional degree of ambient temperature above 25°C. Worse still, some panels perform even more poorly than their specifications detail under these circumstances. On hot summer days, PV panels are generating much less energy than on cool spring or autumn days with similar irradiation.

- If the PV system produces up to 30% less energy due to the panel's temperature coefficient on hot summer days, and then over-produces by as much as 20% on cool days, that means there is a delta of up to 50% in instantaneous energy production on a hot day versus a cold day under the same irradiation.

- Many PV arrays do not generate sufficient dc voltage on hot days to 'turn on' conventional inverters.

Instead of aiming the panels high, consider aligning the panels to optimize the annual yield with an eye to the effects of the ambient temperature. The normal recommendation is an angle equal to the latitude. Then, an enhanced inverter can capture energy effectively all year long, and even a conventional inverter will perform better in these situations.

We have found and continue to observe that the best time to generate PV power from commercially available PV panels is spring and fall. Cool but still relatively long days with bright sunshine mean the panels are operating well, and an enhanced inverter can gather the energy for long periods since there are many more fall, winter, and spring days than summer days.

We have even shown that short snowy northern winter days will still provide energy if the PV panels are correctly aligned and coupled to an enhanced inverter. See reference 4 for a discussion of snow on PV panels.

Conclusion: Angle the panels correctly and optimize electricity generation all year long to earn more annual yield.

Myth Five: On Rooftops, It Is Better To Ballast PV Arrays Than To Mount With Perforations

Because building owners are understandably sensitive to "holes in the roof", many PV installers and many racking manufacturers focus on this and suggest 'ballasted' and self-ballasted systems. Such systems sit directly on the roof surface, in a variety of ways, and it's claimed that these systems do not perforate the roof surface.

This approach is typically a very inexpensive way of installing PV on a roof. Proponents of this belief will argue to keep capital cost low and keep panel angles low (thus sacrificing yield as discussed above) on the basis that high angles increase load on the building and are expensive. They will further argue that a perforation to connect to the building may cause roof leaks.

The reality is that once a building owner drills down through the rhetoric, they will find that most systems, (ballasted or self ballasted) *do* require additional anchoring or roof perforations. Granted these may be comparatively few, but perforations are required just the same. Certainly, it seems that any system with a panel tilt angle in excess of 20 degrees will require anchors (perforations).

Let's examine the real issues with building loading. To be sure, many buildings are not built and designed to support the dead weight load or the wind loading occasioned by a PV array. At Hybridyne, we never install (or even quote) an array on a rooftop until the building has been examined by a civil engineering firm. But even if the building is strong enough, what about the roof itself?

Please remember that the top of a building is two separate things:

- The upper structure (usually steel girders) that holds the building together.

- The roof surface that waterproofs the building. The roof surface is almost never designed to support any extra weight beyond the expected loading due to snow and/or rain.

The engineering surveys for new buildings at 40-degree plus latitudes almost always reveal that the roof surface cannot support much additional dead load. So, does it make sense to add to that load with the significant weight of the PV panels, plus the weight of the racking, plus the weight of ballast to hold it down in the wind? Moreover, all this weight would be sitting on the fragile roof surface.

Consider thousands of pounds of new dead load pressing down on the thin rubber or asphalt roof membrane. Then, add the wind vibrating that weight, grinding the ballast stones or point-load locations into the membrane. And then consider that, in higher latitudes, cold weather can make that membrane brittle. We have seen how this practice can lead to hundreds of unintentional roof perforations, which invariably leak since they are unintentional and therefore not waterproofed.)

We have found that one appropriate solution is to mount the array to the structure of the building, which often can support the load, while the roof usually cannot.

"Aha!" say the ballasting proponents—now you're going to put holes in the roof! True. But please consider that most roofs already have many deliberate perforations for vents, wiring, ducting, and so on. Does anybody seriously think that the roofing industry has been doing these perforations for the last century or so without learning how to make a deliberate perforation waterproof?

We hold that making a few perforations carefully during installation and then properly waterproofing them is far superior to having many perforations made accidentally by ballasted systems in cold weather. Please see reference 4 below for a deeper discussion on this point.

Conclusion: If you are a would-be solar customer or investor, beware of PV systems that simply sit on a roof surface, which is usually not designed to support the load. Beware of installers who propose a PV array at too low an angle (thus significantly sacrificing yield) because of the myth that "any perforations are bad." Beware of racking manufacturers who express an unwillingness to produce and certify a system for wind loading at high angles of incidence for higher latitudes.

Instead, look for a solar proponent who does the following:

1. Insists on a engineering survey of the building (paid for by the owner of the array) before proposing a solution.

2. Offers a realistically low annual power output expectation in the case a low-tilt-angle solution associated with a ballasted or self-ballasted solution. This is for the case where a building analysis has shown that a building will support additional roof-based dead-load and a ballasted or self-ballasted solution can be offered within that load restriction. In this scenario, using a conventional inverter at the 43-degree latitude, it is unlikely that annual power output will reach or exceed 1050 kWh/dc kW installed.

3. Does not add the extra weight of ballasting when perhaps the more-appropriate solution is to attach the array to the structure of the building with properly engineered perforations and thus avoid hundreds of accidental perforations over time.

4. In so doing #3 above, pitches the PV panels at the correct angle to provide the maximum yield. When using an enhanced inverter, the incremental yield will more than offset the additional capital cost of the perforations and custom racking.

References

More in-depth and technical discussions of some of the points above can be found in the following white papers, which can be downloaded at http://www.hybridynepowerelectronics.com/Page_21.08.htm.

1. EMKWHPR0001—The Renewable Energy System Equation.

2. EMKWHPR0002—Accurately Predicting and Optimizing Yield Factors which impact Financial Efficacy of Solar Arrays

3. EMKWHPR0003—Mitigation of Revenue Loss on Solar Arrays from Cloud Cover and other Atmospheric Obstructions

4. An in-depth discussion of rooftop mounting methodologies can be found at http://www.hybridynepowergeneration.com/Page_05.05.htm.

About The Author

Richard Leverton has a degree in Applied Mathematics and Theroretical Physics from McMaster University. After graduation, he joined IBM and spent 19 years primarily on the technical side of the house, rising from programmer to software systems architect, along with several years as an instructor. After IBM, Leverton served as marketing director for Proteo Systems, a software company.

Nearing retirement, Leverton then went back to school, pursuing what he proudly describes as his "postgraduate degree"—a Certificate in Industrial Woodworking. In short, he became a cabinetmaker and operated a furniture-making shop until his retirement.

However, Leverton came out of retirement to join Hybridyne after hearing from Thomas Cleland, Hybridyne's founder and a long-time friend, about the 50-year plan of the company. Leverton is now enjoying his first chance to significantly improve the world.