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Metal Roofing and Solar Systems

Determining the best combination

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AS ENERGY COSTS RISE AND RESOURCES DWINDLE, RENEWABLE ENERGY SYSTEMS—PARTICULARLY PHOTOVOLTAICS (PVS)—ARE BEING CHOSEN AS A VIABLE LONG-TERM SOLUTION TO REDUCE COSTS AND RELIANCE ON FOSSIL FUELS.

Today, this technology of capturing and converting light energy from the sun into electricity is the fastest growing of all renewable energy technologies. In fact, according to Washington, D.C.-based Prometheus Institute for Sustainable Development, the production of PVs has nearly doubled every two years since 2002. As the price of silicon has lowered, and manufacturing for photovoltaics has become more efficient, costs have dropped, and systems have improved in performance and return on investment (ROI). The factors involved in determining a responsible ROI include:

- total turnkey cost of the system being installed;
- projected electricity output (kW);
- incentives and values of sale of electricity;
- operations and maintenance (O&M) expenses;
- projected inflation rate, cost of capital, and expected increase of electricity cost from the utility; and
- the system owner's tax rates.

Challenges still remain, however, in understanding the steps in choosing the best combination of roof and solar systems for each building owner's needs. These might include meeting more stringent energy efficiency codes, decreasing dependence on limited resources by using renewable energy sources, or finding long-term solutions to reducing utility costs.

While improvements in PV technology have made systems more feasible and economical, many owners have also realized the benefit of pairing their new PV system with one of the oldest and most durable roofing materials—metal.

Value

Metal roofing has several benefits as a platform for renewable energy systems, with durability at the top of the list. Metal roof systems can also be installed to use above-sheathing ventilation. This natural convective cooling technique helps keep PV systems mounted to metal roofing cooler, thereby preventing premature degradation of the efficiency. Crystalline PV modules attached to standing-seam roofing are offset from the metal roof surface, which causes shadowing to lower the metal roof surface temperature and allows air to flow under the modules.

Both cooling effects act to prevent early deterioration of the PV systems. Metal roofing is also available in many 'cool' colors that act to lower the surface temperature of the roof. Again, this can aid in preventing heat-induced premature degradation of the PV systems.

Life expectancy is metal's greatest value; these roofs often exceed the life of the PV system. Having a metal roof that meets or exceeds the 25-year life of most solar panels provides tremendous financial savings. Metal also offers the benefit of having low maintenance needs. The minimum slope of a metal roof system that requires virtually no maintenance is five percent in heavy rain areas, and 10 percent in moderate rain areas. (In dry areas, such as the southwest United States, roofs must be washed.)

Tecumseh Arena, in Tecumseh, Ontario, holds what is currently the largest operating rooftop solar PV system in Canada. The 508-kW DC system consists of 2212 230-W panels, two 250-kW inverters, and more than 6000 mini clamps and PV kits.

Photo © Spike Bell Photography

A new metal roof, or one applied as a retrofit over another system, is currently in the $54 to $108 per square meter ($5 to $10 per square foot) range, and a PV installation is in the $324 to $540 square meter ($30 to $50 dollar per square foot) range, before incentives are applied. However, other costs may come into play. For example, to make any repairs or fulfill maintenance needs on a roof, the solar system may need to be removed and reinstalled. This would cost from $54 to $108 per square meter. Additionally, one would need to calculate what would be lost in system generation during the downtime. Those costs could be significant, depending on the building location and the market, so the low maintenance needs of metal roofing can make a huge difference.

Many PV system designers laud metal for being one of the few roofing types that offer longevity and ease of installation. Although other material types may have a lower purchase cost, metal roofing's durability and low maintenance provide a better value over the long term. The lifecycle cost of both the roof and solar components must be calculated when evaluating all components in the system.

Jim Bush, chair of the Metal Construction Association's (MCA's) Roofing Council, says metal roofing's greatest value is the ability to obtain the true-life benefit of the PV product.

"Metal can provide a substrate or roof covering that has a life span equal to or greater than the solar product itself, which is a 20- to 25-year range," he said. "Most other roofing materials do not provide that. If a roofing material wears out sooner than the PV system, the building owner has to remove the PV system, remove and replace the existing roof, and reinstall the PV system, incurring added costs as well as downtime."

Metal roofing also adds other value to PV systems. The roof can be installed to a pitch that maximizes the sun's angle in a given location to help optimize the solar system's output on a direct mount. Since metal roofing can be installed to a slope or pitch (membrane roofing is not normally done this way), its existing angle can be used for PV installations with no added cost of racking to create an angle on a flat roof.

Standing-seam roofing allows PVs to be installed without penetrations in the roof surface. Although some conventional flat roofs may use a fully ballasted system without penetrating the roof, in a 145- to 161-km/h (90- to 100-mph) wind area it would weigh 22 to 29.4 kg/m^2 (4.5 to 6 lb/sf). Further, concerns over the movement and high wind performance would remain. Therefore, they are not a frequently used way of attaching PV systems to conventional roofs.

Metal roofs with a pre-painted, factory-applied cool coating help reduce heat buildup. If laminated PV is applied to a cool roof, there is a slight cooling penalty by covering the roof with a surface that has an effective solar reflectance of 30 percent. However, the area not covered by photovoltaics helps to lower heat gain, thereby lowering the load induced on the electricity of the PV. When a crystalline PV system is added to a pre-painted metal roof, the shading, air flow, and cool nature of the roof itself can help in the efficiency and durability of the PV modules themselves.

Process

In determining whether a PV system is feasible, the building owner must decide what benefits are desirable. In this process, it should also be decided who will own the PV system and apply for any incentives or grants related to it. The PV industry is heavily driven by federal, state, and local incentives; the ability of the PV system to fit these programs is determined by the system owner's location.

These incentives and energy credits for selling back power vary by area. This factor is as important to the total financial evaluation as the cost of the PV system itself. In fact, only about 20 percent of this evaluation focuses on the benefits of different systems—the rest involves how to get a system to work (which means evaluating building orientation), how much electricity can be generated on the roof, and at what cost.

If there is not much usable space on the roof, the decision would have to be made whether to retrofit the roof to create enough space to accommodate a larger PV system. If the architect or owner does not want to change the roof, a wall system that can incorporate renewable energy technology may be a viable option. The efficiency, however, would be less than with a roof, since a horizontal surface is not always exposed to sunlight throughout the day.

A logical process for project evaluation follows these seven steps.

First

Before any type of PV system is considered, it is wise for a building owner to first reduce the building's energy consumption as much as possible. By doing so, the impact of the PV system will be greatly enhanced and the ROI is improved as well.

Second

The building owner should have the roof structure analyzed by a structural engineer to determine its ability to support the system. Crystalline modules weigh about 14.7 kg/m^2 (3 lb/sf). If the roof cannot take the weight of a crystalline system that fits the owner's needs, then thin-film laminates should be considered, as they weigh about 4.9 kg/m^2 (1 lb/sf).

It is important to understand laminates are one product line among the many thin-film offerings. Some thin-film products,

Once the standing seam panels were installed on the roof of Providence College's Slavin Center, the laminate wiring assembly was daisy-chained together, run through a cable tray, and connected to a master wire running into the structure, connecting to various electrical components to supply power to the building.

Photos courtesy ATAS International

such as cells in hard glass panels, weigh almost as much as crystalline panels.

Another consideration is whether the panels will need to tilt toward the sun or can be laid flat. In either case, both offer access and clearance for inspection or repair. Laminated PV is directly adhered to the metal panel and becomes integrated with the roof. Crystalline PV, on the other hand, is mounted atop the standing seams, allowing for roof inspection without removal of the photovoltaics. For roof repair, the PV would likely need to be removed, depending on the nature of the repairs.

Third

In deciding on the roof deck material, it is critically important to think about the durability or the life expectancy of the selected roofing material. The owner should consider something that has low maintenance, long life, and can take a decent amount of foot traffic during the installation phase. After installation, foot traffic should be minor because maintenance on the PV system is minimal. It needs about two annual inspections, which should be performed by the owner or by a third party hired by the owner.

Fourth

The building owner should ask whether the manufacturer of available systems can stand behind the warranty or has a subsidiary that can do so. As PV panels typically have a 25-year warranty, it is important to know the supplier will be around to support this. Warranties and documented or substantiated average service life of the roof system are equally important.

Fifth

The owner or project manager should check installer qualifications and use them appropriately. It is important only those qualified to work on roofs do so, and those qualified to perform electrical work do so. Wherever the PV system touches the roof, the roofer has primary responsibility so the warranty is not voided.

For this phase of the project, it is important to contact the roofing material manufacturer to determine what impact the PV system would have on the warranty. In some cases, temporary protection may be required, but these needs are typically minimal on low-slope metal roofs and with steep-slope metal roofs it is not an issue. In either case, the affect on the ROI would be less than a year.

Some roofing requires extra protection when paired with a PV system. In the case of metal roofs, for example, if the building owner gets a non-penetrating clamp that is accepted or approved by a metal manufacturer, the PV system will have little or no impact on the roof warranty. However, not all manufacturers will accept non-penetrating clamps.

As for wind uplift concerns, at this time, calculations for code compliance for uplift can be run, but have not yet been independently tested. The best course of action is to deal with individual manufacturers on these issues.

If the crystalline is specified, it is important the metal roof installer also become the connector because it is critical the location of the clamps be directly above the seam clip and the metal roofing contractor knows exactly where all clips are located.

When a directly adhered thin-film laminate is chosen, the building owner will need to check with the manufacturer about warranties on field installation compared to factory installation, since some laminate products may have an impact on the metal roof warranty where they directly connect to the roofing material. Likewise, it can be important to the thin-film laminate materials' warranty that the product's manufacturer approves the metal substrate.

Sixth

Due to the extent of their integration, the owner or architect should evaluate specifications for both the roof systems and solar systems ahead of time. The question frequently arises whether PV specs should be part of the roofing or electrical specification, or have their own.

If the photovoltaic system is being bid as an alternate and the specifier wants a specific PV integrator, it is better to make the specifications their own section. If the preference is for a system integrated with the rest of the building, then splitting the electrical and roof portions into their own specs would seem to be the best idea.

As the PV industry matures, specifications will be split between the roof and the electrical just as any other construction item is now. Up to this point, the construction and solar industries are doing it differently, but over time it seems PV systems will be considered more of a 'construction' item.

The architect or project manager occasionally wants a specialized company to install the whole system, or instead desires the primary roofing and electrical contractors to do it all. The contractors should do the installations as they become more comfortable with the PV technology.

Another critically important topic to consider is the layout of the PV panels to allow firefighters to gain access to the roof, and to provide areas for foot traffic. State fire marshals' offices are beginning to raise concerns about rooftop-mounted PV systems with regard to the potential impact on fighting a fire through the attic.

Seventh

It is important the proper commissioning procedure be established ahead of time and followed. Most of this revolves around the performance of the inverter and manufacturer having certain requirements and procedures. Additionally, large electrical wires should be checked with a megger to ensure they have not been nicked or scratched since that could cause a fire at some point. The installer should offer training to the owner on how to maintain the system. Further, the installer should provide a maintenance folder or procedure manual for the owner's use.

Normal electrical building permits are required for a PV installation. A utility interconnect agreement and a renewable energy credit application are also required. Programs vary by area and are specific to each state. The best way to find alternative funding and incentives is to check on the Database of State Incentives for Renewables and Efficiency (DSIRE).[1]

Options

Crystalline panels and thin-film laminates are viable options that should be evaluated. Costs are relatively close on both and each offers certain features and benefits that may or may not fit the owner's needs. Since the industry is still in infancy, and products are constantly changing, it is vital to weigh the long-term established companies and the new ones from a financial standpoint as to whether the PV manufacturer will be around over the long term.

The best PV system needs to be determined based on the application. Many crystalline systems are used over existing roofing. The applicator of the crystalline system should evaluate how the roof was installed and the load it can handle. A metal roof typically can accommodate crystalline panels placed over it so both an architectural and a structural metal roof system must be evaluated. In a structural system, for example, the roof panels might be standing 4.6 m (15 ft) between purlins.

With crystalline panels, there is the possibility of added weight, design and aesthetic problems, and a need for custom drawings during the system design. In some cases, these systems may void a roofing warranty if the roof is penetrated during installation and a leak ensues. Using a standing-seam metal roof avoids these problems.

If a non-roofing contractor penetrates the roof, it automatically voids the manufacturer's warranty; therefore, the roofing manufacturer needs to be involved at the start and can provide all details needed. Further, in any leak situation, a third party should be called in for a thorough inspection.

Thin-film laminates now come in standard system sizes and are designed for quick turnaround of specifications, architectural drawings, and one-line electrical drawings. Typically, a complete equipment schedule is also part of the package.

If factory-applied laminates are used, the installation can be simplified because a roofing contractor certified by the PV provider can install the standing-seam metal roof with the photovoltaics integrated into it. An electrician completes the installation by connecting the PV to the system components and the building's service panel.

Today's thin-film PV laminates could generate as much power as traditional crystalline panels in the right

The laminate can be applied to the metal panels in a controlled, factory environment or on the jobsite. In either method, requirements of both the metal roofing manufacturer and laminate producer must be met to ensure compliance with product warranties.

environment. Each project should be evaluated to determine the best PV panel for that project based on the goals the building owner is trying to achieve. Thin-film PV cells have the ability to produce power in low light and partial shading, meaning the laminates begin generating power earlier in the morning and keep generating it later in the day. However, a thin-film PV laminate may also need more square feet of roof area, where a higher efficiency crystalline panel may produce more power in less square feet.

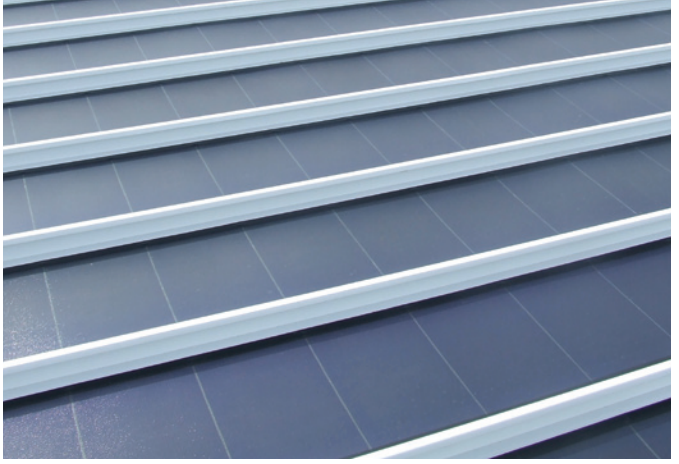
Some owners may worry about technology advances making today's solar system obsolete. However, it is better not to worry about the next five years, and instead install a system now and gain the value of having this technology to save on resources. Additionally, PVs have been around for 30 years and non-crystallines have not changed much in 20 years. The changes are all in other areas, such as the inverter and smart grid, which are both easy to upgrade in a system that has been installed and operating for a while.

Standing-seam metal roofing manufacturers using a renewable energy system analysis program can provide an accurate ROI calculator to help in the planning process. Many manufacturers provide this and none of them charge for it.

Using rooftop PV systems will allow a building that is seeking Leadership in Energy and Environmental Design (LEED) certification to achieve points in Energy and Atmosphere (EA) Credit 2, *Onsite Renewable Energy*. Choosing metal roofing as the platform for a PV system can also help a building acquire a point in:

- Sustainable Sites (SS) Credit 7.2, *Heat Island Effect: Roofs*;
- Materials and Resources (MR) Credit 4, *Recycled Content*; and
- Credit 2, *Construction Waste Management*.

SS Credit 7.2 encourages use of roofing material compliant with solar reflective index (SRI) values. For a low-slope roof, SRI must be greater than or equal to 78. For a steep-slope roof, SRI must be 29 or greater for 75 percent of the roof. The SRI is a unitless value that is calculated using ASTM E 1980, *Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-sloped Opaque Surfaces*. It takes into account the solar



Metal roofing makes an ideal platform for thin-film laminate.

The Peterson Field House at the University of Mount Union (Alliance, Ohio) generates its own electricity, thanks to the installation of a 6132-m^2 (66,000-sf) PV roof system that ranks as the largest single solar array, thin-film laminate system in Ohio.

Photo courtesy Sheffield Metals

New Jersey Meadowlands Commission's Center for Environmental and Scientific Education's 165-unit rooftop crystalline solar panel array generates electricity for the building's power needs. The solar units are expected to produce a peak maximum of 33,000 watts of electricity.

Photo courtesy Englert Inc.

reflectance, thermal emittance, and wind speed (*e.g.* convective cooling) to determine a value that gives an indication of the roof surface's temperature.

Funding

Building owners have several ways to fund a renewable energy system. The four main ways are to pay cash, secure a bank loan, obtain a line of credit, or lease the system through programs such as a power purchase agreement (PPA).

A complete financial analysis on the project begins with the motivation for installing the system and expectations for its performance. If the primary motivation is to be more energy efficient, cost may not be as important. However, looking strictly at upfront costs may not be good since overall costs and internal rate of return (ROR), which equates to the rate of interest on the investment, are affected by several factors, such as:

- system performance;
- rate structures;
- rebates;
- module selection;
- racking solutions; and
- roofing material.

Cost parameters include installation and operating expenses, revenues, and borrowing prices. Government subsidies and incentives, along with the local electricity rate and potential savings, will help calculate the ROR on the investment.

In a PPA agreement, the developer or other third-party entity funds the renewable system and sells the energy to the building owner at a reduced rate. Sometimes in a PPA, the developer owns the power system and guarantees a certain cost of power to the building owner. This method can also finance some or part of the roof system.

In some cases, schools and non-profit organizations have been able to afford a renewable energy system through careful material selection, reliance on rebates, and donations from foundations. For example, an elementary school in rural Nevada faced budget cuts and teacher layoffs. The school administrators thought they could not afford a renewable energy system even though it is what they needed to reduce costs. Their supplier, however, figured out a way to do it by having it paid almost entirely by rebates from utilities and raising the balance through donations. After two months of system operation, the school had reduced its utility expenses enough to hire back two of the teachers.

The project included a new metal roof installed using non-penetrating clamps, which nearly halved the cost of racking and reduced labor time by 25 percent. This saved enough on installation expense to add a second solar array for the school at no additional cost.

Installation

The benefits of combining standing-seam metal roofs with PV systems also flow into the installation process. Thin-film laminates are integrated onto the metal panel system typically at the factory level. How the laminates are applied, and any liabilities for the application, are

important to meeting requirements provided by the laminate manufacturer.

When using laminated thin-film PV on an existing roof, the roof may need to be cleaned or prepared before application since certain heat ranges and techniques are needed for proper adhesion.

Requirements for putting the PV system down properly can come from the manufacturer's recommendations or a roof consultant. Both crystalline and laminate systems have final hook-up and wiring needs.

Making it work

The perceived complexities of choosing the right system are outweighed by the long-term benefits to building owners. As PV technology continues to improve, and is more easily understood, the decision process is also becoming easier. However, one thing remains constant—the long-term value of pairing any metal roofing with any type of commercially viable PV system. **CS**

Notes

[1] Visit www.dsireusa.org for more information.

ADDITIONAL **INFORMATION**

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Abstract

Rooftop renewable energy systems—particularly photovoltaics (PVs)—are being chosen as a viable long-term solution to reducing costs and reliance on fossil fuels. Capturing and converting light energy from the sun into electricity is the fastest growing of all renewable energy technologies. As technology has advanced, the systems have improved in performance and return on investment (ROI). However, challenges still remain in understanding the steps involved in choosing the best system for each building owner's needs.

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