

Integrating Photovoltaics Onto Building Envelope Surfaces

By Michael Gumm

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INTRODUCTION

Over much of the past 30 years, the standard for solar technology installed on buildings has been rack-mounted, silicon crystalline-based solar panels. Today, a new type of technology called thin-film photovoltaics is ready to change the way solar collectors are installed on buildings. This paper gives a broad overview of both the old and the new solar technologies, plus insight on designing and installing photovoltaic systems.

According to the Solar Energy Industry Association, solar power in 2006 represented only one-tenth of one percent of the added electrical power capacity to the U.S. power grid. In three years, solar could grow to 10 percent of new added electrical capacity; and, by 2018, solar is expected to contribute 50 percent of the annual U.S. power increase.

PHOTOVOLTAIC (PV) BASICS

Photovoltaics (PVs) are one of the most promising sustainable renewable energy technologies. Solar (PV) modules produce electricity on site, directly from the sun and with the least environmental harm. Solar has the smallest environmental impact of any of the renewable energy systems. PV modules are solid-state devices that simply make electricity from sunlight. Solar requires little maintenance, produces no pol-

lution, and does not deplete any nonrenewable fossil energy resources, such as oil, natural gas, and coal.

Crystalline Silicon

We are all familiar with the basic PV glass module mounted on racks or posts. Glass-encapsulated crystalline silicon is the most common type of solar module. Most rack-mounted PV modules consist of crystalline silicon, either as a single or as a polycrystalline wafer, to generate electricity.

- Silicon-based PVs have the highest electrical output of any PV material per sq ft.
- Typical power production is between 12 and 18 watts per sq ft.
- Silicon wafer PVs are more expensive and require large amounts of energy to manufacture.
- Silicon modules cost, on average, \$4.85 per watt.¹
- Solid silicon PV modules represent 95% of all solar panels installed.

Other building system applications include semitransparent PV glass modules for windows and skylights using crystalline silicon. Several PV manufacturers have also integrated non-

glass, polymer-surfaced crystalline modules into new roofing products. Leading silicon panel manufacturers include Suntech, ET Solar, SunPower, Schott Solar, Sharp Corporation, and Canon Inc. (See *Figure 1*.)

Thin-Film PVs

A number of new PV technologies have begun to emerge in the marketplace. These newer technologies, called thin-film photovoltaics, include very thin layers of photovoltaically active material placed on glass, flexible metal, or plastic substrates. Flexible thin-film PV modules are made by depositing semiconductor materials on stainless steel foil or a plastic carrier and encapsulating them with a solar transparent plastic



Figure 1 - Crystalline-silicon array on a Voorheesville, NY, school. Photo courtesy of New York State Energy Research & Development Authority.

polymer. Semiconductor materials used in thin-film PVs include:

- Amorphous silicon (a-Si): Uni-Solar, Powerfilm, and Xunlight
- Copper indium gallium diselenide (CIGS): Miasolé, NanoSolar, and Global Solar
- Cadmium telluride (CdTe): First Solar

Other new solar technologies in development include dye-sensitized solar cells using a dye-impregnated layer of titanium dioxide to generate electricity. Dye-sensitized solar cells are printed onto various polymer films with equipment resembling computer printers. Recently, new carbon-based (organic) solar modules have been developed. Thin-film PV materials are used in both glass-encapsulated and flexible-membrane solar modules.

Comparing thin-film pvs to traditional silicon modules:

- Thin-film PV modules generate less power per sq ft (lower power density) compared to crystalline silicon and can produce up to five percent more power in a solar day. Crystalline silicon's peak power production is between 10:00 a.m. and 3:00 p.m., while thin-film modules can generate power throughout the day.
- Thin-film PVs produce more power during low-light (early morning and late afternoon) and overcast conditions compared to crystalline silicon.² A solar module peak-power output is measured at 12:00 noon with the sun directly overhead.
- Thin-film PVs produce 5 to 10 watts of power per sq ft on average, depending on the type of semiconductor material used.
- High rooftop operating temperature has less effect on thin-film solar power output compared to standard crystalline silicon. Crystalline silicon modules start losing power output once PV module temperature exceeds 25°C.
- Thin-film modules' power output is less affected by solar shading (shadows) than crystalline silicon.

Solar module cost can be 50 to 65 percent of a solar array. Thin-film PVs, at \$2.75 to \$4.25/watt, cost less than silicon modules. Module cost depends on the type of semiconductor material used and the

module's construction (glass or polymer).³ Power production per sq ft varies among manufacturers. Unlike the roof industry, with cost per square, the solar industry expresses module and array installation cost by the watt DC.

BUILDING-INTEGRATED PHOTOVOLTAIC (BIPV) SYSTEMS

Building Integrated Photovoltaics is a new building technology concept. BIPV involves integration of PV modules into the building envelope by incorporating them in conventional building products, such as the roof, windows, or walls. BIPV is both the building envelope surface and the building energy source.

BIPV Advantages

- A building owner's BIPV system is connected with the local utility grid, and, with net metering, it can export surplus energy to the utility for later use. The building becomes a distributor of its surplus power production. Net metering banks or deposits that energy with a utility company. The power storage system is essentially free.
- Both the building owner and the utility benefit, as on-site solar power production is typically greatest during times of peak energy need for both buildings and power companies. The PV system reduces energy costs for the building owner, and the exported surplus solar energy provides additional power to the utility grid during the time of its greatest energy demand.
- The utility company can maintain needed power production capacity without the capital investment of building new power generation plants.
- The building owner can draw back the net-metered power at night, when electrical costs tend to be



Figure 2 – Grand Valley State University displaying Uni-Solar, flexible thin-film PV modules.

lower, reducing power cost.

- Photovoltaic systems can become the building's primary energy source in the event of a power failure, and energy can be stored onsite using batteries for emergency backup.

ROOFING and BIPV

Placing rigid solar PV roof panels as a stand-alone or rooftop-equipment-mounted power module array has been around since the invention of solar PV cells. The creative idea of integrating thin-film PV modules into a roofing system dates back to the 1980s. Only recently, with the commercial development of newer, structurally flexible, PV thin-film and polymer-surfaced crystalline-silicon modules, have we seen the integration of PV with traditional roofing materials. Today, there are a number of new roofing systems and products on the market using laminated PV, flexible-film, and polymer-surfaced crystalline. These include shingles, roof tiles, metal roofs, modified bitumen, and single-ply roof membranes. These are dual-function products that weatherproof the building while generating renewable energy from the sun.

Metal Roofs

Uni-Solar pioneered the application of flexible, thin-film PV modules to architectural metal roof panels. Its flexible, thin-film module has a pressure-sensitive, peel-and-stick adhesive on its back surface and can be factory laminated to metal roof panels for new construction. The self-adhesive, flexible, thin-film PV modules can be applied to existing snap-lock and batten standing

seam metal roofs if the metal panels have a flat profile between seams.

Another company, Dawn Solar, has gone a step further by combining flexible solar modules with metal roofing and a concealed radiant heating system under the metal panels, creating both electricity and hot water from the sun.

Standard R-panel metal roofs with complex panel profiles, overlapping seams, exposed fasteners, and stiffener beads or striations have been limited to traditional equipment-mounted, glass, solar modules. A new solar roof system combines certain elastomeric coatings and inter-ply materials with flexible, thin-film PV by SolarPower Restoration Systems. This bridges the R-panel's compound roof profile and exposed fasteners, creating a flat substrate for the PV modules. The SolarSeal PV System uses thin-film modules and coatings to both waterproof the metal roof and generate renewable energy.

Another solar metal roof attachment system by SolarPower uses high-energy flexible magnets for attaching thin-film PV to metal roof panels, creating a redeployable solar roof system. The thin, nitrile-rubber-composite magnets and thin-film module systems perform well in high-wind conditions and have the advantage of being transferable to another solar roof host site.

Flexible thin-film modules are one of the best options to affix a PV array to metal roofs. Rigid glass silicon PV modules work but they require some form of mechanical attachment. It is important to determine how the additional weight of heavier glass modules and rack attachment systems affects the building structure and metal roof system. (See Figure 3.)

Single-Ply Systems

One of the most common low-slope solar roof systems today uses a factory-laminated, flexible, thin-film PV module to a single-ply membrane sheet. This concept was patented by Solar Integrated Technologies over 20 years ago. Working together, Uni-Solar, Sika-Sarnafil, and Solar Integrated Technologies (SIT) created



Figure 3 - Uni-Solar metal panels with thin-film photovoltaics.

the first single-ply BIPV PV roof system. PVC single ply is the membrane polymer of choice, while TPO can also be used.

Both flexible PV modules and single-ply membranes are manufactured in similar fashion into long sheets. The factory-laminated, single-ply membrane and PV panels are shipped to the project site in large, premanufactured rolls. The PV laminated single-ply roof system is installed over an existing compatible roof system or as a new roofing system using traditional roof construction methods and techniques.

On new projects, a new (nonsolar) single-ply roofing system is first installed. It can be mechanically fastened or fully adhered. Next, the factory-laminated, single-ply membrane and flexible PV module are installed directly over the single-ply system and hot-air welded in place.

Open Energy, DRI Systems, and SolarPower Restoration Systems have created a new type of nonglass silicon solar module for BIPV by laminating com-

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Figure 4 – Solar Integrated Technologies' thin-film laminated roofs.

posite panels with crystalline silicon cells covered with a solar, transparent-polymer top surface and attaching the modules to EPDM, PVC, and TPO membranes in the factory or in the field. One advantage of the crystalline silicon systems is the high power density per square foot. More power output per square foot is produced than with the thin-film systems – an important consideration on smaller roofs.

Both crystalline silicon and thin-film solar modules get hot on summer days. Module surface temperatures can exceed 180°F in the Southwest. Photovoltaic modules tend to be dark in color and can absorb a lot of heat. The roofing industry needs to pay attention to solar modules in direct contact with roofing membranes and monitor how long-term surface exposure to higher temperatures affects the service life of the roof membranes. From a design standpoint, refer to single-ply membrane manufacturers' specifications for hot-stack flashings. Several major roof manufacturers recommend placing insulation between a hot-stack surface and the membrane once the surface temperatures reach 120°F. Most white single-ply roofs are known as cool roofs and have surface temperatures normally no more than 10°-15°F above ambient air temperatures. Now, though, white roof membranes with solar laminates are exposed to surface temperatures 30°-70°F higher.

If a high percentage of a white membrane roof is covered with solar modules on its surface, higher R insulation becomes important to reduce heat transfer from the

PV modules to the building interior. Higher heat loading without good insulation can increase building cooling costs, and the designer should make sure the existing HVAC system can handle the additional cooling load. New construction will need to be designed with higher demand loads in mind.

Standard and Modified-Bitumen Roofs

PV systems integrated with standard asphalt and modified-bitumen BIPV roofs have lagged behind in development. With summer surface operating temperatures

approaching 180°F, attaching PV modules directly onto an asphalt-based roof membrane with a lower softening point has proven to be difficult. SBS-modified membranes tend to have lower softening points compared to APP and standard 90-lb cap sheets. The difference in thermal expansion between the modules, adhesives, and asphalt roof makes direct adhesive attachment challenging. Adhesive attachment to granule surfaces can be problematic. As the surface temperature rises, granules may not stay attached to the membrane surface if the systems (module and membrane) have a large range of contraction and expansion over the day/night thermal cycle.

Recently, two companies have been working on new application methods. Performance Roofing Systems has come up with a new field-applied solar roofing system that bonds the Uni-Solar flexible module directly to its DerbiBrite® APP-modified-bitumen membrane. DerbiBrite® originally was developed for restaurant and fast-food roofs. DerbiBrite® high scrim placement and fat-/oil-resistant, factory-applied acrylic surfacing bonds with the Uni-Solar module's butyl-rubber-back surface adhesive.

SolarPower Restoration Systems has developed a new PV system for asphalt-based roofs. The patent-pending SolarSeal PV Roof System combines high-performance, elastomeric roof coatings such as polyurethanes with flexible thin-film or composite panel modules, forming a monolithic, weatherproof membrane that pro-



Figure 5 – Open Energy modules and single-ply membrane system.



Figure 6 – SolarSeal System over SBS membrane with Uni-Solar PV module.

protects the asphalt-based membrane roof system and generates electricity. This is particularly effective when installing a solar array over an existing roof system. (See *Figure 6*.)

Called the SolarSeal Fan-Fold System, a newly developed, nonglass array system combines engineered corrugated composite panels connected together with flexible joints, using crystalline silicon for higher power density with a transparent polymer surface. The adjustable Fan-Fold system unfolds out of the box and can be applied flat directly to the membrane or as a self-contained offset sloped array system. The PV module operating temperature is reduced by airflow through the panel's corrugation. The solar module can be installed with hot asphalt, adhesives, or fasteners. (See *Figure 7*.)

PMR Systems

Protected Membrane Roofs (PMR) or inverted roof membrane assemblies (IRMA) have been in use by the roofing industry for over 30 years. Recently, two manufacturers – T.Clear Corporation and Powerlight Corporation – have created new solar laminated, insulated roof tiles. T.Clear laminated a new nonglass solar crystalline silicon PV module with an old roof industry classic, the T.Clear (LG) LIGHTGUARD® and T.Clear (HG) HEAVYGUARD® insulated roof panel.

The solar PMR

panels separate the membrane roof system from the solar array. Placing the solar insulation panels over the roof system protects the membrane by maintaining a nearly constant temperature. This reduces the harmful effects of freeze-thaw cycling and exposure to harsh UV, lowers heating and cooling costs, and extends the service life of the protected roof membrane system. (See *Figure 8*.)

STEEP-SLOPE SYSTEMS

Glass solar modules have been used on steep-slope residential roofs for years. The flat solar panels are easy to install, requiring only a few roof penetrations to run the wiring. However, glass PV modules are considered by some to be an unattractive roof system. With an expected service of 30 years and a higher surface temperature, glass modules will outlast most roof surfaces, especially those with asphalt shingles. There are a number of new alternative PV roofing products that have incorporated active solar materials into conventional roof products to create true BIPV roofing products.

New solar shingle and tile products use either thin-film or crystalline silicon for a solar-active surface. A number of new solar



Figure 8 – T.Clear Solar LG Insulated Roof Panel.



Figure 7 – SolarSeal Fan-Fold System.

tile modules that can interface with flat, concrete roof tiles are available. The SunPower SunTile is a high-efficiency solar panel that blends invisibly into concrete-tile roofs. GE Solar makes a solar tile with a peak power of 55 watts at 8.4 volts and has a unique interlocking design for concrete-tile applications. SharpSolar offers polycrystalline silicon modules with 62 volts of output. Open Energy makes a polycrystalline, tile-type module that comes in brown, red, and black.

Atlantis Energy Systems manufactures a slate-type tile that works well with flat tiles and slate roofs. (See Figure 9.)

WALL AND WINDOW SYSTEMS

There are a number of new wall and window PV systems. The key limiting factor with wall and window application is the building placement relative to the sun. South, southeast, and southwest walls pro-



Figure 9 – Solar shingles by Open Energy.

duce the most power. Window systems are typically a silicon wafer or thin-film cell laminated between two sheets of glass and are semitransparent. Solar window applications include window glazing, curtain walls, atriums, and skylights.

Solar wall systems vary from integrating glass modules to curtain walls to applying thin-film modules with adhesives to adhere the module to a wall surface. Another solar application system created by SolarSeal Technologies uses thin-film, semiflexible modules with elastomeric coatings for integrating solar modules onto EIFS walls, tilt-wall concrete wall panels, and masonry wall systems.

Currently, wall and window systems are very specialized. Keep watching as the pricing of solar systems continues to drop, and more building wall and window systems start to incorporate solar into more traditional wall and window building products. (See Figure 10.)

PHOTOVOLTAIC ROOF DESIGN

Designing a PV system for BIPV is a complex process, especially for roofing. The solar industry, for the most part, has grown independently of the roofing industry. In the past, it was generally believed that the installation of rack-mounted glass PVs on a residential shingle roof required little more than drilling a few holes in the roof, caulking around the support mounts and wiring penetrations, and installing flashings around the equipment support mounts on a low-slope roof. To this day, many in the solar industry do not understand that changing the roof's use may void the warranty unless the work is completed by a competent installer and is approved by the manufacturer.

With the introduction of new roof systems that combine traditional roof products with PVs, roof designers and roofing contractors must learn a new set of technical skills. Solar integrators and solar design consultants are becoming better educated



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Figure 10 – The main elevation of OpTIC (Opto-electronics Technology and Incubation Centre), United Kingdom, showing the cantilevered business center and 1,000m² PV wall array.

about roofing technologies. With the increasing use of solar arrays and the need to create more energy-efficient and sustainable buildings, both the solar industry and the conventional construction product industry need to work together and learn from one another.

Today, there are several BIPV application options for low-slope roof systems:

- Conventional crystalline-silicon PV-glass-module, rack-and-post-mounted systems.
- Nonglass, composite-panel crystalline-silicon PV modules, surface-and slope-mounted.
- Protective Roof Membrane (PMR) self-ballasted PV tile systems.
- Thin-film PV laminated single-ply membrane and metal roof assemblies.
- Proprietary elastomeric coatings with thin-film and crystalline-composite systems for asphalt-based and single-ply roof systems.
- Ballasted roof-mounted systems.

COST

The design and sales-process timeline for specifying and selling PV roof systems is longer and more complex than that for standard roof systems. PV systems are expensive. The average installed cost of a commercial low-sloped PV roof system before tax credits and state incentives can average between \$50 and \$150 per sq ft, depending on the power density of the PV system. The solar industry uses cost-per-watt pricing. Tax credits and state incentives are priced as dollars per watt. The average cost per watt for solar arrays installed on low-sloped commercial applications is between \$8 and \$12 per watt DC, excluding the cost of the roof.

Governmental bodies and utility companies offer performance-based incentives, grants, government tax credits, and rebates to make solar affordable. Unfortunately,

there is no uniform, state-to-state system of tax credits, incentives, and programs. For the next eight years, the federal government will provide a 30-percent tax credit and five-year accelerated depreciation on commercial and residential solar installations. Several states now mandate that a percentage of utility companies' electrical power production is generated from solar and other renewable sources, and more utility companies are starting to offer solar incentives.

While the Federal Investment Tax Credit (ITC) reduces a percentage of solar's cost, what makes a PV system affordable are the additional state, local, and utility credits, rebates, and performance-based incentives. Many incentive programs are offered throughout the U.S. Some states offer a large number of options from different agencies and utilities, so that a program cost must be calculated by ZIP code. Twelve states still have no net-metering laws. Perhaps less than half of the states have attractive enough incentive programs for solar building to make real economic sense. More states are starting to adopt renewable-energy programs. The Database of State Incentives for Renewables and Efficiency (DSIRE) is the best source to use to look up state tax credits and incentive-based programs. It can be found at www.dsireusa.org.

Determining what financial options are available to the building owner is an important part of the solar design and sales package. After all, while a 300-square roof may cost \$200,000, a 100-kW solar array before tax credits and incentives can easily cost \$800,000 to \$900,000.

Financing Options

It is important to understand and identify an owner's solar financing options. A key part of selling PVs is having access to established leasing programs from leasing and capital investment groups. Capital leases and bond options are very important

options for selling to state and local governments, school districts, and other public agencies. These leases can become another revenue stream and tax credit source, depending on investment packages the contractor or solar integrator has set up with financial-investment companies.

It is important to explain the tax benefits, state utility rebates, performance incentives, and renewable energy credits to the owner to show his real cost plus the monthly energy savings and payback period for his investment. Commercial owners are starting to focus more on commercial leases or power purchase agreements (PPAs). PPAs and leases allow the owner to get into solar without upfront costs or cash outlays. In many instances, the new roof and solar system can be packaged together. Public agencies and schools prefer these financial options because the cost is easier to fund and it is not covered in the capital outlay budget but rather in the general operating budget. Options include:

- **Direct Purchase:** Owners purchase the PV system by using internal cash flow and utilize the tax credits, state and local rebates, utility rebates, and RECs by going to their existing lending/leasing institutions.
- **Finance Lease:** This is like a bank loan, and the owner (the lessee) is considered the owner of the equipment for both accounting and tax purposes.
- **Operating Lease:** The lessor is considered the owner for the tax credits, depreciations, and rebates. The lessee is renting the roof/equipment and can write off the cost of the lease.
- **Tax-Exempt Lease:** This lease type can meet the needs of schools, universities, and state and local governments. The public agency pays for the cost of the roof and PV from cur-

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rent utility costs. The lessor, depending on the lease package structure, takes the tax benefits and, in some cases, can have a tax-exempt package on the earned interest.

- **Power Purchase Agreement:** An outside investment group owns and operates the solar equipment and sometimes the roof. The building owner pays the solar array owner for the electricity produced by the solar array. The array owner in effect is a mini-utility company. The array owner may sell back surplus power by net metering to the local utility company.

These are very complex financial agreements, and it is important to stay within the IRS guidelines to ensure all the ITC benefits are obtained.

PRELIMINARY ROOF INFORMATION COLLECTION

Designing a low-slope-roof and PV system starts out like designing a conventional system. In the case of a reroof, the following information will be necessary to determine if the building is a suitable candidate for a BIPV system:

- New construction, reroof, or existing roof.
- Type of existing roof(s).
- Number of existing roofs.
- Age of roof(s).
- Deck type.
- Structural-load capacity.
- Insulation type.
- Perimeter details.
- Core cuts.
- Photos of roof and major roof elements and site conditions.
- Moisture survey (possibly).
- Existing roof coating, test for adhesion and compatibility.

If the roof is suitable for a solar array, get an existing roof plan of the building or be prepared to create an accurate plan with all curbs, HVAC, electric, drains, and scuppers. All of these items must be pinpointed and measured.

Roof Plan

The building's orientation, solar shading, and insolation are important design elements used to determine what type of PV system can be used and how large of a PV array can be installed. How a solar array performs depends on location and design.

The same 100-kW system designed for San Jose, CA, might only generate 75 kW just a short distance away in San Francisco, CA, due to the differences in their climates.

- Create a roof plan with all rooftop elements (drains, curbs, pipes, etc.).
- Google or equivalent satellite photos of building and surrounding buildings.
- Building site location.
- Building solar orientation (what direction it faces).
- Identify shadow obstacles (rooftop

equipment, surrounding roofs, buildings, and trees can affect the overall effectiveness of the PV system).

- Identify solar access (insolation). Insolation is a measure of solar radiation incident on a surface. It is the amount of solar energy received over a given area in a given time.
- Ceiling space and wall structure access for wiring system to the utility service.



Planning for a new roof? Do the math.

Too often when business owners install a new roof, they're also installing extra costs – expenses they'll be paying off for years, even decades, to come.

Here's a simple comparison: two owners, two identical buildings. Which is the smarter investment?

	Other Roof	Duro-Last® Roof
Roof Product Cost	\$70,000	\$88,000
+ Installation (labor + overhead)	\$60,000	\$45,000
+ Tear-Off and Disposal Costs	\$12,500	\$0
+ Estimated Maintenance Costs (over 20 yrs.)	\$5,000	\$1,500
+ Estimated Repair Costs (over 20 yrs.)	\$7,750	\$0
+ Estimated Energy Savings (over 20 yrs.)	\$0	(\$84,000)
= Estimated Life-Cycle Costs	\$155,250	\$50,500

This chart is an example only.

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Preliminary Power Analysis Data

It is important to determine the electrical energy consumption for the building. The following information is needed on existing buildings. New buildings must calculate this information.

- Utility bills (highest bill per quarter minimum) for the past two years.
- Usage pattern with peak, part-peak, and off-peak usage and summer and winter demand charges.
- Current and future electric rate schedule, factoring in tiered rates

and time-of-use utility pricing and annual rate inflation.

- Inventory list of major appliances and other high-ampere drawing equipment (seasonal/nonseasonal).
- Locate and inventory existing electrical services (photos).

Information Processing and Preliminary Design⁴

The items above are used to calculate the information needed to design the PV system.

- Electrical Load: Determine building power requirements (total peak kW).
- Array Sizing: Calculate array size requirements (kW).
- Array Layout: module size, based on roof size and equipment locations and pricing.
- Wiring System Design: voltage drop, safety building code, NEC code, and environment.
- Combiner Box: size and locations.
- Controller Specifications: size of battery back-up system only.⁵
- Inverter Specifications: size.
- Utility-interactive system design.

Note: When the power grid goes down, the solar array shuts down unless it has a battery system.

Contractor Information Requirements for Estimating

Provide installation contractor(s) with the following information so they can price out the systems.

- Approved roof plan and roof specifications.
- Approved PV array plan and specifications.
- Approved wiring plan and specifications.
- Approved controller plan and specifications (battery systems only).
- Approved inverter plan and specifications.
- Utility-interactive system design.

Photovoltaic estimating software is available from several sources. Input all data into software and generate the PV system cost. Andy Black's OnGrid software system is one of the best. The software provides all the financial information needed to explain the following:

- System cost.
- Operating cost.
- Operating profits.
- Operating losses.
- Net power savings.
- Lifecycle power savings.
- Tax credits.
- Capital depreciation.
- Rebates.
- Return on investment (ROI).
- Equity/property value increases.
- Property resell value.
- System payback period.
- REC (green tag) income.
- Performance-based incentives (PBIs).

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Most software packages will generate charts and graphs so that ROI and payback cycles are clear and easy to understand. Some software packages can fill out the forms needed for state and utility rebates and the forms for commissioning the PV array system with the utility company.

Completing the necessary paperwork for the rebates and tax credits and being aware of the deadlines related to these rebates are very important. A contractor or designer can incur substantial cost and liabilities if he or she fails to complete the rebate and performance-based utility incentives paperwork and forms in a timely fashion to meet specific incentive tier deadlines.

Understanding the rebate and performance-based incentive process is critical for getting the client and contractor the cost savings that make the solar system economically feasible.

These rebates and incentives vary; some states may require PV system installation first, with the owner then applying for the credit later on. In some cases, the state will only pay if it has allocated funds in the account at the time of filing. Other states require one to reserve the rebates by first filing; a set amount of time is then allocated to get the system installed and commissioned. Performance-based incentives mean just that – over time, the array system is monitored and is expected to perform as designed. So be careful with power production estimates when designing a solar array system; a miscalculation could prove to be very expensive!

DESIGNING AHEAD: LIFE CYCLES – ROOFS – WARRANTIES

Photovoltaic manufacturers say their PVs have a long service life. Glass module manufacturers claim their solar modules will produce energy for 30-50 years. Many thin-film PV manufacturers routinely say their modules will generate 80 percent of the modules' installed power production at year 20 or 25.

When designing a solar project, it is important to keep in mind the long service life of PVs in relation to the type of roof system being designed. Chances are, the roof will have to be replaced long before the PV modules do. Does it make economic sense to install an existing roof system with a limited performance life? What is required to maintain the roof? What can be done to extend the roof's service life? Was the cost of removing the PV modules for roof repairs or replacement in the future factored in, and is

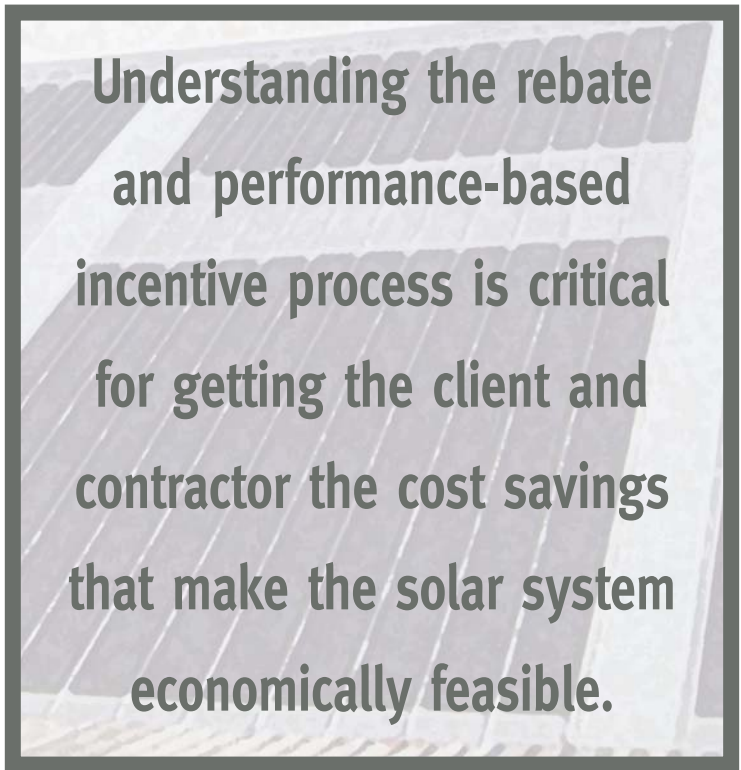
the owner aware of the future cost?

Flexible thin-film PV and composite-paneled crystalline systems have the advantage of direct attachment to the roof membrane or onto the elastomeric coating system. Thin-film modules can last longer than the roof systems. One option developed by SolarPower Restoration Systems combines elastomeric coating with PV modules, creating a new waterproof system. Recoating the elastomeric coating solar composite system with a compatible elastomeric coating in the future synchronizes the service life of the roof with the PV modules.

Do not forget to contact the roof manufacturer if the existing roof is still under warranty. Major modification and changes to roof use can void any existing warranty if the manufacturer is not contacted first and agrees to the solar installation. It is important to monitor any solar array rack-mounted installation for damage due to construction and foot traffic.

In the roofing industry, we are used to specifying a single-source warranty covering all components, material replacement, and workmanship for 10, 15, or 20 years. Currently, single-source PV roof-system warranties do not exist. Photovoltaic modules will have two warranties. One warranty is for material and workmanship defects for manufacturing the PV module. The warranty can be as short as 18 months, but the average warranty is five years for PV module replacement due to defective materials/labor. The second warranty is for power production. Most manufacturers will guarantee their module will generate 90 percent of the installed rated power production at year ten and 80 percent of the installed rated power production at year 20. On average, a PV module will lose 0.5 to 1.0 percent of its installed rated power production a year.

Photovoltaic inverters – devices that convert DC power to AC power – typically are warranted for five to ten years, and over the course of the PV array's service life, they will have to be replaced. On wiring and cabling, code requires UL-rated cable. Most cables are warranted for ten to 20 years (material only), and it makes good sense to install cables in a premanufactured cable channel to protect the wiring. Therefore, with an average roof system and PV system, there will be a roof warranty from one manufacturer and several warranties from the PV module component manufacturers. As traditional roofing manufacturers create standardized solar roof systems, we will eventually get a single-source warranty package.



Codes and Standards

The primary safety and wiring code for PVs is covered by Article 690 of the National Electric Code (NEC), which addresses safety requirements for the installation of PV systems. The latest version is NEC 2008; however, many local building codes may still be using NEC 2002 or 2005. Best practice would be to use the NEC 2008. The NEC covers everything from module installation, wiring, and grounding to connector boxes and inverters. The best source to learn more about PV and the NEC can be found at www.nmsu.edu/~tdi/Photovoltaics/Codes-Stds/PVnecSugPract.html.⁶

Performance and safety standards for individual solar components in the United States are set by Underwriters Laboratories Inc. (UL). The benchmark UL standards are:

- UL 1703 for PV modules.
- UL 1741 for solar inverters.

All components should carry a UL label. In most cases, one cannot receive incentives and rebates for array systems that have not been UL-certified. (Certification can come from other test facilities but will still use the UL benchmark standards.)

The performance standard for solar modules is the Standard Test Conditions (STC), and is a standardized test to factory-benchmark PV module power output. All modules should have an STC rating on the product label. Using the STC means that a solar module can produce X amount of watts under the STC test conditions. In the real world, an installed solar module will not produce the STC-listed power.

Manufacturers are starting to sell plug-and-play, packaged solar arrays. The package might say it is a 50 kW-DC system under STC. In reality, actual power production of the array is dependent on where the system is installed and how the system is

designed. Global location, solar orientation, solar shading, length of power cable runs, wiring size, and inverter DC-to-AC conversion rating all play a role in actual AC power output to the consumer. A good rule of thumb is to use 75%-77% of the DC rating to determine actual AC power output. A 50 kW-DC system might only produce 37.5 kW-AC or even less.

Fire and Wind Ratings and Codes

With few exceptions, most PV modules are fire-rated UL Class C. Only a handful of PV modules have been rated UL Class A. Look up the UL 1703 information on a PV module and cross-reference it to find out what the system fire rating is. Fire rating assemblies are difficult to determine. Many thin-film modules on single-ply membrane assemblies are outdated and are no longer effective or have not been tested.

It is important to have both the roofing and PV manufacturer provide approvals. UL has been flexible in some cases and has allowed UL Class C module attachment to a UL Class A roof assembly, accepting the hybrid system as UL Class A. This may change in the near future; UL started a new test study to see how these hybrid-rated

systems really perform. This is the result of California fire marshals' concerns with burning embers falling onto a roof. The results of this new study will determine if this practice is acceptable in the future.

One of the most common questions from the roofing community is, "Is the solar array rated FM I-90?" So far, it seems Factory Mutual (FM) has not been actively engaged in testing solar arrays and roof systems. BIPV is a new concept. Most people in the solar industry have never heard of FM. It's hard to imagine FM not becoming involved once solar becomes more common and once conventional roof manufacturers deploy new solar roof systems and millions of dollars of solar arrays on FM-insured roofs.

Some solar and roof manufacturers are assuming that if a thin-film module is laminated to an FM-approved roof assembly, the wind-uplift dynamics of the roof system are not going to change, but to the author's knowledge, no one has completed any testing. FM fire ratings are another issue; FM and UL approach fire testing differently, and until FM becomes involved and creates standards, one must take a wait-and-see approach.

Rack-mounted and ballasted solar arrays are either engineered or wind-tunnel tested. Most current rack-mounted array systems have not been tested. Module-mounted arrays can act as giant sails or aircraft wings on the roof. Design has to cover not only the mounting system, but the stresses the array system will transfer onto the roof structure, and this is said to be difficult to engineer in high-wind areas without testing.

Just recently, a new code board was created to start formulating a national code and standards for solar applications. Unfortunately, not many in the roofing industry are involved. The new board is called the Solar America Board for Codes and Standards (Solar ABCS), and the Web site is www.solarabcs.org. Anyone who is interested in solar applications should join Solar ABCS and become an active stakeholder so that the roofing industry can have input on the new codes and standards that will affect all of us in the near future.

Other standards are in development, many in areas we as consultants are not used to working with. Fire codes (both local and national) are starting to be developed that will determine the roof array size, the size and number of walkways between the modules, the access clearance around the

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roof perimeter and interior walls, and the amount of array clearance around skylights and other rooftop equipment so that firefighters can vent a fire if needed. Disconnect switches, cable and array equipment labeling, cable placement, grounding requirements, and lightning protection standards are being developed. Other agencies are starting to work on permits and system approvals. With a typical PV power string having up to 600 volts DC, safety is very important.

As an industry, solar is an area in which we need to become fully engaged. Looking back over the years, we can all remember some of the mistakes made when new roofing technologies were introduced and not properly studied or tested. Solar power and roofing are going to play an important role in creating a new national energy policy and energy resource. We need to get solar power and roofing right the first time. 

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Michael Gumm



Michael Gumm, president of Corporate Roof Consultants, has been actively involved in the roofing industry for the past 25 years in manufacturing, sales, contracting, and consulting. Michael is a Professional member of RCI and NRCA. He is the founder and president of SolarPower Restoration Systems Inc. and SolarSeal Technologies Inc. Both companies are engaged in developing new building-integrated photovoltaic (BIPV) application technologies. Mr. Gumm is a BIPV pioneer and inventor with seven patents pending. He is a member of the Solar Energy Industry Association (SEIA), The Renewable Energy and Energy Efficiency Partnership (REEEP), The American Council on Renewable Energy (ACORE), and ASTM, and he is active in developing codes and standards for solar roof systems.

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