Integrating Thin-Film Photovoltaics Onto Building Envelope Surfaces

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ABSTRACT

This paper covers design and installation methods for Building Integrated Photovoltaics (BIPV) using the new thin-film photovoltaic module technologies with conventional construction products over the following building envelope surfaces:

- Single-ply, modified bitumen, and metal roofs
- EIFS and concrete and masonry wall surfaces
- Concrete surfaces, such as parking lots and architectural elements

Installation methods include thin-film photovoltaic modules laminated to single-ply membranes; flexible photovoltaic modules combined with elastomeric coatings applied over roofs, concrete, and walls; and re-deployable photovoltaic systems with magnetic membranes for metal roof applications and self-ballasted insulated roof panels. The subject matter covers new construction and building restorations. Information for array design and the various finance options available to owners is also provided.

SPEAKER

Michael Gumm has been actively involved in the roofing industry for the past 25 years in manufacturing, sales, contracting, and consulting. 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 five patents pending covering a number of BIPV application technologies using conventional building products with photovoltaic systems to create new building envelope surfaces that both weatherproof and generate renewable energy from the sun

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INTRODUCTION:

The industry standard for solar technology since photovoltaic systems have been installed on buildings has been glass-mounted, silicon-based solar panels. Today, a new type of photovoltaic technology called thin-film photovoltaic technologies is ready to change the way photovoltaics are installed on buildings. This paper is written to give our industry a broad overview of both old and new solar technology plus insight on designing and applying these 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 will grow to 15 percent of added capacity and by 2018, solar is expected to contribute 50 percent of the annual U.S. power increase. If you have not seen solar on a project in the past, chances are you will in the near future.

PHOTOVOLTAIC BASICS

Photovoltaics (PV) are one of the most promising sustainable energy technologies. Solar PV modules produce electricity on site, directly from the sun, with the least environmental harm. Solar has the smallest environmental impact of any of the renewable energy systems. Photovoltaic modules are solid-state devices that simply make electricity from sunlight. They require little maintenance, produce no pollution, and don't deplete any nonrenewable fossil energy resources such as oil, natural gas, and coal.

Crystalline Silicon

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

- Silicon-based photovoltaics have the highest electrical output of any photovoltaic material per sq ft.
- Typical power production is between 12 to 15 watts per sq ft.
- Silicon wafer photovoltaics are more expensive and require large amounts of energy to manufacture. Silicon modules costs $4.85 per watt on average.[1]
- In 2006, solid silicon photovoltaic modules represented about 95% of all solar panels installed.

Other building system applications include semi-transparent photovoltaic glass modules for windows and skylights using crystalline silicon, and one PV manufacturer has integrated thin silicon wafers into a single-ply roofing product. Leading silicon panel manufacturers include SunPower, Sharp, Schott Solar, Sharp Corporation, and Canon Inc.

Thin-Film Photovoltaics

A number of new photovoltaic technologies have begun to emerge into the marketplace.

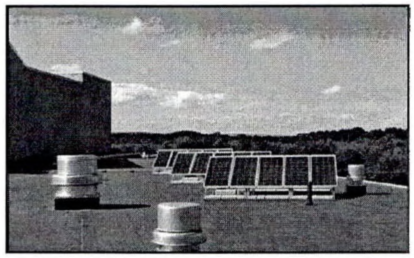

Figure 1 – Crystalline silicon array on the New York State Energy Research & Development Authority's Voorheeville, NY, school.

These newer technologies, called thin-film photovoltaics, include very thin layers of photovoltaicly active material placed on a glass superstrate, 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 with a solar transparent plastic polymer.

Semiconductor materials used in thin-film photovoltaics include:

- Amorphous silicon (a-Si) : Uni-solar and MWOE-solar
- Copper indium gallium diselenide (CIGS): Mia solé, 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 will be printed onto various polymer films with equipment resembling computer printers. Thin-film photovoltaic materials are used in both glass-encapsulated and flexible-membrane solar modules.

Thin-film photovoltaics' difference over traditional silicon modules include:

- Thin-film photovoltaics generate less power per sq ft than crystalline silicon, but produce more overall total power output over the solar day compared to silicon-based photovoltaics. Thin-film photo voltaics do this because they produce more power in low and overcast light conditions compared with crystalline silicon. Most power measurements for silicon are taken during peak power production times at midday.
- Thin-film photovoltaics on average produce 6 to 10 watts of power per sq ft, depending on the type of semiconductor material used.
- Thin-film solar photovoltaics' power production is not affected by higher environmental operating temperatures. Silicon-based modules start dropping power output once module temperature exceeds 25 degrees C.
- Solar shading does not lower the entire thin-film module power output.

Thin-film photovoltaics cost less than silicon modules. Average cost, depending on the type of semi-conductor material used and if the module substrate is glass or polymer-encapsulated, is between $3.00 and $4.24 a watt.[2] Power production per sq ft varies between manufacturers; the solar industry tends to price product cost by watt rather then per sq ft, because rebates and incentives are priced out in watts.

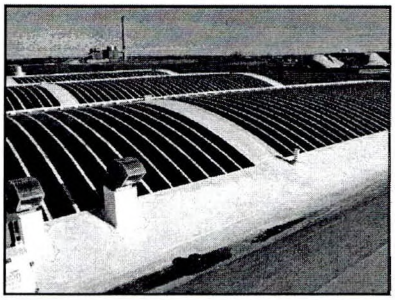

Figure 2 – Flexible, thin-film photovoltaic module at Grand Valley State University, displaying Uni-Solar thin-film solar cells.

BUILDING INTEGRATED PHOTOVOLTAICS (BIPV) SYSTEMS

Building-Integrated Photovoltaics (BIPV) is a new sustainable-energy-source building technology. Photovoltaics are one of the most promising renewable energy-source building technologies. A BIPV system consists of integrating photovoltaic modules into the building envelope with conventional building products, such as the roof, windows, or walls. BIPV is simultaneously 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, can export surplus energy to the utility for use later, when the building requires utility energy.
- The building becomes a power distributor at the point of use by net metering the building's surplus power production. Think of net metering as a method to bank or deposit surplus solar energy production during the day with a utility company. The power storage system is essentially free.
- Both the building owner and the utility benefit with grid-tied BIPV, as on-site solar power production is typically greatest during a building and power company's peak energy needs.
- The photovoltaic 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, typically when electrical costs are lower, helping to reduce the cost of utility-generated power.
- Photovoltaic systems can become the building's primary energy source in the event of a power failure and energy can be stored onsite for emergency backup using batteries.

BIPV systems are available for a number of building-envelope surfaces, including roofs, walls, windows, and concrete.

ROOFING AND BIPV

Placing rigid solar photovoltaic roof panels as a stand-alone or roof-top, equipment-mounted power module array has been around since the invention of solar-photovoltaic 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 modules, have we seen the integration of PVs into traditional roofing materials. Today there are a number of roofing systems and products on the market using laminated PV flexible films, including shingles, roof tile, metal roofs, modified bitumen, and single-ply roof membranes. These are dual-functional products, both weatherproofing the building and generating renewable energy from the sun.

Metal Roofs and Photovoltaics

Uni-Solar pioneered the application of flexible thin-film PV modules to architectural metal roof panels. The Uni-Solar's flexible thin-film module has a pressure-sensitive peel-and-stick adhesive on the back surface of the flexible modules and can be factory laminated to metal roof panels for new construction. The Uni-Solar 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 and combined flexible solar modules with metal roofing and a concealed radiant-heating system under the metal panels, producing both electricity and hot water from the sun.

Metal roof R-panel roof systems with overlapping seams and exposed fasteners or metal roof panels with stiffener beads or striations have been limited to traditional equipment-mounted glass modules. SolarSeal Technologies created a new solar roof system by combining certain elastomeric coatings and different inter-ply construction elements with flexible thin-film photovoltaics to bridge the metal-roof profile and exposed fasteners while creating a flat substrate for the PV modules. The SolarSeal System creates a monolithic membrane with the

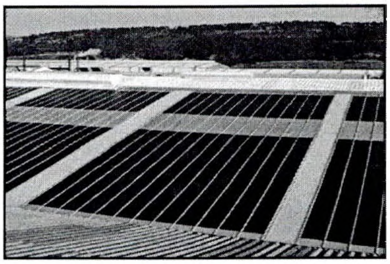

Figure 3 – Uni-solar metal panels with thin-film photovoltaics.

thin-film modules and coatings that both waterproofs the metal roof and generates renewable energy.

Flexible thin-film modules offer the best options for adding a photovoltaic array to a metal roof system. Rigid glass silicon PV modules can be used on metal roofs, but require some type of mechanical surface attachment. Surface-mounted or rack-mounted silicon PV modules or arrays do not keep the existing metal roofs watertight, and should the metal roof leak in the future, the attached PV array may have to be removed for roof repairs. It is important to determine how the additional weight of the heavier glass modules and rack attachment system will affect the metal-roof system. Silicon module systems can be quite heavy.

LOW-SLOPE ROOFS AND PHOTOVOLTAICS

Solar and single-ply systems

The most common BIPV low-slope roof system today is 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 with Uni-Solar and Sika-Sarnafil, the Solar Integrated Technologies (SIT) created the first single-ply BIPV photovoltaic roof system. PVC single-ply is the membrane polymer of choice and TPO can 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 roof project site in large, pre-manufactured rolls. The PV laminated single-ply roof system is installed over an existing compatible roof membrane or is installed as a new roofing system using traditional roof construction methods and labor techniques.

With the SIT system, a new single-ply roofing system is applied to the roof. The new single-ply roof system can be mechanically fastened or fully adhered. The factory-laminated single-ply membrane and flexible PV module is then installed directly over the new single-ply roof system and hot-air welded in place. On partial roof installations, photovoltaic laminated single-ply membranes can be adhered to the existing roof substrate using polyurethane foam as an adhesive, double-sided tape or bonding adhesive. In most cases, these partially attached system applications are not waterproofed. The SIT system patent ended last year, and several other commercial roofing manufacturers are expected to bring similar solar single-ply roof systems into the market over the next two years as

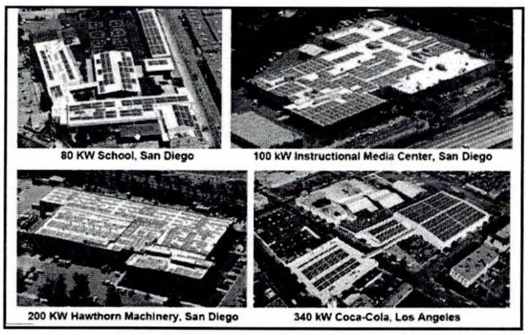

Figure 4 – Solar Integrated Technologies' thin-film laminated roofs.

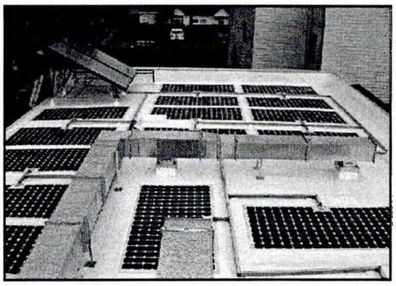

Figure 5 - Open-energy photovoltaic module and single-ply membrane system.

the roofing industry starts embracing solar roof systems and renewable energy.

Silicon wafers can be used with a single-ply membrane system. The Open Energy SolarSave PV module is a single-ply membrane and photovoltaic composite panel using thin silicon crystalline wafers covered with a solar transparent polymer on top of an aluminum substrate with a single-ply PVC or TPO membrane laminated to the back side. Like the SIT flexible PV membrane, the Open Energy module can be hot-air welded to a new or existing single-ply membrane. The Open Energy panel, with its crystalline silicon, generates twice the electrical power per sq ft compared to the Uni-Solar panel. The Open Energy panels cost more per watt than the SIT solar single-ply system. The higher energy cost of the Open Energy module can be offset when more power production is needed with limited roof area or when more power is wanted over a larger roof area.

Photovoltaic modules get hot on a hot summer day. We have seen surface temperatures up to 165 degrees. Many thin-film photovoltaic modules use a stainless-steel carrier to deposit their solar active materials; these stainless carriers absorb heat. We will need to pay attention to the heat build up and heat transfer from the modules to the roof membrane systems and monitor to see if the additional heat load will affect the long-term performance of the roof membranes.

Most white single-ply roofs are known to be cool roofs, with a typical surface temperature not more than 10-15 degrees hotter then ambient air temperature. Now they will be subjected to long-term temperature exposure 30-40 degrees higher. Good insulation in the roof system is important in reducing heat transfer from the PV modules to the building interior. Thin-film modules with plastic carriers should be cooler, but as of today are still in development and will not be deployed for another two or three years.

Solar and BUR-Modified Bitumen

Photovoltaic systems integrated with standard asphalt roofing and modified-bitumen roof-system BIPV has lagged behind in development. With a surface-operating temperature up to 165 degrees, attaching a thin-film photovoltaic module 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-pound cap sheets. The difference in thermal expansion between the modules, adhesive, and asphalt roofs makes direct adhesive attachment challenging.

Recently, SolarSeal Technologies developed a new PV roof system for asphalt-based roof systems. The SolarSeal PV Roof System first applies high-performance elastomeric roof coatings to the asphalt-based roof membrane, creating a continuous waterproof roof surface. The flexible PV module is embedded onto the first elastomeric coatings with additional elastomeric coating and textile interply components to form a monolithic, weatherproof membrane that both protects the building and generates electricity. The SolarSeal System is the only universal roof-integrated photovoltaic system that can be applied to either new or existing roofs, including asphalt-based roof systems and single-ply roof systems.

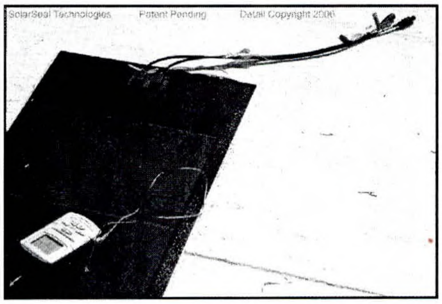

Figure 6 – SolarSeal system over SBS membrane with Uni-Solar PV module.

SLOPED ROOFING SYSTEMS

Glass photovoltaic modules have been used on high-slope residential roofs for years. The flat panels are easy to install and only require a few roof penetrations to run the wiring. However, glass PV modules are considered by some to be unattractive roof systems. With an expected service of 30 years and higher, surface-temperature glass modules will outlast many surfaces, especially shingle roof systems. These days, there are a number of alternative photovoltaic roofing products in which the solar active materials have been incorporated into the roof products to create true BIPV roofing products.

These new shingle and tile products use either thin-film or crystalline silicon for a solar-active surface. Uni-Solar makes a flexible solar shingle module that integrates into a regular shingle roof. The Uni-Solar module is dark blue in color, is 12 in x 86.5 in long, and produces 17 watts per module run. There are a number of Solar Tile modules available today that interface with flat concrete tiles. The SunPower SunTile is a high-efficiency solar panel that blends invisibly into concrete tile roofs. GE Solar makes 18 single-crystal cells connected in a series module with a peak power of 55 watts at 8.4 volts and has a unique interlocking design for concrete tile applications. Sharp-Solar offers polycrystalline silicon modules with 62 volts of output. Open Energy makes a poly-crystalline tile type module that comes in brown, red, and black colors. Atlantis Energy Systems makes a slate type tile that works well with flat tiles and slate roofs.

Figure 7 - Solar shingles by Open Energy.

WALL AND WINDOW SOLAR SYSTEMS

There are a number of new wall and window photovoltaic systems. The key limiting factor with wall and window application is the building placement in relationship to the sun. Southern-exposure walls produce the most power. Window systems are typically a silicon wafer or thin-film cell laminated between two sheets of glass and are semi-transparent. Solar window applications include window glazing, curtain walls, atriums, and skylights.

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

Right now, wall and window systems are very specialized. As the pricing of solar systems continues to drop, more building wall and window systems will start to incorporate solar into more traditional wall and window building products.

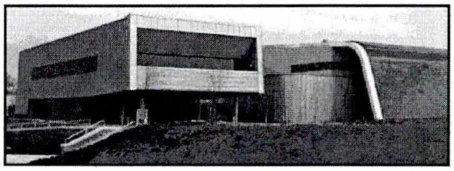

Figure 8 - Solar wall at the main elevation of OpTIC, showing the cantilevered business center and 1,000m² PV wall array.

PHOTOVOLTAIC ROOF DESIGN

Designing a photovoltaic system for BIPV is a complex process, especially for roofing. The solar industry for the most part has grown up independently of the roofing industry. Installing rack-mounted glass photovoltaics on a roof requires few roofing skills other than drilling a few holes in the roof and caulking around the wiring penetration or flashing around the support mounts.

With the introduction of new roof systems that combine traditional roof products with photovoltaics, roof designers and roofing contractors are learning a new set of technical skills. Solar integrators and solar design consultants are becoming more educated about roofing technologies. With photovoltaic building surfaces becoming more commonplace and the need to create more energy-efficient and sustainable buildings, both the solar industry and the conventional construction product industry need to be able to work with and learn from each other.

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

- Conventional silicon-based PV-glass module rack- and post-mounted systems.
- Protective Roof Membrane (PMR) self-ballasted photovoltaic tile systems, such as Powerlight's PowerGuard panels or the SolarSeal Surface OverLay System.
- PVC or TPO single-ply membrane and thin-film PV module composites by Solar Integrated Technologies and Open Energy.
- Proprietary elastomeric coatings and thin-film PV-module composite systems for asphalt-based roof and single-ply roof systems developed by SolarSeal Technologies.

Thin-film photovoltaics are a new roofing and building material technology and a number of application technologies for installing these thin-film modules are under development as these products leave the laboratories and become commercialized.

There are a number of contractor and installation options.

- Roofing contractor – design and estimate – installer
- Roofing contractor and so lar contractor subcontractor – hybrid
- Solar contractor and roof ing subcontractor – hybrid
- Manufacturer design – roofing contractor estimate – installer
- Roof consultant design – contractor estimate – installer
- Solar consultant design – contractor estimate – installer
- Architectural design – contractor estimate – installer

- Solar integrator – roofing contractor subcontractor – hybrid

The design and sales process timeline for specifying and selling photovoltaic roof systems is much longer and far more complex compared to selling standard roof systems. The cost of a roof system with a photovoltaic system is expensive; the average installed cost of a commercial low-slope roofing and photovoltaic system before tax credits and rebates can average between $72 and $110/ sq ft, depending on the photovoltaic system used. The solar industry uses cost-per-watt for pricing, due to the variation in power output with different solar technologies. The tax credits and rebates tend to be stated in cost-per-watt. The average cost per watt installed on low-slope commercial applications is between $8 and $9 per watt DC. Photovoltaic systems and components are priced per watt, so the roofing cost must be estimated and then translated into cost-per-watt.

The incentives, grants, federal- and state-tax credits and rebates make BIPV affordable. Unfortunately, there is no uniform system of tax credits and rebates. The federal government provides a 30% tax credit and five-year accelerated depreciation on a commercial BIPV system cost. While this helps to reduce the overall cost, what makes a solar system cost-effective is the additional state, local, and utility credits, rebates, and performance-based incentives. Many varied rebate programs are offered throughout the United States. Some states have such a large number of rebate options that one must calculate the performance-based incentives, utility, and state rebate costs by zip code. There are still 12 states with no net-metering laws. Out of the 50 states, less than half have attractive enough incentive programs for solar energy to make real economic sense. The Database of State Incentives for Renewables and Efficiency (DSIRE) is the best source for looking up any state and regional tax credit and incentive based state programs and can be found at www.dsireusa.org/.

Determining what financial options are available to building owners is an important part of the design and sales package.

Financing Options

It is important to understand and identify the owner's special needs for financing the project. The designer and contractor must be knowledgeable and communicate to the building owner, the different financial options available to them. A key part of selling photovoltaics is having access to established lease programs from leasing and capital investment groups. Capital leases, power purchase agreements (PPAs) and bond options are very important for selling to state, local governments, school districts, and other public agencies. These leases can become another revenue stream, tax-credit source, depending on investment packages the contractor or solar integrator has set up with the financial companies. With the commercial owner, it is important to explain the tax benefits, state utility rebates, performance incentives, and renewable energy credits to show the owner their real cost, plus monthly energy savings and payback period for their investment. With commercial owners, the recent trend is going towards either commercial leases or the power purchase agreements.

Financial Options

- **Direct Purchase**. Owners purchase the photovoltaic system using internal cash flow and utilize the tax credits, state and local rebates, utility rebates, and RECs, or they can go to their existing lending/ leasing institutions.
- **Finance lease**. This is similar to a bank loan, and 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**. These lease types can meet the needs of schools, universities, state, and local governments. The public agency pays for the cost of the roof and photovoltaics from current utility cost. 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.

Preliminary roof information collection

Designing a low-slope roof and photovoltaic system starts out like a conventional roofing system, and in the case of a re-roof, will require the following information to determine if the building is a suitable candidate for a BIPV roof system.

- 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 may be required
- Existing roof coating, test for adhesion and compatibility

If the roof is suitable for a BIPV system, on the next phase, either get an existing roof plan of the building, or be prepared to create an accurate roof plan with all curbs, HVAC, drains, and scuppers on the roof. All of these items must be pinpointed and measured.

Preliminary Roof Information for Photovoltaics

The building's orientation, solar shadowing, and solar insolation are important design elements used to determine what type of PV system can be used and how large a photovoltaic system can be installed on the roof.

Create a roof plan with all roof-top elements (drains, curbs, pipes, etc.)

- Google satellite photo of building and surrounding buildings
- Building-site location
- Building solar orientation (what direction does it face to the sun)
- Identify shadow obstacles (roof-top equipment, surrounding roofs, buildings, and trees can affect the overall effectiveness of the photovoltaic system) .
- Identify solar access (solar 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

Preliminary power analysis data

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

- Utility bills (highest bill per quarter minute) for the past two years.
- Usage pattern with peak, part-peak, and off-peak usage; summer and winter demand charges.
- Current and future electric rate schedule. Factor 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/non-seasonal).
- Locate and inventory existing electrical services (photos).

Information Processing and Preliminary Design

The above information is used to calculate the following information to design the PV system.

- Electrical load: Determine building power require ments (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 build ing code, NEC code, and environment)
- Combiner box: (size and locations)
- Controller specifications [(size) battery back-up sys tem only]
- Inverter specifications (size)
- Utility-interactive system design

Contractor information requirements for estimating

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

1. Approved roof plan and roof specifications
2. Approved PV array plan and specifications
3. Approved wiring plan and specifications
4. Approved controller plan and specifications (battery systems only)
5. Approved inverter plan and specifications)
6. Utility-interactive system design

Photovoltaic estimating software is available from several sources. Input all data into solar sales and Estimating tool software. Software packages will 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
- PBIs (performance-based incentives)

Most software packages will generate charts and graphs, so ROI and payback cycles are clear and easy to understand. Some software packages will 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 is 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. Understanding the rebate and performance-based incentive process is critical for getting one's client and the contractor the cost savings that make the solar system economically feasible. These rebate and backsides vary. Some states even require the PV system to be installed first, then the credit applied for, and the state will pay out only if is has allocated funds in the account at the time of filing. Others require owners to reserve the rebates by first filing and then there is a set amount of time to get the system installed and commissioned. Performance-based incentives, means 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

DESIGNING AHEAD: LIFE CYCLES, ROOFS, WARRANTIES

Photovoltaic manufacturers say their photovoltaics will have a long service life. Glass-module manufacturers claim their modules will produce energy for 30-50 years. Many thin-film photovoltaic manufacturers routinely say their modules will be guaranteed for 80% of the modules' installed power production at year 20 or 25.

When designing a roof, it is important to keep the long service life of photovoltaics in mind. Chances are the roof will have to be replaced long before the photovoltaic modules are. One has to ask oneself, does it make economic sense to install a rack or pole-mounted array system over an existing roof system with a limited performance life? What are the options to maintain the roof? What can you do to extend the roof's service life? Have you factored in the cost of removing the PV modules for roof repairs or replacement at some future time and is the owner aware of this future cost? Flexible, thin-film PV systems have the advantage of direct attachment to the roof membrane or onto the elastomeric coating system. These thin-film modules can last longer then the roof systems. The single-ply solar composite system or solar elastomeric coating composite system can be coated and recoated again with compatible elastomerics coatings at some future time, synchronizing the service life of the roof and thin-film modules.

You should also contact the roof manufacturer if the existing roof is still under warranty. Major modification or changes in roof use can void the existing roof warranty if the manufacturer is not contacted and agrees to the solar installation. It is important to monitor any photovoltaic rack installation on any existing or new roof for damage due to construction and foot traffic.

In the roofing industry, we are used to specifying and getting a single-source roof warranty covering all roof components, material replacement, and workmanship for 10, 15, or 20 years. Photovoltaic system warranties do not exist.

The photovoltaic module will have two warranties. One warranty is for material and workmanship defects for manufacturing the PV modules. This warranty can be as short as 18 months, and 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 modules will generate 90% of the rated installed power production at year ten and 80% of the installed rated power production at year 20. On average, a PV module will lose 0.5% to 1.0% of its installed rated power production a year.

Photovoltaic inverters, the devices that convert DC power to AC power, typically are warranted for five to ten years, and over the course of the photovoltaic array's service life, will have to be replaced. On wiring and cabling, code requires UV-rated cable. Most cables are warranted for 10 to 20 years (material only), and it makes good sense to install cables in a pre-manufactured cable channel to protect the wiring. With an average roof system and PV system, therefore, one will have a roof warranty from one manufacturer and several warranties from the PV-module component manufacturers. Over time, as traditional roofing manufacturers create standardized PV roof systems, we will eventually get a single-source warranty package.

Basic Design Resources

Creating a small 2- or 3-KW residential array system is not very difficult; most PV module manufacturers can help with the basics. A good resource for understanding and learning the solar installation process can be found in the photovoltaic *Design and Installation Manual* published by Solar Energy International. A number of hands-on schools with week-long classes can be found through the American Solar Energy Society (ASES) that can provide the knowledge and skills for residential projects.

Commercial roof applications are far more complex. Besides array layout design, cabling layout, running the wiring to the combiner boxes, and incorporating lighting protections, disconnect switches, and grounding can be challenging. While DC current is safer than AC current, most commercial systems array strings will be running voltages up to around 525 volts DC, so the systems must be carefully designed. Photovoltaic wiring is controlled primarily by Article 690 of the 2005 National Electrical Code. With commercial systems, it is best to collaborate with an experienced solar integrator or electrical engineer with solar experience.

One of the best resources for the NEC 2005 and wiring photovoltaics is John Wiles at New Mexico State University. He may be contacted via e-mail at jwiles@nmsu.edu, and a PV Systems Inspector/Installer Checklist will be sent via e-mail to those requesting it. An e-mailed copy of the 100-page "Photovoltaic Power Systems and the National Electrical Code: Suggested Practices," published by Sandia National Laboratories and written by John Wiles will be sent at no charge to those requesting a copy. The Southwest Technology Development Web site (www.nmsu.edu/~tdi) maintains all copies of the "Code Corner" columns written by John Wiles and published in *Home Power Magazine* over the last ten years.[3]

SUMMARY

The solar industry grew up largely independent of the traditional construction trades and product industry. New solar technology companies are just starting to explore the application possibilities with their new solar products in development. Solar power systems will become more common in the future. These new solar products will become integrated into many traditional building systems. Today is a good time for our industry to start learning more about solar technologies and how these new technologies will affect the design and installation of building systems with which we work.

SPECIFICATION REFERENCES

Photovoltaic specification references can be found in CSI Specification Section 13625 - Photovoltaic Energy Systems. Key photovoltaic standards can be found in the following:

1990 National Electrical Code

American National Standards Institute (ANSI) ANSI C2-1990

Institute of Electrical and Electronic Engineers (IEEE)

IEEE 519 (2004) Recommended Practice and Requirements for Harmonic Control in Electrical Power Systems

IEEE 928 (2004) Recommended Criteria for Terrestrial PV Power Systems

IEEE 929 (2004) Recommended Practices for Utility Interface of Residential and Intermediate PV Systems

IEEE 1374 (2004) Guide for Terrestrial PV Power Safety Systems

International Electronic Electrotechnical Commission (TEC)

IEC 1173 (2000) Overvoltage Protection for PV Power Generating Systems

IEC 1277 (2000) Guild-General Description of PV Power Generating Systems

IEC 61646 (1996) Thin-Film Terrestrial Photovoltaic Modules

National Fire Protection Association (NFPA)

NFPA 70 (2005) National Electrical Code

Underwriters Laboratories (UL) UL 1703 (2002), Interconnected Electrical Power Production Sources

UL 1741 (1984, R 2004), Flat Plate PV Modules and Panels

FOOTNOTES

1. Silicon PV module cost only: SolarBuzz www.solarbuzz.com/ on 08/25/2007
2. Silicon PV module cost only: SolarBuzz www.solarbuzz.com/ on 08/25/2007
3. Taken from IAEI (*Electrical Inspectors Magazine*), March/April 2005 www.iaei.org/subscriber/magazine/05_b/wiles.htm.